EFFECTS OF GUINEAGRASS ON NORTHERN BOBWHITE HABITAT USE

A Thesis

By

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ABSTRACT

Effects of Guineagrass on Northern Bobwhite Habitat Use

(August 2010)

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Guineagrass (*Urochloa maxima*) is native to Africa, and was introduced to the U.S. for erosion control and to improve grazing productivity. Over the past 20 years, it has invaded large areas of northern bobwhite (*Colinus virginianus*) habitat in southern Texas and northern Mexico. The objectives of this study were to 1) determine the effects of guineagrass on bobwhite nesting habitat, 2) determine the effects of guineagrass on bobwhite foraging and brooding habitat, and 3) evaluate the effects of guineagrass on bobwhite habitat characteristics. Bobwhites were monitored using radio telemetry during the breeding season (April–September) during 2008–2009 in Kenedy County, Texas, USA. Vegetation was sampled at nests, organism-centered, and random locations. Bobwhites nested in guineagrass and did not select or avoid guineagrass for general habitat use. Total species richness declined with increasing guineagrass cover; whereas percent horizontal cover increased with increasing guineagrass. Invasion of native grassland by guineagrass did not reduce bobwhite use, but may have reduce nesting success and negatively impacted forbs important as food for bobwhites.

DEDICATION

To Christ, my Lord and Savior; and to Joey, my love and soul mate.

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CHAPTER I

INTRODUCTION

Bobwhite Population Declines

Northern bobwhite (*Colinus virginianus*) populations have declined throughout their range for at least the past 40 years (Peterson et al. 2002), though evidence suggests trouble began for these populations as early as 1905 (Brennan 1991, Peterson et al. 2002). The most common factor associated with quail declines is habitat loss in relation to changing land uses in agriculture, forestry, and urban-suburban development encroaching into rural areas (Kuvlesky et al. 2002, Peterson et al. 2002, Brennan et al. 2007). Clean-farming practices, high-density planted-pine silviculture, and a decline in use of fire are some of the most likely causes of habitat loss and the subsequent decline in bobwhite populations (Brennan et al. 2007), although there are other contributing factors.

While many quail populations in Texas are severely declining, South Texas is known as one of the last places that supports abundant northern bobwhites. This is due to the presence of large, private landholdings such as King Ranch, Kenedy Ranch, and other large ranches, which have formed the backbone of quail habitat across large regions of Texas for over a century (Lehmann 1984, Brennan et al. 2007). Here, quail have been a by-product of range management for livestock in South Texas (Brennan et al. 2007).

Fee-lease hunting in Texas started in the 1930s and developed into a lucrative economic asset on many Texas ranches (Brennan et al. 2007). Hunting opportunities for white-tailed deer and quail have become such a significant source of revenue that many

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This manuscript follows the style of the Journal of Wildlife Management landowners are motivated to sustain these wildlife populations through management.

With the widespread decline of quail populations and their increasing economic importance throughout the Southeast, it is becoming increasingly imperative to maintain quail habitat in South Texas to sustain populations for the future.

Exotic Grass: Introduction and Concerns

Exotic species have become a major economic and biological threat to the U.S. during the past 50 years (Kuvlesky et al. 2002). More than 2,000 exotic plant species are currently established within the continental U.S. (Vitousek et al. 1997), and they are currently second only to habitat loss as the largest threat to conservation of biodiversity (Ramirez et al. 2007).

Most exotic grasses, including guineagrass (*Urochloa maxima*), were introduced for erosion control and to improve grazing productivity (Kuvlesky et al. 2002). Exotic grass invasions are now occurring on thousands of hectares of rangeland in the southwestern U.S., and little research has been conducted to determine how these invasions are impacting wildlife populations inhabiting these rangeland ecosystems (Kuvlesky et al. 2002).

Exotic grasses can reduce the diversity of native plant communities by disrupting ecosystem functions 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). Furthermore, exotic grasses are capable of modifying these processes in their favor, thereby perpetuating invasions (Christian and Wilson 1999, Kuvlesky et al. 2002, Butler and Fairfax 2003, McIvor 2003). Guineagrass and buffelgrass (*Pennisetum ciliare*), for example, both support a fire cycle to which native plants are not adapted (Calvert 1999), and because these species are fire resistant, they dominate the landscape after a fire (Tan 2001). Guineagrass also grows quickly and outcompetes seedlings of native plants, forming dense monocultures (Calvert 1999, Ramirez et al. 2007). This can result in the exclusion of valuable native plants essential to wildlife, including plants important for insects and for producing seeds eaten by quail and other bird species (Kuvlesky et al. 2002).

Impacts of Exotic Grasses on Birds

Grassland bird populations have exhibited greater declines than any other avian guild in North America during the past 25 years, and these trends are evident in grassland birds in South Texas (Askins 1993, Knopf 1994, Flanders et al. 2006). Habitat loss is often cited as an important factor contribution to this decline (Flanders et al. 2006). Because exotic plant invasions are synonymous with habitat loss, the magnitude of their threat to native bird communities may be larger than previously believed (Flanders et al. 2006).

Compared to landscapes dominated by native grasses, exotic grass-dominated landscapes support lower abundance of several grassland birds, including northern bobwhites (Flanders et al. 2006). The exact mechanism by which dominance of exotic grasses decreases abundance of grassland birds is still largely unknown. One possible factor is that, because these invasions typically form dense monocultures, they can reduce herbaceous structural diversity, which in turn reduces niche diversity, forage plants and insects, and mobility (Guthery 1986, Kuvlesky et al. 2002).

Impacts of Exotic Grasses on Bobwhites

Forbs are essential dietary items for bobwhites (Lehmann 1984:188, Guthery 1986:145, Kuvlesky et al. 2002) and insects are essential food items of young chicks, and adults for at least portions of the year (Lehmann 1984:192, Guthery 1986:147, Kuvlesky et al. 2002). Additionally, herbaceous habitats that provide adequate nesting, escape, thermal, and brooding cover are important to all quail species (Kuvlesky et al. 2002). Therefore, exotic grass invasions could negatively impact quail populations if these invasions limit one or more of the habitat attributes required by quail to fulfill their specific life history requirements (Kuvlesky et al. 2002).

In a study by Flanders et al. (2006), bobwhites were about twice as abundant on native sites compared with exotic sites, which could possibly be explained by the significant (40.6%) decrease in arthropod abundance between native and exotic grass plots in this study. Townsend et al. 2001 found that, in mixed prairie habitat, bobwhites prefer nesting sites with dense vegetation cover, especially bunchgrasses such as little bluestem (*Schizachyrium scoparium*). However, it is also possible that presence of exotic grasses benefit quail populations by providing a habitat attribute that was limited or missing prior to exotic grass invasions (Kuvlesky et al. 2002). Burger et al. (1990) and Burger (1993) believed that Conservation Reserve Program (CRP) fields consisting of the exotic grass tall fescue (*Festuca arundinacea*) and red clover (*Trifolium pratense*) established in northern Missouri provided habitat conditions suitable for bobwhite production (Kuvlesky et al. 2002). Conversely, Barnes et al. (1995), concluded that tall fescue fields in Kentucky provided poor bobwhite habitats (Kuvlesky et al. 2002). Additionally, Tjelmeland (2007) and Sands (2007) found that bobwhites readily nest and roost in buffelgrass, which suggests that bobwhites are capable of utilizing buffelgrass to fulfill at least some of their requirements even though this grass generally reduces habitat quality for bobwhites and other grassland bird species. Tjelmeland (2007) also found that buffelgrass in his study did not significantly inhibit movement of quail. These results indicate that factors other than lack of nesting sites and movement impediments may limit bobwhite densities in buffelgrass-dominated landscapes. Research suggests that lack of insects (Flanders et al. 2006) or decreased abundance of foraging plants (Sands 2007) may be contributing factors (Tjelmeland 2007).

In spite of extensive research on bobwhites in South Texas (Hernández et al. 2002), few studies have examined the impacts of exotic grass invasions on bobwhites even though hundreds of thousands of hectares of exotic grass exist in Texas alone (Kuvlesky et al. 2002). It would be in the best interests of many ranchers who derive income from quail hunting to know if exotic grass invasions are detrimental to bobwhite populations inhabiting the properties of private landowners (Kuvlesky et al. 2002).

CHAPTER II

THE EFFECTS OF GUINEAGRASS ON BOBWHITE NESTING HABITAT

Abstract

Guineagrass (*Urochloa maxima*) is native to Africa, and was introduced to the U.S. for erosion control and to improve grazing productivity. Over the past 20 years, it has invaded large areas of northern bobwhite (*Colinus virginianus*) habitat in southern Texas and northern Mexico. My objective was to determine if northern bobwhites use or avoid guineagrass for nesting. Bobwhites were monitored using radio telemetry during the breeding season (April–September) during 2008–2009 in Kenedy County, Texas. I measured vegetation attributes at nests and paired random points. I analyzed data using paired t-tests and case-controlled logistic regression. Nest sites had on average 6.9% (95% CI = -2.6–16.4) more guineagrass cover than random sites, yet differences were not distinguishable from 0. Odds of nest success decreased by a factor of 0.96 (95% CI = 0.84–1.0) for every 1% increase in guineagrass canopy cover. Habitat characteristics that most distinguished nest sites from random points were total grass cover and percent horizontal cover. Although bobwhites do not avoid nesting in guineagrass, probability of nesting success is reduced slightly with increasing guineagrass cover. My overall conclusion was that guineagrass provides adequate nesting habitat for northern bobwhites.

Introduction

Northern bobwhites (*Colinus virginianus*) nest in a variety of vegetation species, including shrubs and prickly pear cactus (*Opuntia engelmannii*) (Stoddard 1931, Hernández et al. 2007). For the most part, however, bobwhites tend to use warm-season, perennial, native bunchgrasses (Lehmann 1984, Townsend et al. 2001, Hernández & Peterson 2007). Native bunchgrasses are selected by bobwhites for nesting in part because their growth form and morphology are conducive to nest concealment (Lehmann 1946, White et al. 2005, Brennan et al. 2007).

Bobwhites typically select vegetation that conceals the nest from predators (Errington 1933:123, Lusk et al. 2006, Hamrick et al. 2007). For example, bobwhites in south Texas constructed nests in vegetation that was taller and denser than at random locations (Rader et al. 2007). Similarly, bobwhites in west Texas used areas that had >40 cm vegetation height, <30% bare ground exposure, and >25% shrub cover for nesting (Lusk et al. 2006). Other habitat components related to nest concealment that influence bobwhite nest site selection are herbaceous canopy cover (Townsend et al. 2001, Arredondo et al. 2007) and visual obstruction (Arredondo et al. 2007, Rader et al. 2007). Nest success also depends on the level of nest concealment and protection, regardless of vegetation species that provides it (Townsend et al. 2001, Hernández et al. 2003, Lusk et al. 2006).

Exotic grasses possibly benefit quail populations by providing habitat attributes such as nest concealment or visual obstruction that were limited or missing prior to exotic grass invasions (Kuvlesky et al. 2002). For example, in the absence of native grasses bobwhites will readily nest in exotic grasses such as buffelgrass (*Pennisetum ciliare*) (Sands 2007, Tjelmeland 2007). Conversely, many exotic grasses lack attributes important for nesting habitat (Kuvlesky et al. 2002, Larson et al. 2010). Value of guineagrass, an exotic, warm season grass for bobwhite nesting habitat is unknown. Guineagrass is native to Africa, and was intentionally introduced to the U.S. for erosion control and to improve grazing productivity around 1818 (Parsons 1972, Kuvlesky et al.

2002), but may have been accidentally introduced to North America from slave ships as early as 1684 (Larson et al. 2010). Over the past 20 years, it has invaded large areas of northern bobwhite habitat in southern Texas and northern Mexico. This is of significant concern for conservation of northern bobwhites because southern Texas is one of the few regions of the U.S. that supports large areas of contiguous bobwhite habitat and sustainable populations of the species (Lehmann 1984, Brennan et al. 2007). Like other exotic grasses, guineagrass reduces diversity of plant communities by disrupting ecosystem functions. For example, guineagrass supports a fire cycle to which native plants are not adapted (Calvert 1999). Furthermore, because this grass is fire resistant, it will dominate the landscape after a fire (Tan 2001). Guineagrass grows quickly and outcompetes seedlings of native plants, forming dense monocultures (Calvert 1999, Ramirez et al. 2007). This can result in the exclusion of valuable native plants essential to wildlife, including plants important for insects and for producing seeds eaten by quail and other bird species (Kuvlesky et al. 2002, Veldman et al. 2009). There is a lack of published research on how invasions of guineagrass impacts wildlife populations, especially on bobwhites.

My objective was to investigate impacts of guineagrass on bobwhite nesting habitat. My specific objectives were to determine whether bobwhites nest in guineagrass in proportion to its availability, prefer it over other grasses, or avoid it. I hypothesized that northern bobwhite hens would avoid nesting in guineagrass. Alternative hypotheses were that they would select guineagrass in proportion to its availability for nesting, or they would select guineagrass for nesting in preference to native grasses.

Study Area

I conducted field work during 2008–2009 on a 1,643 ha portion of a private ranch in Kenedy and Brooks counties, Texas, USA, from March–September. The ranch lies in the South Texas Plains ecoregion of Texas (Gould 1975) where the climate is subtropical humid (Larkin and Bomar 1983), with extreme variability in annual precipitation (Fulbright et al. 1990). In 2008, the study area received 64 cm of rainfall, with July–September receiving about 75% of this total, while in 2009, the study area received 52 cm, with September–December receiving 78%. The study area was in severe drought during June 2008 and in severe to extreme drought during April to October 2009 based on the Palmer Drought Severity Index (NOAA 2010). Soil series at this site included sandy, tight sandy loam, and loamy sand (USDA-NRCS, 2009). The study area was grassland interspersed with mottes of woody plants. Historical grassland for the area is a seacoast bluestem (*Schizachyrium scoparium*) and balsamscale (*Elionurus tripsacoides*) association (McLendon 1991). Common subdominants were arrowfeather threeawn (*Aristida pupurascens*), thin paspalum (*Paspalum setaceum*), brownseed paspalum (*P. plicatulum*), coastal sandbur (*Cenchrus spinifex*), tanglehead (*Heteropogon contortus*), big bluestem (*Andropogon gerardii*), Texas snoutbean (*Rhyncosia texana*), Lindheimer's hoarypea (*Tephrosia lindheimeri*), snake cotton (*Froelichia drummondii*), honey mesquite (*Prosopis glandulosa*), prickly pear (*Opuntia lindheirmeri*), and yucca (*Yucca constricta*) (McLendon 1991). The major shrubland association was mesquite-granjeno (*Celtis pallida*) (McLendon 1991). Common subdominants included prickly pear, lime prickly ash (*Zanthoxylum fagara*), hogplum (*Colubrina texensis*), blackbrush (*Acacia rigidula*), and wolfberry (*Lycium berlandieri*). Important understory species included guayacan (*Porlieria angustifolia*) and tasajillo (*Opuntia leptocaulis*) (McLendon 1991). Management practices on the study area have included fire, mechanical brush removal, and rotational grazing. Prescribed burns included 197 ha in 2004, 231 ha in 2005, 253 ha in 2007, and about 57 ha in 2009 (Figure 1). Brush removal techniques included dozing, root plowing, and raking on 776 ha in 2004 and 367 ha in 2005 (Figure 2). Rotational grazing within the study area took place in 2007 from October–December. The study area was grazed by longhorn cattle (*Bos bos*) from autumn 2008–spring 2009. From January–early March, there were 319 longhorns in the study area for 60 days (0.19 animal units/ha), then the number of cattle was reduced to 118 for 21 more days until late March (0.07 animal units/ha).

Methods

Data Collection

Trapping and Telemetry. — I trapped bobwhites during 2008 and 2009 using walk-in funnel traps baited with milo (*Sorghum bicolor*) (Stoddard 1931). Trapping protocol was approved by Texas A&M University-Kingsville Institutional Animal Care and Use Committee, approval number 2008-01-18B. Trapping began in mid-March and continued through mid-September to maintain a sample of ≥20 radio-marked bobwhite hens. I marked every captured bird with an aluminum leg band, and I fitted birds weighing ≥150 g with a necklace-mount, 6-g radio transmitter (American Wildlife Enterprises, Monticello, Florida, USA). I kept detailed records on captured birds including sex, age, body mass, time and date of capture, band number, and radio transmitter frequency. I recorded known mortalities of radio collared birds when possible. I tracked birds 2–3 times/week from March–October in 2008 and May–

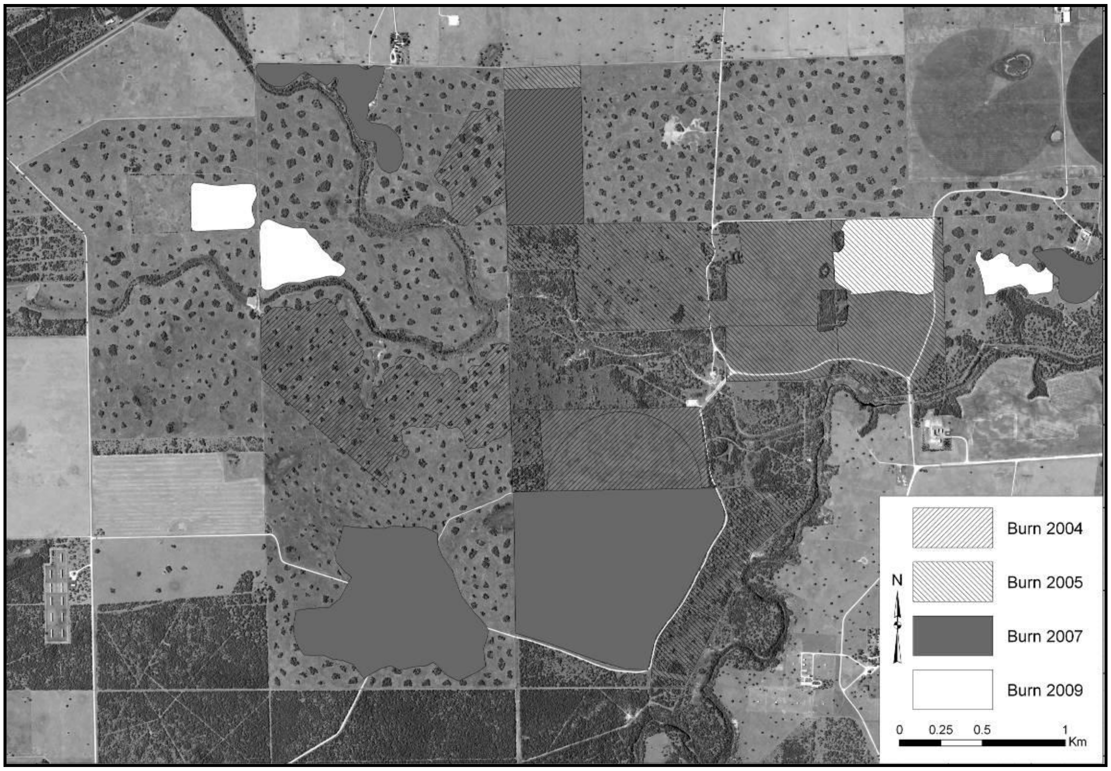

Figure 1. Prescribed burns included 197 ha in 2004, 231 ha in 2005, 253 ha in 2007, and about 57 ha in 2009, Kenedy County, Texas, USA.

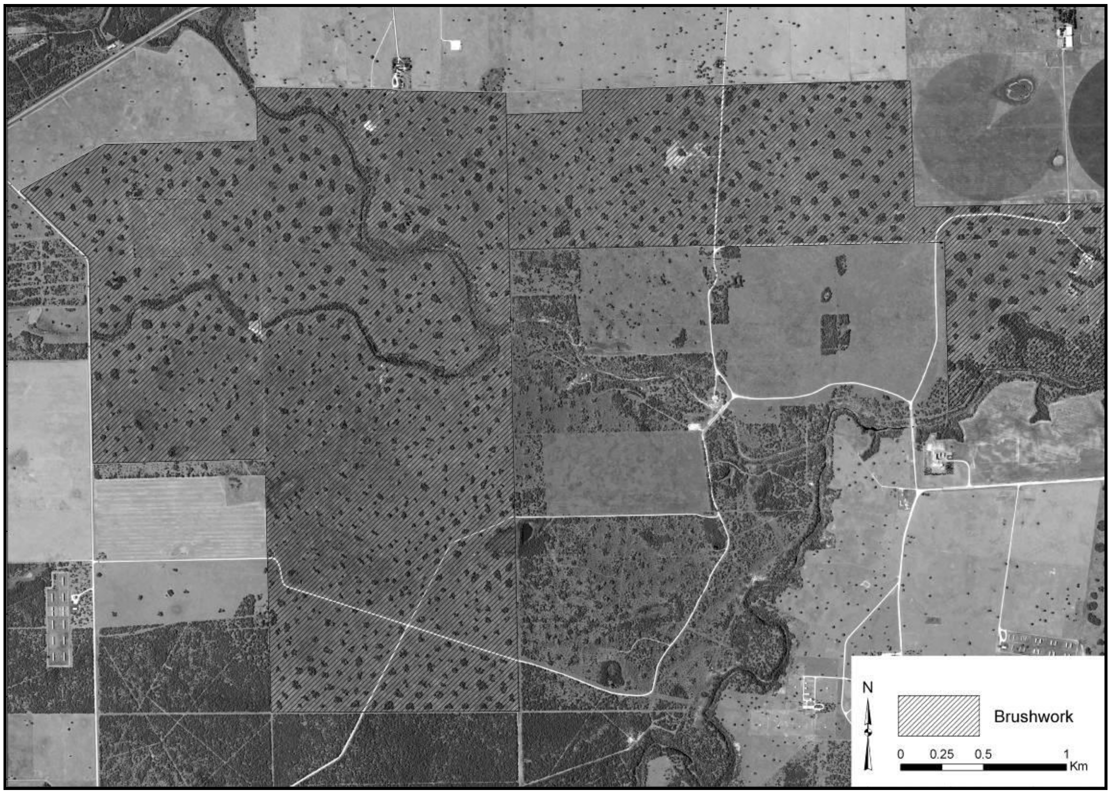

Figure 2. Brush removal included 776 ha in 2004 and 367 ha in 2005, Kenedy County, Texas, USA.

September in 2009, and recorded their GPS coordinates. I tracked birds using a Yagi-style antenna and an R-1000 telemetry receiver (Communications Specialists, Inc., Orange, CA, USA) as well as an R-4000 telemetry receiver (Advanced Telemetry Systems, Inc., Isanti, MN, USA) . No more than 1 location/bird/day was recorded. I tracked quail from early morning to late evening and stratified results based on time of day. Specifically, data were collected during morning feeding (sunrise – 0959 hrs), afternoon loafing (1000–1659), and evening feeding (1700 – sunset). When quail were located by homing, I recorded their position with an HP rx5910 PDA (Palo Alto, CA, USA) and a Trimble Juno SB handheld (Westminster, CO, USA) equipped with ArcPad, accurate to ±3 m. I then imported locations into geographic information systems (GIS) software (ArcMap Version 9.1, Redland, California, USA) to establish a visual representation of habitat use and home range size.

Nest Site Selection. — I found nests either by flushing radio marked females from the nest site or, when possible, by locating the nest before she flushed. Once a quail nest was discovered, I recorded its coordinates with a handheld global position system (GPS) unit, and marked its location by placing flagging ≥2 m apart on either side of the nest. I recorded date of nest initiation, last date known to be active, date terminated, and fate. I monitored presence or absence of the female on the nest, without flushing, 3 times/week until nest fate (success, failure) was determined. Nests were considered successful if ≥1 egg hatched. Because nests were not measured daily, 2 measures of nest success were used. Nests were considered successful if hatched egg shells were present in the nest, or if hatchlings were present with a recently nested hen. I also recorded proportion of eggs hatched to determine egg hatchability for each nest.

Vegetation Sampling. — After the nest was terminated, I conducted vegetation measurements at each nest and at a randomly selected point located between 50–100 m from the nest along a randomly selected bearing. Distances between 50 and 100 m were assumed to be far enough away to be distinguishable from the used location, but close enough to be comparable to the used location for research purposes (Hernández et al. 2003, Lusk et al. 2006).

I used a modified, extended Daubenmire frame (three 20 x 50 cm frames joined) to estimate absolute percent cover of bare ground, litter, bare ground exposure, canopy cover of species of grass, forbs, and woody plants (Bonham et al. 2004, Lusk et al. 2006) (Figure 3). I alternated frame orientation between north-south and east-west with each pair of points to avoid bias.

I measured height of vegetation (cm) at the center of the nest and at each corner of the middle Daubenmire frame at random points (Winter et al. 2005). I estimated litter depth (cm) at the nest by averaging the litter depth at 4 cardinal directions beside the nest. I recorded the vegetation species the nest was in. To estimate bunchgrass density by species, I counted bunchgrass clumps inside a 0.5 m radius circular plot centered on the nest and random location. Bunchgrass density was estimated as the average number of bunchgrasses/m^2. I estimated cactus and woody plant density by counting number of stems above the ground within a circular plot with a radius of 2 m from the nest and random location. Woody plant and cactus density was calculated as the average number of stems/m^2.

To estimate percent horizontal cover, I used a modified staff-ball method based on Collins and Becker (2001) who found this technique to be more precise and faster than

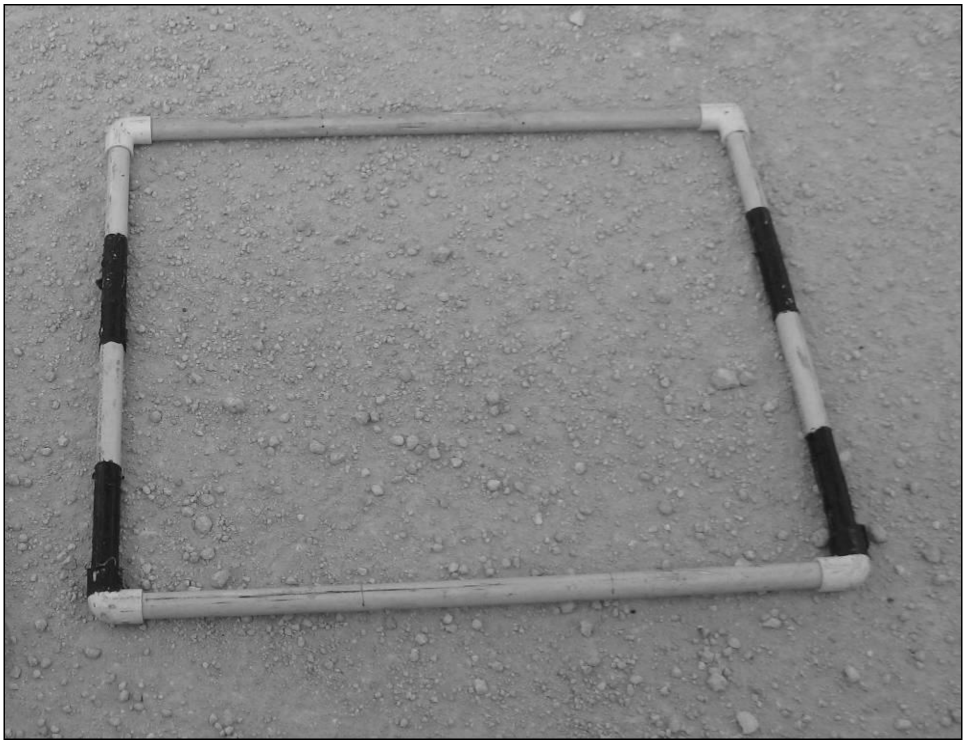

Figure 3. Modified, extended Daubenmire frame (3-20 x 50 cm frames joined) used to estimate percent cover, Kenedy County, Texas, USA, 2008 and 2009.

the Robel pole or profile board methods. Instead of a staff and ball, I used a 1 m tall, 2.54 cm PVC pipe sprayed with orange paint, which I positioned at the center of the sampling point by supporting it with a 0.5 m long piece of rebar I hammered into the ground. I constructed a periscope out of PVC pipe (cut to lengths of 12, 25, and 50 cm) and a Geographic Resource Solutions (GRS) densitometer (Geographic Resource Solutions, Arcata, California, USA) (Figure 4a and 4b). I used 3 lengths of PVC pipe to estimate horizontal cover at heights of 12, 25, and 50 cm. These heights represent the average height of a bobwhite (12 cm), a ground predator (25 cm), and overhead screening cover from aerial predators (50 cm). I determined a sight distance (radius) of 3 m based on the distance that would produce visual obstruction 50% of the time (Collins and Becker 2001). I walked a circle around the nest, stopping 8 times to determine if the orange pole could be sighted through the scope (Figure 5). I recorded the total number of locations where the pole was obstructed. This method was repeated for heights of 12 cm, 25 cm, and 50 cm. Percent horizontal cover was calculated by dividing number of locations that were obstructed by the total number of locations (across all heights) times 100%.

Data Analysis

Nest Success. — I estimated the proportion of successful nests (apparent nest success) separately for 2008 and 2009. I used logistic regression to determine the relationship between nest success and guineagrass percent cover, buffelgrass percent cover, native grass percent cover, and percent cover of dead grass excluding guineagrass, separately (Ramsey and Schafer 2002).

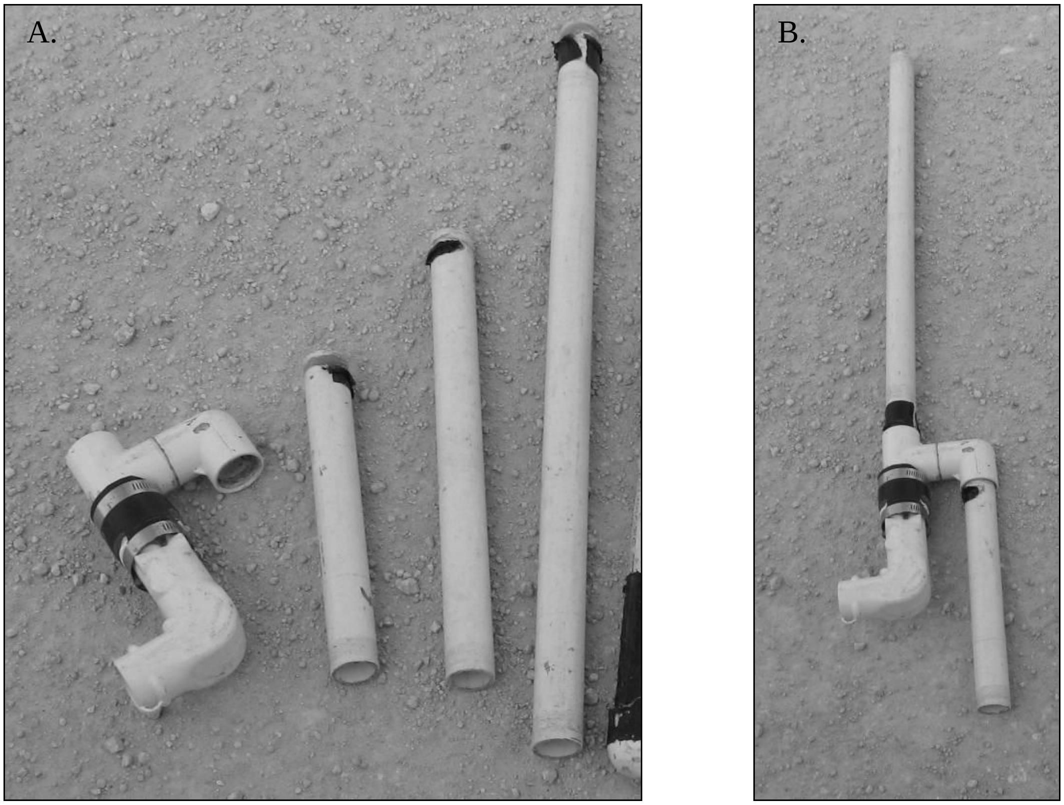

Figure 4. A) PVC pipe of lengths 12, 25, and 50 cm and a GRS densitometer was used to construct B) the periscope to estimate percent horizontal cover, Kenedy County, Texas, USA, 2008 and 2009.

Figure 5. Percent horizontal cover was estimated by walking a circle around the nest, stopping 8 times to determine if the orange pole could be sighted through the scope, Kenedy County, Texas, USA, 2008 and 2009.

I used the Mayfield Method to calculate a corrected estimate of nest success with standard errors and 95% confidence intervals (CI), using a nesting period of 34 days (Mayfield 1961, Johnson 1979). Because a nest was only observed if it contained an egg (i.e., nest bowls were not counted), the nesting period was defined as the average laying period (average clutch size = 11) plus the incubation period (23 days) (Brennan et al. 2007).

Habitat Variables.— Plant species were lumped into functional groups for analysis (Lusk et al. 2006, Larson et al. 2010). Functional groups included percent cover of bare ground, litter, bare ground exposure, guineagrass, all grasses, native grass species, exotic grass species, all forb species, primary forb species, secondary forb species, woody species (Table 1). Other functional groups included densities of all grass species, native grass species, exotic grass species, and woody species, and litter depth, vegetation height, and percent horizontal cover.

Statistical Analysis. — I compared guineagrass percent cover at nests and random points with paired t-tests. Nests were the sampling units and were treated as independent from each other. I first assessed whether there was year-to-year variation in the differences in percent cover between nests and random points during 2008 and 2009. Years were pooled together because they were similar.

To quantify the difference in vegetation between nests and random sites, I conducted paired t-tests for all vegetation measurements including percent canopy cover of guineagrass, bare ground, litter, bare ground exposure, all grass (all grass + standing dead grass), invasive grass, native grass, total forbs, primary forbs, and secondary forbs. Forbs

Table 1. Functional groups of plant species for Kenedy County, Texas, USA, 2008 and 2009 (USDA 2008).

Functional group	Species	
Native grasses		
	three-awn (*Aristida* spp.)	southern witchgrass (*Panicum capillarioides*)
	hairy grama (*Bouteloua hirsuta*)	Texas panicum (*Panicum texanum*)
	coastal sandbur (*Cenchrus* spinifex)	paspalum (*Paspalum* spp.)
	windmillgrass (*Chloris* spp.)	seacoast bluestem (*Schizachyrium scoparium*),
	Durban crowfoot (*Dactyloctenium aegyptium*)	bristlegrass (*Setaria* spp.)
	dichanthelium (*Dichanthelium* spp.)	purple dropseed (*Sporobolus purpurascens*)
	fall witchgrass (*Digitaria cognata*)	multiflowered false rhodesgrass (*Trichloris pluriflora*)
	crabgrass (*Digitaria* spp.)	fringed signalgrass (*Urochloa ciliatissima*)
	lovegrass (*Eragrostis* spp.)	sabi grass (*Urochloa mosambicensis*)
	tanglehead (*Heteropogon contortus*)	liverseed grass (*Urochloa* spp.)
	tropic sprangletop (*Leptochloa virgata*)	Texas wintergrass (*Vaseyochloa multinervosa*)
	beaked panicum (*Panicum anceps*)	
Exotic grasses	bermudagrass (*Cynodon dactylon*)	Kleberg bluestem (*Dichanthium annulatum*)
	buffelgrass (*Pennisetum ciliare*)	kleingrass (*Panicum coloratum*)
	guineagrass (*Urochloa maxima*)	natal grass (*Melinis repens*)
Primary forbs	American snoutbean (*Rhynchosia americana*)	partridge pea (*Chamaecrista fasciculata*),
	cowpen daisy (*Verbesina encelioides*),	scarlet pea (*Indigofera miniata*)

Table 1. Continued

Functional group	Species	
Primary forbs	croton (*Croton* spp.)	vervain (*Verbena* spp.)
	erect day flower (*Commelina erecta*)	western ragweed (*Ambrosia psilostachya*)
	hoary milkpea (*Galactia canescens*)	wild mercury (*Argythamnia humilis*)
	Kairn's sensitive briar (*Schrankia latidens*)	
Secondary forbs		
	cardinal's feather (*Acalypha radians*)	silverleaf nightshade (*Solanum elaeagnifolium*)
	ground cherry (*Physalsis* spp.)	wedgeleaf prairie clover (*Dalea emarginata*)
	hairy tube tongue (*Siphonoglossa pilosella*)	wild grape (*Vitis* sp.)
	rose palafox (*Palafoxia rosea*)	yellow wood-sorrel (*Oxalis stricta*)
	sida (*Sida* spp.)	
Woody species		
	brasil (*Condalia hookeri*)	honey mesquite (*Prosopis glandulosa*)
	chile pequin (*Capsicum annuum*)	huisache (*Acacia farnesiana)*
	eupatoria (*Eupatorium odorata*)	lime prickly ash (*Zanthoxylum fagara*)
	granjeno (*Celtis pallida*)	Texas lantana (*Lantana urticoides*)
	hog plum (*Colubrina texensis*)	wolfberry (*Lycium* spp.)

were grouped into primary and secondary categories based on importance for foraging (Larson et al. 2010). I also included densities of guineagrass, total bunchgrasses, native bunchgrass, invasive bunchgrass, and woody plants. Additional paired t-tests included litter depth (cm), vegetation height (cm), total species richness, and percent horizontal cover. The distribution of the mean of the differences for each variable was examined, and each were approximately normal. Because of this, I used paired t-test instead of Mann-Whitney U (or non-parametric) paired t-tests. I examined outliers to see if there were any influential points.

I used case-controlled logistic regression with stepwise variable selection ($P = 0.05$ to enter or remove) to determine which variables most effected the odds of a point being a nest (Powell and Steidl 2002, Thomas and Taylor 2006). I constructed correlation matrices to eliminate vegetation variables with high levels of correlation (≥ 0.70). The logistic procedure was then used to calculate odds ratios and Wald's 95% CI.

Results

Trapping and Telemetry

Throughout the study (2008 – 2009) I captured and banded 213 (97 female; 116 male) bobwhites and radio-marked 107 (88 females and 19 males) with transmitters. During 2008, I captured 102 (47 females: 55 males) bobwhites and radio-marked 56 (43 females and 13 males). Of the 43 females that were collared, 21 nested (73%) and 9 of those hens renested (36%). During 2009, I captured 111 (50 female: 61 male) bobwhites and radio-marked 51 (45 females and 6 males). Of the 45 females that were collared 16 nested (36%) and none of those hens renested.

Nest Success

During 2008–2009, I found 46 nests, 15 of which successfully hatched with 10 and 5 successful nests during 2008 and 2009, respectively (Table 2). Nest success calculated using Mayfield's Method differed from apparent nest success. Nesting period was defined as laying period (average clutch size = 11) plus incubation period (23 days). For the entire study, 18% of the nests were successful.

Table 2. Mean apparent nest success and Mayfield's nest success (%), lower (LCI) and upper (UCI) 95% confidence intervals, and SE for northern bobwhite nests, Kenedy County, Texas, USA, 2008 and 2009.

Year	Number of nests	Apparent nest success (%)	Mayfield's nest success			
			%	LCI	UCI	SE
2008	30	33	19.8	19.7	19.8	0.00
2009	16	31	15.4	15.3	15.4	0.00
Combined	46	33	17.9	17.9	17.9	0.00

Odds of nest success decreased 0.96 times (95% CI = 0.84 – 1.00) for every 1% increase in guineagrass percent canopy cover, or for every 1% increase in guineagrass cover, nest success decreased by 4% (Figure 6a). Buffelgrass, native grass, and dead grass did not affect nest success (Figure 6b-6d).

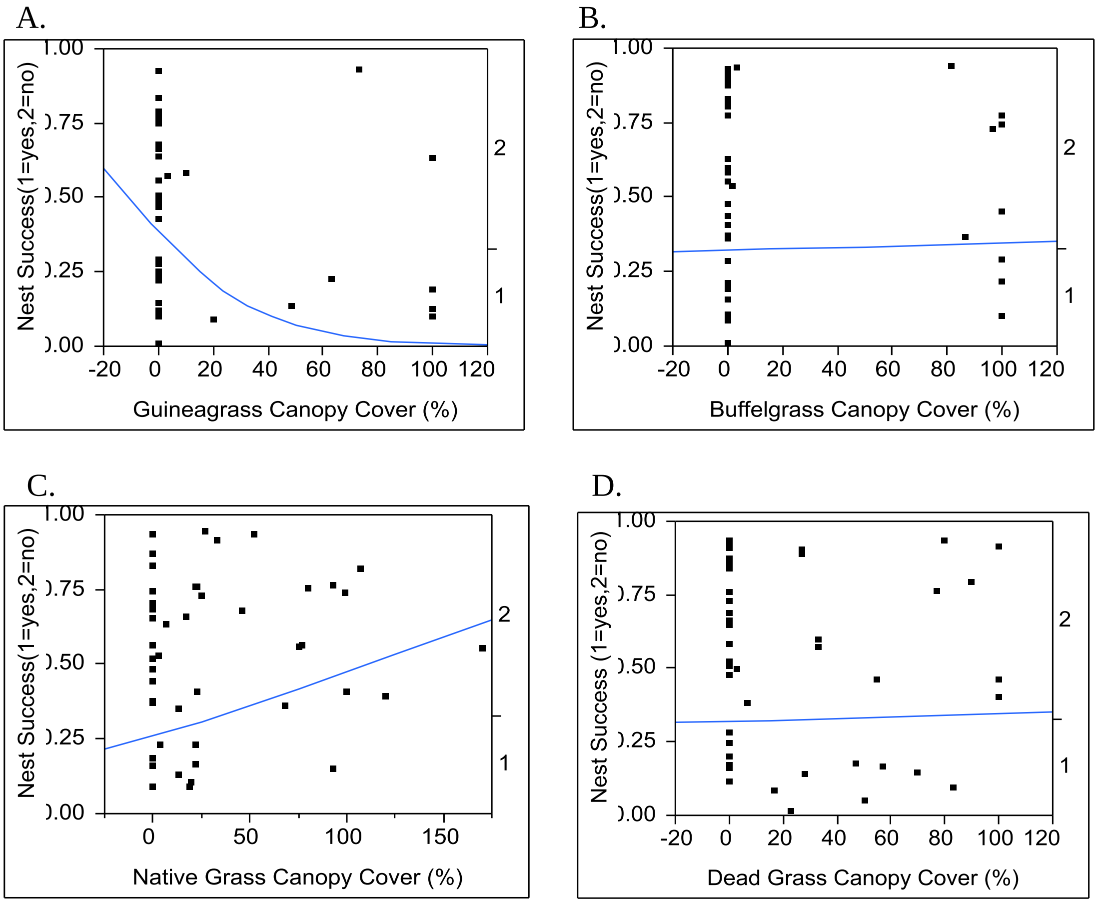

Figure 6. Logistic regression relationship between nest success (1 = success, 2 = failure) and A) guineagrass percent canopy cover [logit(π)= -0.46–0.04*guineagrass percent cover, X_1^2 = 4.94, P = 0.026], B) buffelgrass percent canopy cover [logit(π)= -0.75+0.00*buffelgrass percent cover, X_1^2 = 0.02, P = 0.894], C) native grass percent canopy cover [logit(π)= -1.05 +0.01*native grass percent cover, X_1^2 = 1.63, P = 0.202], D) dead grass percent canopy cover [logit(π)= -0.76 +0.00*dead grass percent cover, X_1^2 = 0.02, P = 0.896] for bobwhite nests, Kenedy County, Texas, USA, 2008 and 2009.

Paired t-tests

Nest sites had 5 vegetation characteristics that were significantly different from random locations (Table 3). Nest sites had on average 12 % less litter cover, 34% more total grass cover, 29% greater horizontal cover, 2 cm deeper litter, and 18 cm taller vegetation than did random locations. Guineagrass percent canopy cover was similar between nests and random points. The most frequently used primary nesting substrate was dead grass, with guineagrass being used for 8 nests (17%; Table 4).

Case-Controlled Logistic Regression

Variables that were removed from analyses because they were highly correlated with others included bare ground percent cover, primary forb percent cover, guineagrass density, native grass density, and vegetation height. Stepwise selection, therefore, began with a set of 12 variables, including litter percent cover, bare ground exposure, guineagrass percent cover, total grass percent cover, native grass percent cover, invasive grass percent cover, total forb percent cover, secondary forb percent cover, total grass density, invasive grass density, litter depth, and percent horizontal cover.

Habitat characteristics that best predicted the odds of a point being a nest site were total grass percent cover and percent horizontal cover. Case-controlled logistic regression revealed that the odds of a point being a nest site increased by 3.3% (95% CI = 0.20 – 6.50) for every 1% increase in total grass cover ($X_2^2 = 4.33$, $P = 0.037$) after accounting for percent horizontal cover. Also, the odds of a point being a nest increased by 12.2% (95% CI = 3.1 – 22.0) for every 1% increase in horizontal cover ($X_2^2 = 7.15$, $P = 0.008$) after accounting for total grass percent cover.

Table 3 Means and 95% lower (LCI) and upper (UCI) confidence intervals for vegetation variables at bobwhite nest sites and random sites and results for paired t-tests, Kenedy County, Texas, USA, 2008 and 2009.

	Nest sites (n = 46)			Random sites (n = 46)			Difference* (n = 46)			*t* statistic	*p*-value
Variable	Mean	LCI	UCI	Mean	LCI	UCI	Mean	LCI	UCI		
Percent cover											
Guineagrass	13	4	23	6	1	12	-7	-3	1	1.46	0.1518
Bare ground	0	4	23	2	0	5	-2	-4	1	-1.53	0.1324
Litter	8	3	13	20	11	28	-12	-22	-2	-2.37	0.0219
Bare ground exposure	1	0	2	3	0	6	-2	-5	1	-1.36	0.1818
Total grass	99	89	110	65	53	78	34	20	49	4.74	<0.0001
Invasive grass	43	28	59	30	18	42	13	-2	29	1.71	0.0934
Native grass	32	20	44	33	21	46	-1	-14	12	-0.20	0.8462
Total forbs	29	18	41	38	25	51	-9	-25	8	-1.03	0.3107
Primary forbs	11	4	18	18	9	28	-7	-19	4	-1.27	0.2122
Secondary forbs	5	2	9	6	3	1	-1	-6	4	-0.35	0.7280
Density (no. bunchgrasses/m^2)											
Guineagrass	1.72	0.55	2.89	1.25	0.21	2.28	0.47	-0.61	1.55	0.70	0.3843
Total bunchgrass	9.25	7.23	11.27	10.32	7.99	12.66	-1.07	-3.69	1.54	-0.83	0.4127
Native bunchgrass	5.90	3.80	8.00	7.53	4.97	10.10	-1.63	-4.32	1.05	-1.22	0.2270

Table 3. Continued

Variable	Nest sites (n = 46)			Random sites (n = 46)			Difference* (n = 46)			t statistic	p-value
	Mean	LCI	UCI	Mean	LCI	UCI	Mean	LCI	UCI		
Density (no. bunchgrasses/m^2)											
Invasive bunchgrass	3.35	1.87	4.83	2.80	1.24	4.36	-1.26	-14.29	11.76	-0.20	0.8463
Other											
Total sp. rich. (no./0.3 m^2)	4.43	3.54	5.33	5.33	4.26	6.39	-0.89	-1.86	0.08	-1.85	0.0709
Percent horizontal cover	63.13	56.05	70.22	33.96	28.56	39.36	29.17	21.51	36.84	7.66	<0.0001
Litter depth (cm)	4.17	3.63	4.72	2.11	1.46	2.75	2.07	1.29	2.84	5.38	<0.0001
Vegetation height (cm)	39.03	30.43	47.63	20.94	15.67	26.21	18.09	10.13	26.05	4.57	<0.0001

* nest - random

Table 4. Primary nesting substrate and percentage of nests for each, Kenedy County, Texas, USA, 2008 and 2009.

Nest substrate	Number of nests	% of nests
Exotic grasses		
Buffelgrass	8	17.4
Guineagrass*	8	17.4
Kleingrass	2	4.3
Natal grass	1	2.2
Native species		
Fall witchgrass	2	4.3
Tanglehead	6	13.0
Texas panicum	2	4.3
Cowpen daisy	2	4.3
Unknown dead grass	15	32.6

*****4 nests were in dead guineagrass and the other 4 were in alive guineagrass.

Discussion

Northern bobwhite hens in this study did not select or avoid guineagrass bunches for nest sites; vegetation structure was more important in nest site selection than was plant species. Selection for structure, specifically nest sites that provide greater nest concealment through taller vegetation and greater structural complexity, than what was available at random is a commonality among other nest site selection studies that have been conducted throughout the range of bobwhites (Townsend et al. 2001, Hernández et al. 2003, Tjemeland 2007). Vegetation height most suitable for nest site locations based on my results and on those of other researchers is around 40 cm (Klimstra and Roseberry 1975, Brennan et al. 1999, Lusk et al. 2006). Furthermore, bobwhite nests generally have greater structural complexity, including greater grass cover, greater visual obstruction, and less bare ground than at random sites (Townsend et al. 2001, Rader et al. 2007, Buelow 2009). These findings agree with the results of my study; a conclusion based on my results and those of others is that any plant species with these characteristics are potential nesting sites.

Bobwhites nest in a variety of plant species throughout their range (Stoddard 1931, Rosene 1969, Lehmann 1984, Hernández and Peterson 2007). This includes many native grasses (Lehmann 1946, Peoples et al. 1996, Townsend et al. 2001, Brennan et al. 2007), exotic grasses like buffelgrass (Sands 2007, Tjelmeland 2007), and even forbs and shrubs (Lehmann 1984:81, Carter, Rollins, and Scott 2002, Hernández et al. 2003). Additionally, bobwhites in my study used guineagrass for nesting. These results further indicate that structure of the nesting substrate is important, not the plant species.

Guineagrass invasion does not preclude invaded areas from use as nesting habitat. Guineagrass is suitable nesting cover because it offers tall, dense bunchgrass cover for nest concealment, even when present as dead culms from the previous growing season. Similar observations have been reported in other studies where bobwhites used standing dead herbaceous vegetation from the previous growing season (Stoddard 1931, Brennan 1999). The fact that dead guineagrass culms from the previous growing season provide adequate nesting cover for bobwhites may be important when a period of adequate rainfall for plant growth is followed by drought. Under those conditions, growth of native grasses is often minimal and may not meet nesting cover requirements.

Guineagrass invasion may have negative implications for bobwhite population dynamics, however, since nesting success declines with increasing guineagrass cover. These findings contradict other studies that have found that nest success depends on the level of nest concealment and protection, regardless of vegetation species that provides it (Errington 1933:123, Townsend et al. 2001, Hernández et al. 2003, Lusk et al. 2006). Results from Chapter IV (page 76) indicate that habitat attributes associated with nest concealment, such as percent horizontal cover, increase with increasing guineagrass cover. Furthermore, nest success was unrelated to the amount of buffelgrass, native grass, and dead grass excluding guineagrass. Therefore, there must be other factors associated with guineagrass that result in reduced nest success.

One hypothesis for this reduction in nest success involves the drought conditions of the study area during this study period. Because guineagrass provides adequate cover for nesting even as dead growth from the previous growing season, as drought conditions worsen, and cover of native grasses declines, bobwhites may use guineagrass bunches more frequently. Furthermore, because bobwhite productivity is highly correlated with annual rainfall (Guthery et al. 2002, Hernández et al. 2005, Brennan 2007), drought and effects of guineagrass on nest success may have been confounded. However, if this were the case, we would have expected nest success to decline with an increase in other dead grass species. This was not the case, however. Nest success was unrelated to the amount of dead grass present at the nest site. Therefore, drought likely caused reduced nest success during this study, but there were apparently other factors associated with guineagrass that caused a further reduction in nest success.

Another hypothesis relates to the habitat quality of guineagrass-invaded areas in this study. Forbs are essential dietary items for bobwhites, and are thus an important component of their habitat (Lehmann 1984:192, Guthery 1986:147, Kuvlesky et al. 2002). Therefore, a lack in forbs would indicate poor habitat quality. Sites with guineagrass cover in this study had a clear reduction in forb cover and diversity compared to sites without guineagrass (Chapter IV, page 69). Because the productivity of a species is directly tied to the quality of its habitat (Van Horne 1983), the decreased productivity of bobwhites in guineagrass-invaded areas shown by reduced nest success indicates that guineagrass may be associated with reduced bobwhite habitat quality. Specifically, forb reduction may increase the distance a hen must travel, thus increasing the amount of time and energy she must spend, searching for food. This would cause the nest to be exposed longer, increasing the probability of nest failure. Furthermore, this would also increase the opportunity of predation of the bird and may reduce nutritional success of the hen.

Management Implications

Bobwhites use guineagrass stands to meet their nesting cover requirements in south Texas. However, because nest success declines with increasing guineagrass, possibly in relation to reduced forb cover, this indicates that invasion of large areas by guineagrass may be detrimental to bobwhites. Therefore, it is important to maintain areas with native vegetation to provide adequate forage and brooding habitat. Where guineagrass has invaded the majority of the landscape, prescribed fire and grazing can increase diversity and abundance of native plants essential to bobwhites for foraging (Ramirez et al. 2007). Therefore, implementing these tools to manage for a mosaic of guineagrass stands interspersed among areas of native vegetation for foraging would benefit quail populations.

CHAPTER III

EFFECTS OF GUINEAGRASS ON BOBWHITE FORAGING AND LOAFING HABITAT USE

Abstract

Guineagrass (*Urochloa maxima*) is native to Africa, and was introduced to the U.S. for erosion control and to improve livestock grazing productivity. Over the past 20 years, it has invaded large areas of bobwhite (*Colinus virginianus*) habitat in southern Texas and northern Mexico. My objective was to determine if northern bobwhites use or avoid guineagrass during daily foraging and loafing. Bobwhites were monitored using radio telemetry during the breeding season (April–September) during 2008–2009 in Kenedy County, Texas, USA. I measured vegetation attributes, at organism-centered and paired random points. I analyzed data at microhabitat scales using paired t-tests and generalized linear mixed models, and at macrohabitat scales using a chi-square contingency analysis. Bobwhites did not significantly use or avoid guineagrass at the microhabitat scale, but used guineagrass-dominated areas at the macrohabitat scale for loafing activities. For foraging activity, organism-centered points averaged 14% more total forb cover, 1 more total plant species, 0.7 more total forb species, and 0.3 more primary forb species than random points.

Introduction

Bobwhites in south Texas tend to prefer habitat that consists of a mosaic of woody cover for loafing, herbaceous cover including a diversity of forage plants, abundant insects, and bare ground for mobility (Hernández and Peterson 2007, Kuvlesky et al. 2002). Seed-producing forbs and grasses are essential dietary items for bobwhites, and insects provide important protein for young chicks and also for adults (Lehmann 1984:192, Guthery 1986:147, Kuvlesky et al. 2002). Additionally, herbaceous plant-dominated habitats that provide adequate cover for escaping from predators, thermal protection, and brooding cover are important to all quail species (Kuvlesky et al. 2002). Therefore, guineagrass invasion into native grassland could degrade bobwhite loafing and foraging habitat if it limits one or more of the habitat attributes required by quail to fulfill their specific life history requirements (Kuvlesky et al. 2002).

There is evidence that monocultures formed by many exotic grasses create poor quality habitat for bobwhites. Dense monocultures reduce herbaceous structural diversity, which in turn reduces niche diversity, forge plants and insects, and mobility (Guthery 1986, Kuvlesky et al. 2002). Bobwhites were about twice as abundant on sites dominated by native grasses in southern Texas compared with exotic-grass dominated sites, which possibly resulted in part from a 40.6% decrease in arthropod abundance between native and exotic grass plots (Flanders et al. 2006). Tall fescue fields in Kentucky provide poor bobwhite habitats because of lack of foraging plants and simplified floristic structure (Barnes et al. 1995). In southern Texas, areas of extensive buffelgrass (*Pennisetum ciliare*) coverage exhibit a simplified herbaceous vegetation community in terms of species richness and diversity, when compared to areas of native grasses (Sands et al. 2009). Forb canopy coverage, species richness, and diversity decline with increasing buffelgrass canopy cover (Sands et al. 2009).

Presence of exotic grasses may also benefit quail populations, however, by providing a habitat attribute that was limited or missing before exotic grass invasion (Kuvlesky et al. 2002). Conservation Reserve Program (CRP) fields in northern Missouri consisting of the exotic grass tall fescue (*Festuca arundinacea*) and red clover (*Trifolium pratense*) provide habitat conditions suitable for bobwhite production (Burger et al. 1990, Burger 1993). Additionally, bobwhites readily roost in buffelgrass, which suggests that bobwhites are capable of utilizing buffelgrass to fulfill at least some of their requirements even though this grass generally reduces habitat quality for bobwhites and other grassland bird species (Sands 2007, Tjelmeland 2007).

Guineagrass is native to Africa, and was intentionally introduced to the U.S. for erosion control and to improve grazing productivity around 1818 (Parsons 1972, Kuvlesky et al. 2002,), but may have been accidentally introduced to North America from slave ships as early as 1684 (Larson et al. 2010). Over the past 20 years, it has invaded large areas of quality bobwhite habitat in southern Texas and northern Mexico. This is of significant concern for conservation of northern bobwhites because southern Texas is one of the few regions of the U.S. that supports large areas of contiguous bobwhite habitat and sustainable populations of the species (Lehmann 1984, Brennan et al. 2007). Like other exotic grasses, guineagrass can reduce diversity of plant communities by disrupting ecosystem functions. For example, guineagrass supports a fire cycle to which native plants are not adapted (Calvert 1999). Furthermore, because this grass is fire resistant, it often dominates the landscape after a fire (Tan 2001). Guineagrass grows quickly and outcompetes seedlings of native plants, forming dense monocultures (Calvert 1999, Ramirez et al. 2007). This can result in exclusion of valuable native plants essential to wildlife, including plants important for insects and for producing seeds eaten by quail and other bird species (Kuvlesky et al. 2002, Veldman et al. 2009). There is a lack of published research on how invasions of guineagrass impacts wildlife populations, especially bobwhites.

My objective was to investigate the impacts of guineagrass on bobwhite habitat use at micro and macrohabitat scales. Guineagrass-dominated areas possibly lack diversity and abundance of forage plants; however, guineagrass may possess structural characteristics desirable for loafing. I hypothesized that bobwhites avoid guineagrass and guineagrass-dominated patches for foraging but use guineagrass and guineagrass-dominated patches for loafing.

Study Area

I conducted field work on a 1,643 ha portion of a private ranch in Kenedy and Brooks counties, Texas, USA, during March–September 2008–2009. The ranch lies in the South Texas Plains ecoregion of Texas (Gould 1975) where the climate is subtropical humid (Larkin and Bomar 1983), with extreme variability in annual precipitation (Fulbright et al. 1990). In 2008, the study area received 64 cm of rainfall, with July–September receiving about 75% of that total, while in 2009, the study area received 52 cm, with September–December receiving 78%. The study area was in severe drought during June 2008 and in severe to extreme drought during April to October 2009 based on the Palmer Drought Severity Index (NOAA 2010). Soils series at this site included sandy, tight sandy loam, sandy, and loamy sand (USDA-NRCS, 2009). The study area was grassland interspersed with mottes of woody plants. Historical grassland for the area is a seacoast bluestem (*Schizachyrium scoparium*) and balsamscale (*Elionurus tripsacoides*) association (McLendon 1991). Common subdominants were arrowfeather threeawn (*Aristida pupurascens*), thin paspalum (*Paspalum setaceum*), brownseed paspalum (*P.*

plicatulum), coastal sandbur (*Cenchrus spinifex*), tanglehead (*Heteropogon contortus*), big bluestem (*Andropogon gerardii*), Texas snoutbean (*Rhyncosia texana*), Lindheimer's hoarypea (*Tephrosia lindheimeri*), snake cotton (*Froelichia drummondii*), honey mesquite (*Prosopis glandulosa*), prickly pear (*Opuntia* lindheirmeri), and yucca (*Yucca constricta*) (McLendon 1991). The major shrubland association was mesquite-granjeno (*Celtis pallida*) (McLendon 1991). Common subdominants included prickly pear, lime prickly ash (*Zanthoxylum fagara*), hogplum (*Colubrina texensis*), blackbrush (*Acacia rigidula*), and wolfberry (*Lycium berlandieri*). Important understory species included guayacan (*Porlieria angustifolia*) and tasajillo (*Opuntia leptocaulis*) (McLendon 1991). Management practices on the study area have included fire, rotational grazing, and mechanical brush removal techniques including dozing, root-plowing, and raking. Prescribed burns included 197, 231, 253, and about 57 ha in 2004, 2005, 2007, and 2009 respectively (Figure 1, page 11). Brush removal techniques included dozing, root plowing, and raking on 776 ha in 2004 and 367 ha in 2005 (Figure 2, page 12). Rotational grazing within the study area took place in 2007 from October–December. The study area was grazed by longhorn cattle (*Bos bos*) from autumn 2008–spring 2009. From January–early March, there were 319 longhorns in the study area for 60 days (0.19 animal units/ha), then the number of cattle was reduced to 118 for 21 more days until late March (0.07 animal units/ha).

Methods

Data Collection

Trapping and Telemetry. — I trapped bobwhites during 2008 and 2009 using walk-in funnel traps baited with milo (*Sorghum bicolor*) (Stoddard 1931). Trapping protocol was approved by Texas A&M University-Kingsville Institutional Animal Care and Use Committee, approval number 2008-01-18B. Trapping began in mid-March and continued through mid-September to maintain a sample of ≥20 radio-marked bobwhite hens. I marked every captured bird with a numbered aluminum leg band, and I fitted birds weighing ≥150 g with a necklace-mount, 6-g radio transmitter (American Wildlife Enterprises, Monticello, Florida, USA). I kept detailed records on captured birds including sex, age, body mass, time and date of capture, band number, and radio transmitter frequency. I recorded known mortalities of radio collared birds when possible. I tracked birds 2–3 times/week from March–October in 2008 and May–September in 2009, and recorded their GPS coordinates. I tracked birds using a Yagi-style antenna and an R-1000 telemetry receiver (Communications Specialists, Inc., Orange, CA, USA) as well as an R-4000 telemetry receiver (Advanced Telemetry Systems, Inc., Isanti, MN, USA). No more than 1 location/bird/day was recorded.

When quail were located by homing, I recorded their position with an HP rx5910 PDA (Palo Alto, CA, USA) and a Trimble Juno SB handheld (Westminster, CO, USA) equipped with ArcPad, accurate to ±3 m. I then imported locations into geographic information systems (GIS) software (ArcMap Version 9.1, Redland, California, USA) to establish a visual representation of habitat use and home range size.

Habitat use was evaluated at 2 temporal scales. This was achieved by tracking quail from early morning to late evening and stratifying results based on time of day. Specifically, I collected data during morning feeding (sunrise–0959 hrs), afternoon loafing (1000–1659), and evening feeding (1700–sunset). Therefore, the first time period included the morning and evening feeding hours, and the second time period included the afternoon loafing hours.

After completion of the 2009 tracking season, I delineated stands of guineagrass, buffelgrass, and mixed buffelgrass-guineagrass throughout the study area using a GPS unit and an ATV. Only the portion of the study area that was used by collared bobwhites during the 2008–2009 field season was mapped. These delineations were then imported into GIS software and used to estimate macrohabitat use. I quantified plant community structure for areas dominated by native grass, guineagrass, buffelgrass, and mixed buffelgrass-guineagrass. I did this by calculating mean relative canopy cover, confidence intervals, and standard errors of native grass, guineagrass, buffelgrass, other exotic grasses, and forbs for all random vegetation points, and absolute canopy cover for woody and cactus species. This was done separately for points located in grassland and in mottes (clusters of woody plants) for each plant community type.

Vegetation Sampling. — I randomly selected 10 birds for vegetation sampling each week, without replacement, until all the birds were sampled, then the process was repeated. I sampled vegetation within 2 days after relocation of the bird to ensure characteristics were similar to those the day the bird was located. I conducted vegetation measurements at each organism-centered and at a randomly selected point located between 50–100 m from the organism-centered point along a randomly selected compass bearing. Distances between 50 and 100 m were assumed to be far enough away to be distinguishable from the used location, but close enough to be comparable to the used location for research purposes (Hernández et al. 2003, Lusk et al. 2006). Sampling was stratified into grassland and mottes; for example, if a quail was relocated in a motte, the random site was also in a motte. I first selected a random compass bearing and distance between 50–100 m from the organism-centered point, and then selected the closest motte to the point. I then determined the width of the motte by pacing, and I selected a random number between this width to sample.

I used a modified, extended Daubenmire frame (three joined 20 x 50 cm frames) to estimate absolute percent cover of bare ground, litter, bare ground exposure, canopy cover of species of grasses, forbs, and woody plants (Bonham et al. 2004, Lusk et al. 2006) (Figure 3, page 15). I alternated frame orientation between north-south and east-west with each pair of points to avoid bias.

I estimated height of vegetation (cm) by averaging the height at each corner of the middle Daubenmire frame (Winter et al. 2005). I recorded litter depth (cm) at the middle of the middle Daubenmire frame. I also recorded canopy height (cm) of sampling points in mottes. To estimate bunchgrass density by species, I counted bunchgrass clumps inside a 0.5 m radius circular plot centered on each point. Bunchgrass density was estimated as the average number of bunchgrasses/m^2. I estimated cactus and woody plant density by counting number of stems above the ground within a circular plot with a radius of 2 m from each point. Woody plant and cactus densities were calculated as the average number of stems/m^2.

To estimate percent horizontal cover, I used a modified staff-ball method based on Collins and Becker (2001) who found this technique to be more precise and faster than the Robel pole or profile board methods. Instead of a staff and ball, I used a 1 m tall, 2.54 cm PVC pipe sprayed with orange paint, which I positioned at the center of the sampling point by supporting it with a 0.5 m long piece of rebar I hammered into the ground. I constructed a periscope out of PVC pipe (cut to lengths of 12, 25, and 50 cm) and a Geographic Resource Solutions (GRS) densitometer (Geographic Resource Solutions, Arcata, California, USA) (Figure 4a and 4b, page 17). I used 3 lengths of PVC pipe to estimate horizontal cover at heights of 12, 25, and 50 cm. These heights represent the average height of a bobwhite (12 cm), a ground predator (25 cm), and overhead screening cover from aerial predators (50 cm). I determined a sight distance (radius) of 3 m based on the distance that would produce visual obstruction 50% of the time (Collins and Becker 2001). I walked a circle around the sampling point, stopping 4 times to determine if the orange pole could be sighted through the scope (Figure 5, page 18). I recorded the total number of locations where the pole was obstructed. This method was repeated for heights of 12 cm, 25 cm, and 50 cm. Percent horizontal cover was calculated by dividing number of locations that were obstructed by the total number of locations (across all heights) times 100%.

Data Analysis

Habitat Variables.— Plant species were lumped into functional groups for analysis (Lusk et al. 2006, Larson et al. 2010). Functional groups included percent cover of bare ground, litter, bare ground exposure, standing dead grass, standing dead forb, standing dead shrub, guineagrass, all grasses, native grass species, exotic grass species, all forb species, primary forb species, secondary forb species, and woody species (Table 1, page 20). Other functional groups included densities of all grass species, native grass species, exotic grass species, and woody species, as well as litter depth, vegetation height, canopy height, and percent horizontal cover.

Statistical Analysis. — I estimated mean home range size and standard error of birds that had ≥20 relocations using the 95% fixed-kernel method in ArcMap (Environmental Systems Research Institute, Inc., Redlands, California, USA). This method provides more accurate representations of home range size and is least affected by sample size (when n <50) compared to other home range estimation methods, such as minimum convex polygon, bivariate normal, and harmonic mean methods (Worton 1987, Worton 1989, Seamen and Powell 1996, Franzreb 2005). I examined macrohabitat use by first defining available habitat as that habitat contained within the home ranges of the bobwhites (Janis and Clark 2002, Bond et al. 2002, Thomas and Taylor 2006). I then calculated the portions of the home ranges that were dominated by guineagrass, buffelgrass, mixed buffelgrass-guineagrass, and native vegetation using ArcMap 9.1. Habitat use was defined as the number of relocation points found in each cover type. Macrohabitat data were analyzed in 2 separate activity periods: foraging and loafing. I performed a chi-square contingency analysis on both groups to test whether guineagrass was used for general habitat in proportion to its availability during these activities (Brennan et al. 1987).

I examined microhabitat use with univariate statistics using SAS software. Organism-centered data were analyzed in 2 separate activity periods: foraging and loafing. I compared guineagrass percent cover at organism-centered and random points with paired t-tests. I first assessed whether there was year-to-year variation in the differences in percent cover between organism-centered and random points during 2008 and 2009. Years were pooled together because the differences were similar between years.

To quantify the difference in vegetation variables between organism-centered and random sites, I conducted paired t-tests while accounting for repeated and unequal observations per bird (Thomas and Taylor 2006, SAS Institute 2010) for all vegetation measurements including percent canopy cover of guineagrass, bare ground, litter, bare ground exposure, all grass (all grass + standing dead grass), invasive grass, native grass, total forbs, primary forbs, secondary forbs, and woody plants. Forbs were grouped into primary and secondary categories based on importance for foraging (Larson et al. 2010). I also included densities of guineagrass, total bunchgrasses, native bunchgrass, invasive bunchgrass, and woody plants. Additional paired t-tests included litter depth (cm), vegetation height (cm), canopy height (cm), total species richness, and percent horizontal cover. Residual plots of each variable were examined to meet assumptions, and variances of each were approximately equal.

A generalized linear mixed model with backwards variable selection was used to determine which variables most affected the odds of a point being an organism-centered point. This was done while maintaining pairing between points and accounting for unequal observations per bird (SAS Institute 2006, Thomas and Taylor 2006). I constructed correlation matrices to eliminate highly correlated vegetation variables (≥0.70). All procedures were repeated for all organism data, and for the 2 activity periods (feeding and loafing) separately.

Results

Home Range Analysis

During the study (2008–2009), I captured and banded 213 (97 female: 116 male) bobwhites and radio-marked 107 (88 females and 19 males) with transmitters. Of these quail, 30 were relocated ≥20 times and were used for kernel home range calculation. Mean home range size for bobwhites during the 2008–2009 field season was 23± 3 ha with a range of 3-86 ha.

An 891 ha portion of the study area used by bobwhites with transmitters was mapped. Of this portion, 123 (14%) was dominated by guineagrass, 118 ha (13%) were dominated by buffelgrass, 58 ha (7%) were dominated by a buffelgrass-guineagrass mixture, and the remaining 592 ha (66%) was dominated by native vegetation (Figure 7, Table 5). Mottes had greater relative cover of guineagrass than any other herbaceous plants.

On a few occasions, a few birds ventured out of the study area onto adjacent property. Therefore, because I did not map the vegetation anywhere off the study area, these points were not included in macrohabitat analysis. To avoid bias, only the portions of home ranges that were within the study area were included. Therefore, there was a 62 ha portion of total home range size out of the mapped area, which encompassed 7 relocations. This reduced total home range size by 9%, from 692 ha down to 630 ha.

Macrohabitat Analysis

Total habitat availability within all home ranges combined for the 30 birds with ≥20 relocations was 631 ha. Within the home ranges, 62 ha (10%) was dominated by buffelgrass, 112 ha (18%) was dominated by guineagrass, 62 ha (10%) was dominated by a buffelgrass-guineagrass mixture, and 395 ha (63%) was dominated by native grass. Of the 667 relocation points in these home ranges, 309 were classified as foraging while 358 were loafing points. Bobwhites used these plant communities for foraging in proportion to their availability (Table 6). However, bobwhites used these plant communities for loafing disproportionately to their availability; guineagrass communities were used 11%

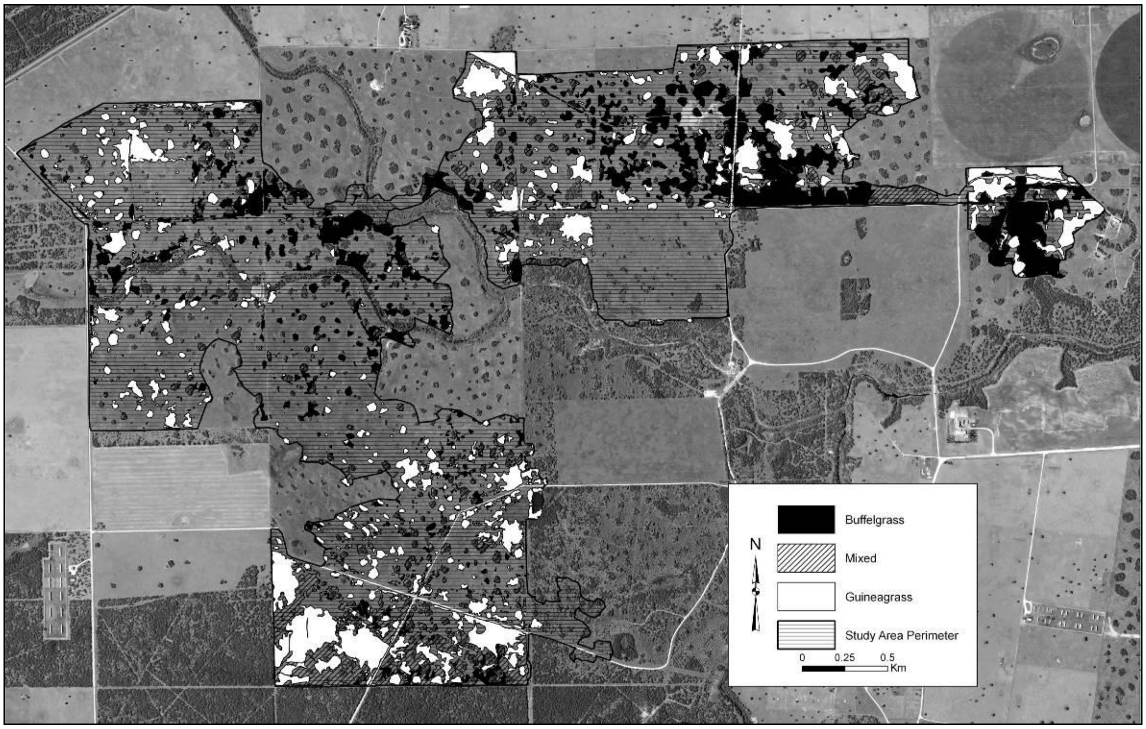

Figure 7. Vegetation map delineating stands of buffelgrass, mixed buffelgrass-guineagrass, and guineagrass, Kenedy County, Texas, USA, 2008 and 2009.

Table 5. Mean relative canopy cover (%), lower (LCI) and upper (UCI) 95% confidence intervals, and SE of native grasses, guineagrass, buffelgrass, and forbs and absolute canopy cover (%) of woody plants for grasslands and mottes with herbaceous plant communities dominated by native plants, guineagrass, buffelgrass, and mixed buffelgrass and guineagrass, Kenedy County, Texas, USA, 2008–2009.

Plant community type		Relative cover of native grass (%)				Relative cover of guineagrass (%)				Relative cover of buffelgrass (%)			
Point type	*n*	Mean	LCI	UCI	SE	Mean	LCI	UCI	SE	Mean	LCI	UCI	SE
Native grass													
Grassland	96	43	36	49	3.30	1	0	2	0.53	0	0	1	0.14
Motte	15	1	0	3	0.98	8	0	23	6.72	1	0	3	0.90
Guineagrass													
Grassland	25	4	0	10	2.94	65	51	80	7.01	1	0	4	1.09
Motte	13	7	0	21	6.04	46	18	75	13.08	8	0	19	4.84
Buffelgrass													
Grassland	23	4	0	10	2.67	1	0	4	1.40	50	31	69	9.11
Motte	7	0	0	0	0.00	14	0	49	14.29	19	0	54	14.29
Mixed Buffel-Guinea													
Grassland	6	29	0	57	10.99	15	0	38	8.96	25	0	68	16.58
Motte*	2												

Table 5. Continued

Plant community type		Relative cover of other exotic grass (%)				Relative cover of forbs (%)				Absolute cover of woody species (%)			
Point type	*n*	Mean	LCI	UCI	SE	Mean	LCI	UCI	SE	Mean	LCI	UCI	SE
Native grass													
Grassland	96	16	10	21	2.84	39	33	45	2.90	1	0	3	1.03
Motte	15	24	5	43	8.91	53	30	76	10.67	127	94	161	15.66
Guineagrass													
Grassland	25	12	2	21	4.63	14	5	23	4.48	12	0	24	5.76
Motte	13	9	0	25	7.67	29	7	52	10.47	100	54	145	20.71
Buffelgrass													
Grassland	23	16	4	29	6.19	23	9	37	6.75	13	0	31	8.43
Motte	7	10	0	33	9.52	29	0	74	18.44	166	85	247	33.24
Mixed Buffel-Guinea													
Grassland	6	1	0	2	0.69	31	2	59	10.97	17	0	60	16.67
Motte*	2												

*insufficient sample size

Table 6. Chi-square contingency analysis of bobwhite foraging macrohabitat use, Kenedy County, Texas, USA, 2008 and 2009.

Plant community	Proportion	Number of observations		Chi-square value
		Observed	Expected	
Guineagrass	0.177	66	55	
Buffelgrass	0.098	21	30	
Mixed	0.098	36	30	
Native	0.627	186	194	$P > 0.05$

Table 7. Chi-square contingency analysis of bobwhite loafing macrohabitat use, Kenedy County, Texas, USA, 2008 and 2009.

Plant community	Proportion	Number of observations		Chi-square value
		Observed	Expected	
Guineagrass	0.177	103	63	
Buffelgrass	0.098	27	35	
Mixed	0.098	52	35	
Native	0.627	176	224	P < 0.0001

more frequently and native grass communities 14% less frequently than was expected (Table 7).

Microhabitat Analysis

Paired t-Tests.— Vegetation sampling was conducted on 70 bobwhites, each of which had 1–4 pairs of sampling points, for a total of 141 point pairs. Sixty-one birds were relocated while foraging for a total of 184 point pairs. Thirty-nine birds were relocated while loafing for a total of 98 point pairs.

For foraging activity, organism-centered points averaged 14% more total forb cover than random points (Table 8). Organism-centered points also averaged 1 more total species, 0.7 more forb species, and 0.3 more primary forb species, but these differences are relatively small from a biological standpoint. Guineagrass percent canopy cover was similar between organism-centered and random points. For loafing, no characteristics were significantly different between organism-centered and random points, including guineagrass (Table 9).

Generalized Linear Mixed Model.—For foraging, variables that were removed from analyses because they were highly correlated with others included bare ground exposure, litter percent cover, native grass percent cover, invasive grass percent cover, primary forb percent cover, cacti percent cover, total grass density, guineagrass density, cacti density, woody species number, grass species number, forb species number, primary forb species number, percent horizontal cover, and canopy height. The base generalized linear mixed model, therefore, began with a set of 13 variables, including bare ground percent cover, total grass percent cover, guineagrass percent cover, total forb percent cover, secondary forb percent cover, woody percent cover, native grass density, invasive grass density, woody density, total species number, secondary forb species number, litter depth, and vegetation height. The habitat characteristic that best predicted the probability of a point being an organism-centered point was total forb percent canopy cover. The odds of a point being a bird location increased by 1.9% (95% CI = 0.7 – 3.1) for every 1% increase in total forb percent cover (t_{122}= 3.05, P = 0.003).

Table 8. Means and lower (LCI) and upper (UCI) 95% confidence intervals for vegetation variables at organism-centered sites for foraging and random sites and results for paired t-tests, Kenedy County, Texas, USA, 2008 and 2009.

	Org-Centered sites *n* = 61			Random sites *n* = 61			Difference* *n* = 61				
Variable	Mean	LCI	UCI	Mean	LCI	UCI	Mean	LCI	UCI	*t* stat	*p*-value
Percent Cover											
Guineagrass	5	1	10	10	6	15	-5	-11	2	-1.50	0.1385
Bare ground	3	2	5	4	2	6	-1	-3.20	2.28	-0.33	0.7402
Litter	33	27	39	34	28	40	-1	-9.45	7.21	-0.27	0.7891
Bare ground exp.	4	2	7	5	3	8	-1	-4.42	1.94	-0.78	0.4384
Total grass	44	37	52	49	42	57	-5	-15.02	5.47	-0.93	0.3552
Invasive grass	13	7	20	19	13	26	-6	-14.73	3.01	-1.32	0.1913
Native grass	25	19	32	23	17	30	2	-6.87	11.63	0.51	0.6085
Total forbs	31	25	37	17	11	23	14	5.60	22.25	3.34	0.0014
Primary forbs	8	5	12	6	3	9	2	-2.16	6.66	1.02	0.3114
Secondary forbs	1	1	1	1	0	1	0	-0.04	0.36	1.64	0.1064
Total woody	15	7	23	10	2	18	5	-6.59	16.15	0.84	0.4034
Density (no./m^2)											
Guineagrass	1.16	0.28	2.04	1.29	0.41	2.17	-0.12	-1.37	1.12	-0.20	0.8418
Total bunchgrass	3.02	1.18	4.85	3.58	1.75	5.42	-0.56	-3.16	2.03	-0.43	0.6660

Table 8. Continued.

	Org-Centered sites			Random sites			Difference*				
Variable	Mean	LCI	UCI	Mean	LCI	UCI	Mean	LCI	UCI	*t* stat	*p*-value
Density (no./m^2)											
Native bunchgrass	8.04	5.74	10.33	7.85	5.56	10.15	0.19	-3.06	3.43	0.11	0.9091
Invasive bunchgrass	1.86	0.80	2.91	2.33	1.27	3.38	-0.47	-0.20	1.02	-0.63	0.5300
Woody plants	0.10	0.02	0.18	0.14	0.06	0.22	-0.04	-0.15	0.07	-0.74	0.4598
Species Richness (no./0.3 m^2)											
Total species	5.00	4.43	5.57	4.05	3.49	4.62	0.95	0.15	1.75	2.36	0.0213
Grass species	1.99	1.73	2.24	1.80	1.55	2.06	0.18	-0.18	0.55	1.02	0.3107
Forb species	2.63	2.23	3.03	1.97	1.56	2.37	0.66	0.09	1.23	2.33	0.0232
Primary forbs	1.11	0.87	1.34	0.79	0.56	1.03	0.32	-0.02	0.65	1.89	0.0631
Secondary forbs	0.73	0.59	0.87	0.57	0.42	0.71	0.16	-0.04	0.36	1.64	0.1064
Woody species	0.35	0.21	0.48	0.28	0.15	0.42	0.07	-0.12	0.26	0.69	0.4949

Table 8. Continued.

	Org-Centered sites			Random sites			Difference*				
Variable	Mean	LCI	UCI	Mean	LCI	UCI	Mean	LCI	UCI	*t* stat	*p*-value
Other											
Litter depth (cm)**	2.14	1.68	2.59	2.15	1.70	2.61	-0.02	-0.66	0.62	-0.06	0.9546
Veg. height (cm)***	9.93	7.06	12.81	12.12	9.26	14.98	-2.18	-6.24	1.87	-1.08	0.2852
Horizontal cover (%)	31.77	27.00	36.54	34.60	29.83	39.37	-2.83	-9.57	3.92	-0.84	0.4052

* organism centered - random
***n* = 59
*** *n* = 58

Table 9. Means and lower (LCI) and upper (UCI) 95% confidence intervals for vegetation variables at organism-centered sites for loafing and random sites and results for paired t-tests, Kenedy County, Texas, USA, 2008 and 2009.

	Org-Centered sites *n* = 39			Random sites *n* = 39			Difference* *n* = 39				
Variable	Mean	LCI	UCI	Mean	LCI	UCI	Mean	LCI	UCI	*t* stat	*p*-value
Percent cover											
Guineagrass	9	2	17	13	5	21	-4	-14	7	-0.68	0.5011
Bare ground	2	0	5	4	1	7	-2	-6	2	-0.90	0.3713
Litter	34	24	44	26	16	36	8	-6	3	1.15	0.2558
Bare ground exp.	3	0	6	7	4	10	-4	-9	1	-1.69	0.0988
Total grass	35	23	47	34	22	46	1	-16	18	0.13	0.9002
Native grass	10	4	17	6	0	12	5	-4	13	1.15	0.2575
Invasive grass	18	8	29	24	14	35	-6	-21	8	-0.89	0.3814
Total forbs	12	6	17	14	9	20	-2	-10	6	-0.61	0.5463
Primary forbs	3	1	6	3	1	6	0	-3	4	0.27	0.7852
Secondary forbs	1	-1	4	4	2	6	-3	-6	1	-1.62	0.1130
Total woody	99	76	123	91	68	115	8	-25	42	0.50	0.6231
Density (no./m^2)											
Guineagrass	1.72	0.28	3.15	2.50	1.06	3.93	-0.78	-2.81	1.25	-0.78	0.4418
Total bunchgrass	6.94	4.53	9.35	5.69	3.28	8.10	1.25	-2.16	4.65	0.74	0.4635

Table 9. Continued.

	Org-Centered sites			Random sites			Difference*				
Variable	Mean	LCI	UCI	Mean	LCI	UCI	Mean	LCI	UCI	*t* stat	*p*-value
Density (no./m^2)											
Native bunchgrass	3.48	1.69	5.27	1.56	-0.23	3.35	1.92	-0.61	4.45	1.54	0.1322
Invasive bunchgrass	3.46	1.53	5.38	4.13	2.21	6.06	-0.68	-3.40	2.04	-0.50	0.6178
Woody plants	0.59	0.37	0.80	0.67	0.46	0.88	-0.09	-0.38	0.21	-0.58	0.5639
Species Richness (no./0.3m^2)											
Total species	4.00	3.37	4.63	3.63	3.01	4.26	0.37	-0.52	1.25	0.84	0.4059
Grass species	1.06	0.73	1.39	0.98	0.65	1.31	0.08	-0.38	0.55	0.36	0.7239
Forb species	1.43	0.99	1.87	1.24	0.80	1.69	0.18	-0.44	0.81	0.59	0.5562
Primary forb species	0.51	0.28	0.74	0.35	0.12	0.57	0.16	-0.16	0.48	1.03	0.3105
Secondary forb species	0.22	0.06	0.38	0.33	0.17	0.49	-0.10	-0.33	0.12	-0.91	0.3664
Woody species	1.47	1.17	1.77	1.39	1.08	1.69	0.08	-0.35	0.51	0.38	0.7025

Table 9. Continued

	Org-Centered sites			Random sites			Difference*				
Variable	Mean	LCI	UCI	Mean	LCI	UCI	Mean	LCI	UCI	*t* stat	*p*-value
Other											
Litter depth (cm)	1.69	1.33	2.05	1.72	1.36	2.08	-0.03	-0.54	0.48	-0.12	0.9050
Veg. Height (cm)**	9.96	4.81	15.12	14.30	9.14	19.45	-4.33	-11.62	2.96	-1.21	0.2355
Horizontal cover (%)	34.86	27.79	41.92	38.59	31.52	45.66	-3.73	-13.73	6.26	-0.76	0.4541
Canopy height (cm)***	178.7	134.3	223.0	184.3	139.9	228.6	-5.6	-68.3	57.1	-0.18	0.8555

* organism centered - random
**n = 35
***n = 25

For loafing, variables that were removed from analyses because they were highly correlated with others included bare ground percent cover, native grass percent cover, invasive grass percent cover, secondary forb percent cover, cacti percent cover, total grass density, invasive grass density, guineagrass density, woody density, cacti density, total species number, grass species number, forb species number, primary forb species number, woody species number, and vegetation height. The base generalized linear mixed model, therefore, began with a set of 11 variables, including litter percent cover, bare ground exposure, total grass percent cover, guineagrass percent cover, total forb percent cover, primary forb percent cover, woody percent cover, native grass density, secondary forb species number, percent horizontal cover, and litter depth. No habitat characteristics significantly predicted the probability of a point being a bird location.

Discussion

Northern bobwhites in my study did not select or avoid guineagrass for foraging or loafing at the microhabitat scale. At the macrohabitat-patch scale, they used guineagrass-dominated areas in greater proportion than was available for loafing, but not for foraging. Forb cover was the most important microhabitat component within locations selected by bobwhites while foraging, regardless of whether or not guineagrass or other invasive grasses were present. Selection for higher canopy cover and diversity of forage plants, specifically through greater forb cover and greater plant species richness, than what was available at random is a common finding among other habitat selection studies that have been conducted throughout the range of bobwhites (Kuvlesky et al. 2002, Sands 2007, Buelow 2009). Bobwhite foraging habitat is typically comprised of herbaceous cover that contains a diversity of forage plants, abundant insects, and bare ground for mobility

(Hernández and Peterson 2007, Kuvlesky et al. 2002). Seed-producing forbs and grasses are essential dietary items for bobwhites, and herbaceous plants are needed for producing insects that are an important source of protein for young chicks and also for adults for at least portions of the year (Lehmann 1984:192, Guthery 1986:147, Kuvlesky et al. 2002).

Bobwhites typically use habitat that offers at least 25% of bare ground for ease of movement while foraging, while providing overhead screening cover during movement and feeding (Lehmann 1984, Kopp et al. 1998, Hernández et al. 2007). However, there was no evidence in this study that bobwhites selected for greater bare ground cover than what was found at random. This is mainly because mean bare ground during this study was ≤4% at organism-centered or random sites, which indicates that there was a consistent lack of bare ground on this study site. This would explain why there was no discernable selection for this habitat component.

Bobwhites use brushy areas that provide cover for dusting, protection from predators, and thermal protection for resting during midday loafing periods (Kuvlesky et al. 2002, Johnson and Guthery 1988, Guthery 2006). Furthermore, bobwhites prefer loafing sites which provide greater canopy cover, and thus more shade, than is generally available (Guthery 2006). Bobwhites selected mottes of woody vegetation for loafing at the microhabitat scale, which can be seen in the 84% increase in woody cover found in the proportion of locations used for loafing compared to those used for foraging. Also, having a higher proportion of locations in mottes during the middle of the day for both micro and macrohabitat scales supports previous findings that bobwhites prefer mottes for loafing purposes.

At the macrohabitat scale, bobwhites used guineagrass-dominated areas in greater proportion than was available only during loafing activities. These mottes had greater relative cover of guineagrass than other herbaceous plants growing beneath their canopies, which reflects the shade-tolerance of this grass that it is commonly found beneath woody plants (Skerman and Riveros 1989, Lonard et al. 2000, Tan 2001). All birds that were located in mottes of guineagrass-dominated areas were using guineagrass canopy cover, because all of these locations had ≥1% guineagrass canopy cover. Relative canopy cover of guineagrass beneath mottes in buffelgrass- and native grass-dominated areas was negligible compared to relative cover of guineagrass beneath mottes in guineagrass-dominated areas. These findings suggests that there is something about the association of woody cover and guineagrass canopy cover that bobwhites prefer.

Because bobwhites tended to select mottes in guineagrass-dominated areas over those dominated with buffelgrass or native grass, and because bobwhites were found using guineagrass canopy cover in these mottes, it is possible that guineagrass canopies provide an additional layer for shade, making these mottes more preferable loafing sites. Mottes in guineagrass-dominated areas had 18% and 43% more absolute canopy cover of herbaceous plants in their understory than mottes in areas dominated by native grass and buffelgrass, respectively. This suggests that mottes in guineagrass-dominated areas may have denser shade, and are possibly cooler than mottes in areas dominated by native grass and buffelgrass. Tall, dense cover that reduces temperatures near the soil surface during midday is critically important for survival of bobwhites during summer in subtropical environments (Johnson and Guthery 1988, Forrester et al. 1998). Also, because bobwhites are selecting mottes in guineagrass-dominated areas, this indicates that guineagrass is not severely inhibiting their movement.

Because bobwhites use and do not avoid guineagrass-dominated areas for foraging and loafing, guineagrass invasion does not preclude invaded areas from use for these activities. Bobwhites may use guineagrass for loafing cover because it offers a tall and complex structure, even when present as dead culms from the previous growing season. The fact that dead guineagrass culms from the previous growing season provide adequate cover for bobwhites may be important during years of drought when growth of native grasses is minimal and may not meet escape and screening cover requirements.

Management Implications

Bobwhites use guineagrass stands to meet escape and screening cover requirements in south Texas; however, they also select areas with greater forb canopy cover for foraging. The reduction in forbs on sites with guineagrass indicates that invasion of large areas by guineagrass may be detrimental to bobwhites. Guineagrass effects on bobwhites appeared minimal in my study area. However only 18% of their home range was dominated by guineagrass, while over half remained as native vegetation. Therefore, where guineagrass has invaded the majority of the landscape, prescribed fire and grazing can be used to increase native plant diversity and abundance (Ramirez et al. 2007). Using these tools to manipulate areas invaded by guineagrass to increase forb abundance and species richness, while protecting mottes with guineagrass for loafing cover, would benefit bobwhite populations.

CHAPTER IV

EFFECTS OF GUINEAGRASS ON NORTHERN BOBWHITE HABITAT STRUCTURE

Abstract

Guineagrass (*Urochloa maxima*) is native to Africa, and was introduced to the U.S. for erosion control and to improve livestock grazing productivity. Over the past 20 years, it has invaded large areas of bobwhite (*Colinus virginianus*) habitat in southern Texas and northern Mexico. My objective was to evaluate the effects of guineagrass on bobwhite habitat characteristics. Bobwhites were monitored using radio telemetry during the breeding season (April–September) during 2008–2009 in Kenedy County, Texas. I measured vegetation attributes, at nest, organisms-centered, and paired random points. Plots were then divided into groups based on presence or absence of guineagrass. I analyzed data using two-sample t-tests and simple linear regression. Guineagrass sites had 23% less native grass canopy cover, 17% less total forb canopy cover, and 9% less primary forb canopy cover than sites with no guineagrass. Guineagrass sites also had denser total grass (10 bunchgrass/m^2) than sites with no guineagrass; however, they had lower density of native bunchgrasses (7 bunchgrasses/m^2) than sites with no guineagrass. Guineagrass sites had 30% less total species, 55% less forb species, and 11% greater horizontal cover than sites without guineagrass. Percent horizontal cover increased ($r^2 = 0.35$) with increasing guineagrass cover; whereas total species richness decreased ($r^2=0.10$) with increasing guineagrass cover. Guineagrass invasion of native grassland may hinder habitat characteristics that are important for bobwhite foraging and brood rearing, but may benefit nesting habitat.

Introduction

Guineagrass is native to Africa, and was intentionally introduced to the U.S. for erosion control and to improve livestock grazing productivity around 1813 (Parsons 1972, Kuvlesky et al. 2002), but may have been accidentally introduced to North America from slave ships as early as 1684 (Larson et al. 2010). Over the past 20 years, it has invaded large areas of northern bobwhite (*Colinus virginianus*) habitat in southern Texas and northern Mexico. This is of significant concern for conservation of northern bobwhites because southern Texas is one of the few regions of the U.S. that supports large areas of contiguous bobwhite habitat and sustainable populations of the species (Lehmann 1984, Brennan et al. 2007). Warm-season subtropical exotic grasses including guineagrass may expand their range northward if the climate continues to warm (Archer and Predick 2008).

Like many other exotic grasses, guineagrass can reduce diversity of plant communities by disrupting ecosystem functions. For example, guineagrass supports a fire cycle to which native plants are not adapted (Calvert 1999). Furthermore, because this grass is fire resistant, it often dominates the landscape after a fire (Tan 2001). Guineagrass grows quickly and outcompetes seedlings of native plants, forming dense monocultures (Calvert 1999, Ramirez et al. 2007). This can result in exclusion of valuable native plants essential to wildlife, including plants important for insects and for producing seeds eaten by quail and other bird species (Kuvlesky et al. 2002, Veldman et al. 2009). There is a lack of published research on how invasions of guineagrass impact wildlife populations, especially bobwhites.

Bobwhites require habitat consisting of a patchy mosaic that offers high plant diversity which can typically be found in early to mid successional stage vegetation (Brennan 1999). These types of habitats fulfill life history requirements of bobwhites by offering adequate food, cover, and bare ground for foraging. Seed-producing forbs and grasses are essential dietary items for bobwhites, and insects provide important protein for young chicks and also for adults for at least portions of the year (Lehmann 1984:192, Guthery 1986:147, Kuvlesky et al. 2002). Additionally, herbaceous plant-dominated habitats that provide adequate nesting, escape, thermal, and brooding cover are important to all quail species (Kuvlesky et al. 2002). Therefore, exotic grass invasions could negatively impact quail populations if these invasions limit one or more of the habitat attributes required by quail to fulfill their specific life history requirements (Kuvlesky et al. 2002).

There is evidence that monocultures formed by many exotic grasses create poor quality habitat for bobwhites. Dense monocultures reduce herbaceous structural diversity, which in turn reduces niche diversity, forage plants and insects, and mobility (Guthery 1986, Kuvlesky et al. 2002). Bobwhites were about twice as abundant on native sites in southern Texas compared with exotic sites, which possibly resulted in part from a 40.6% decrease in arthropod abundance between native and exotic grass plots (Flanders et al. 2006). Tall fescue fields in Kentucky provide poor bobwhite habitat because of lack of foraging plants and simplified floristic structure (Barnes et al. 1995). In southern Texas, buffelgrass (*Pennisetum ciliare*) stands have a negative impact on forb coverage, density, species richness, and diversity (Sands 2007).

My objective was to determine effects of guineagrass encroachment into native grassland on bobwhite habitat characteristics. My specific objectives were to determine which habitat characteristics were negatively influenced by guineagrass cover, and which ones were positively influenced. My hypothesis was that coverage and diversity of native grass and forbs decrease with increasing guineagrass cover; whereas percent horizontal cover and vegetation height increase.

Study Area

I conducted field work during 2008–2009 on a 1,643 ha portion of a private ranch in Kenedy and Brooks counties, Texas, USA, from March–September. The ranch lies in the South Texas Plains ecoregion of Texas (Gould 1975) where the climate is subtropical humid (Larkin and Bomar 1983), with extreme variability in annual precipitation (Fulbright et al. 1990). In 2008, the study area received 64 cm of rainfall, with July – September receiving about 75%, while in 2009, the study area received 52 cm, with September–December receiving 78% of the annual total. The study area was in severe drought during June 2008 and in severe to extreme drought during April to October 2009 based on the Palmer Drought Severity Index (NOAA 2010). Soil series at this site included sandy, tight sandy loam, sandy, and loamy sand (USDA-NRCS 2009). The study area was grassland interspersed with mottes of woody plants. Historical grassland for the area is a seacoast bluestem (*Schizachyrium scoparium*) and balsamscale (*Elionurus tripsacoides*) association (McLendon 1991). Common subdominants were arrowfeather threeawn (*Aristida pupurascens*), thin paspalum (*Paspalum setaceum*), brownseed paspalum (*P. plicatulum*), coastal sandbur (*Cenchrus spinifex*), tanglehead (*Heteropogon contortus*), big bluestem (*Andropogon gerardii*), Texas snoutbean

(*Rhyncosia texana*), Lindheimer's hoarypea (*Tephrosia lindheimeri*), snake cotton (*Froelichia drummondii*), honey mesquite (*Prosopis glandulosa*), prickly pear (*Opuntia* lindheirmeri), and yucca (*Yucca constricta*) (McLendon 1991). The major shrubland association was mesquite-granjeno (*Celtis pallida*) (McLendon 1991). Common subdominants included prickly pear, lime prickly ash (*Zanthoxylum fagara*), hogplum (*Colubrina texensis*), blackbrush (*Acacia rigidula*), and wolfberry (*Lycium berlandieri*). Important understory species included guayacan (*Porlieria angustifolia*) and tasajillo (*Opuntia leptocaulis*) (McLendon 1991). Management practices on the study area have included fire, mechanical brush removal, and rotational grazing. Prescribed burns included 197 ha in 2004, 231 ha in 2005, 253 ha in 2007, and about 57 ha in 2009 (Figure 1, page 11). Brush removal techniques included dozing, root plowing, and raking on 776 ha in 2004 and 367 ha in 2005 (Figure 2, page 12). Rotational grazing within the study area took place in 2007 from October–December. The study area was grazed by longhorn cattle (*Bos bos*) from autumn 2008–spring 2009. From January–early March, there were 319 longhorns in the study area for 60 days (0.19 animal units/ha), then the number of cattle was reduced to 118 for 21 more days until late March (0.07 animal units/ha).

Methods

Data Collection

Trapping and Telemetry. — I trapped bobwhites during 2008 and 2009 using walk-in funnel traps baited with milo (*Sorghum bicolor*) (Stoddard 1931). Trapping protocol was approved by Texas A&M University-Kingsville Institutional Animal Care and Use Committee, approval number 2008-01-18B. Trapping began in mid-March and continued through mid-September to maintain a sample of ≥20 radio-marked bobwhite hens. I marked every captured bird with a numbered aluminum leg band, and I fitted birds weighing ≥150 g with a necklace-mount, 6-g radio transmitter (American Wildlife Enterprises, Monticello, Florida, USA). I kept detailed records on captured birds including sex, age, body mass, time and date of capture, band number, and radio transmitter frequency. I recorded known mortalities of radio collared birds when possible. I tracked birds 2–3 times/week from March–October in 2008 and May–September in 2009, and recorded their GPS coordinates. I found nests either by flushing radio collared females from the nest site or, when possible, by locating the nest before she flushed. Once a quail nest was discovered, I recorded its coordinates. I tracked birds using a Yagi-style antenna and an R-1000 telemetry receiver (Communications Specialists, Inc., Orange, CA, USA) as well as an R-4000 telemetry receiver (Advanced Telemetry Systems, Inc., Isanti, MN, USA). No more than 1 location/bird/day was recorded.

When quail were located by homing, I recorded their position with an HP rx5910 PDA (Palo Alto, CA, USA) and a Trimble Juno SB handheld (Westminster, CO, USA) equipped with ArcPad, accurate to ±3 m. I then imported locations into geographic information systems (GIS) software (ArcMap Version 9.1, Redland, California, USA) to establish a visual representation of habitat use and home range size.

Vegetation Sampling. — Vegetation characteristics were sampled at nests, organism-centered points, and at random locations. I randomly selected 10 birds for vegetation sampling each week, without replacement, until all the birds were sampled, then the process was repeated. I sampled vegetation within 2 days after relocation of the bird ensure similar characteristics as the day the bird was located. I conducted vegetation measurements at each nest point and organism-centered point, and at a randomly selected point located between 50–100 m from the nest and organism-centered point along a randomly selected bearing. Distances between 50 and 100 m were assumed to be far enough away to be distinguishable from the used location, but close enough to be comparable to the used location for research purposes (Hernández et al. 2003, Lusk et al. 2006). Sampling was stratified in that if a quail was relocated in a motte, the random site was also in a motte. I first selected a random bearing and distance between 50–100 m from the organism centered point, and then selected the closest motte to the point. I then determined the width of the motte by pacing and selected a random number between 0 and this width to sample.

I used a modified, extended Daubenmire frame (three 20 x 50 cm frames joined) to estimate absolute percent cover of bare ground, litter, bare ground exposure, canopy cover of species of grass, forbs, and woody plants (Bonham et al. 2004, Lusk et al. 2006) (Figure 3, page 15). I alternated frame orientation between north-south and east-west with each pair of points to avoid bias.

I estimated height of vegetation (cm) by averaging the height at each corner of the middle Daubenmire frame for organism-centered and random points and at the center of the nest for nest sites (Winter et al. 2005). I estimated litter depth (cm) at nests by averaging the litter depth at 4 cardinal directions beside the nest and at the middle of the middle Daubenmire frame for organism-centered and random points and. To estimate bunchgrass density by species, I counted bunchgrass clumps inside a 0.5 m radius circular plot centered on each point. Bunchgrass density was estimated as the average number of bunchgrasses/m^2. I estimated cactus and woody plant density by counting number of stems above the ground within a circular plot with a radius of 2 m from each point. Woody plant and cactus densities were calculated as the average number of stems/m^2.

To estimate percent horizontal cover, I used a modified staff-ball method based on Collins and Becker (2001) who found this technique to be more precise and faster than the Robel pole or profile board methods. Instead of a staff and ball, I used a 1 m tall, 2.54 cm PVC pipe sprayed with orange paint, which I positioned at the center of the sampling point by supporting it with a 0.5 m long piece of rebar I hammered into the ground. I constructed a periscope out of PVC pipe (cut to lengths of 12, 25, and 50 cm) and a Geographic Resource Solutions (GRS) densitometer (Geographic Resource Solutions, Arcata, California, USA) (Figure 4a and 4b, page 17). I used 3 lengths of PVC pipe to estimate horizontal cover at heights of 12, 25, and 50 cm. These heights represent the average height of a bobwhite (12 cm), a ground predator (25 cm), and overhead screening cover from aerial predators (50 cm). I determined a sight distance (radius) of 3 m based on the distance that would produce visual obstruction 50% of the time (Collins and Becker 2001). I walked a circle around the sampling point, stopping 4 times for organism-centered points and 8 times for nest sites to determine if the orange pole could be sighted through the scope (Figure 5 , page 18). I recorded the total number of locations where the pole was obstructed. This method was repeated for heights of 12 cm, 25 cm, and 50 cm. Percent horizontal cover was calculated by dividing number of locations that were obstructed by the total number of locations (across all heights) times 100%.

Data Analysis

Habitat Variables.— Plant species were lumped into functional groups for analysis (Lusk et al. 2006, Larson et al. 2010). Functional groups included percent cover of bare ground, litter, bare ground exposure, guineagrass, all grasses, native grass species, exotic grass species, all forb species, primary forb species, and secondary forb species (Table 1, page 20). Other functional groups included densities of all grass species, native grass species, and exotic grass species, and litter depth, vegetation height, and percent horizontal cover.

Statistical Analysis.— To estimate guineagrass effects on habitat characteristics throughout the study area, random points were used for analysis, resulting in n = 187 independent estimates of habitat variables. I only used random points to ensure I had a sample that was representative of my study area. First, I separated points into those that had ≥1% canopy cover of guineagrass (sites with guineagrass) and those that had <1% canopy cover of guineagrass (sites without guineagrass). To quantify the difference in vegetation between guineagrass sites and sites with <1% canopy cover of guineagrass, I conducted two-sample t-tests for all vegetation measurements including percent canopy cover of guineagrass, bare ground, litter, bare ground exposure, all grass (all grass + standing dead grass), invasive grass, native grass, total forbs, primary forbs, and secondary forbs. Forbs were grouped into primary and secondary categories based on importance for foraging (Larson et al. 2010). For this analysis forbs were not categorized into primary and secondary. I also included densities of guineagrass, total bunchgrasses, native bunchgrass, and invasive bunchgrass. Additional t-tests included total species richness, grass species richness, forb species richness, litter depth (cm), vegetation height (cm), and percent horizontal cover. Total species richness, grass species richness, and forb species richness were quantified as the number of different species/0.3m^2 sampling point. I transformed data as needed to meet assumptions for homogeneity of variance. When these assumptions were not met, I used two-sample t-tests for unequal variances. I reported raw means and confidence intervals of all data, and I reported t statistics and *p* values for transformed data and data with unequal variances.

For points that had ≥1% guineagrass canopy cover, linear regression was used to examine the relationship between each dependent vegetation variable and the independent variable percent canopy cover of guineagrass. I transformed data as needed to meet assumptions for homogeneity of variance of residuals. I reported raw means and confidence intervals of all data and reported *t*-statistics and *p*-values for transformed data.

Results

Vegetation Analysis

Forty-one of the 187 random points had ≥1% guineagrass canopy cover and 146 had <1%. Variances between presence and absence groups of canopy cover of native grass, total forbs, and primary forbs, density of total bunchgrass and native bunchgrass, and species richness of total species and grass species were unequal. Log-transformations of canopy cover of native grass and forbs, total bunchgrass density, and litter depth helped meet equal variances assumptions. For primary forb canopy cover, native bunchgrass density, total species richness, and grass species richness I used nonparametric t tests. Guineagrass sites had 23% less native grass canopy cover, 17% less total forb canopy cover, and 9% less primary forb canopy cover than sites without guineagrass (Table 10). Guineagrass sites also had denser total grass (10 bunchgrass clumps/m^2) than sites

Table 10. Means and 95% confidence intervals for vegetation variables at sites with ≥1% guineagrass canopy cover and sites with ≤1% guineagrass canopy cover and results for two-sample t-tests, Kenedy County, Texas, USA, 2008 and 2009.

	≥1% guineagrass (*n* = 41)			<1% guineagrass (*n* = 146)			Difference				
Variable	Mean	LCI	UCI	Mean	LCI	UCI	Mean[a]	LCI	UCI	*t* statistic	*p*-value
Percent Cover											
Bare ground	4	0	7	4	2	5	0	-4	4	0.08	0.9401
Litter	21	12	30	30	26	35	-10	-20	1	-1.81	0.0714
Bare ground exposure	6	2	10	5	3	7	1	-3	6	0.48	0.6342
Total grass	59	47	72	46	40	53	13	0	27	1.91	0.0572
Native grass[b]	3	-7	12	26	21	31	-23	-34	-12	-5.96	<0.0001
Invasive grass	53	42	63	15	10	21	37	25	49	6.21	<0.0001
Total forbs[b]	8	0	18	25	20	30	-17	-27	-6	-4.09	<0.0001
Primary forbs[c]	2	0	3	10	7	14	-9	-13	-5	-4.45	<0.0001
Secondary forbs	4	1	7	6	4	7	-2	-5	2	-0.90	0.3718
Density (no./m^2)											
Total bunchgrass[b]	14	11	17	4	2	5	10	7	13	5.79	<0.0001
Native bunchgrass[c]	1	0	1	8	6	9	-7	-9	-5	-7.59	<0.0001
Invasive bunchgrass	8	6	10	1	1	2	7	5	8	6.88	<0.0001

Table 10. Continued

Variable	≥1% guineagrass (n = 41)			<1% guineagrass (n = 146)			Difference			t statistic	p-value
	Mean	LCI	UCI	Mean	LCI	UCI	Mean[a]	LCI	UCI		
Species Richness (no./$0.3m^2$)											
Total species[c]	3.2	2.6	3.8	4.6	4.1	5.0	-1.4	-2.1	-0.6	-3.50	0.0007
Grass species[c]	1.5	1.3	1.7	1.7	1.5	2.0	-0.3	-0.6	0.1	-1.52	0.1303
Forb species	1.0	0.4	1.6	2.2	1.9	2.5	-1.2	-1.8	-0.5	-3.50	0.0006
Other											
Litter depth (cm)[b,d]	2.4	1.8	3.1	1.9	1.6	2.2	0.5	-0.2	1.2	1.44	0.1502
Vegetation height (cm)[e]	18.8	13.3	24.3	13.9	11.1	16.7	4.9	-1.2	11.0	1.57	0.1178
Horizontal cover (%)	44	38	51	33	29	37	11	4	19	2.91	0.0040

[a] presence - absence

[b] transformed

[c] unequal variance t-test

[d] absence (n=145)

[e] presence (n=37)

without guineagrass, while they had less density of native bunchgrasses (7 bunchgrass clumps/m^2) than sites without guineagrass. Guineagrass sites had 30% less total species, 55% less forb species, and 11% greater horizontal cover than sites without guineagrass.

For sites with guineagrass, percent horizontal cover increased with increasing guineagrass canopy cover (Figures 8a–8b). Total species richness declined with increasing guineagrass canopy cover; however, the relationship was weak. Five vegetation variables were transformed, including total species richness. Seven vegetation variables had no linear relationship with guineagrass canopy cover. Lack of a linear relationship with guineagrass canopy cover for bare ground cover, native grass cover and density, and primary and secondary forb cover resulted in part from a large number of points with estimates of 0 for these variables (Figures 9a–9e). Litter cover and vegetation height were not linearly related to guineagrass canopy cover, but they did have interesting patterns. Litter cover was highly variable, but the maximum litter cover decreased with increasing guineagrass canopy cover (Figure 9f). This is intuitive because litter cover includes only the portion of litter that is not covered by overhanging vegetation (Daubenmire 1959). Vegetation height was highly varied at points with 1 – 5% guineagrass cover, then between 10–65% guineagrass cover this variation declined, then became highly varied again (Figure 10g).

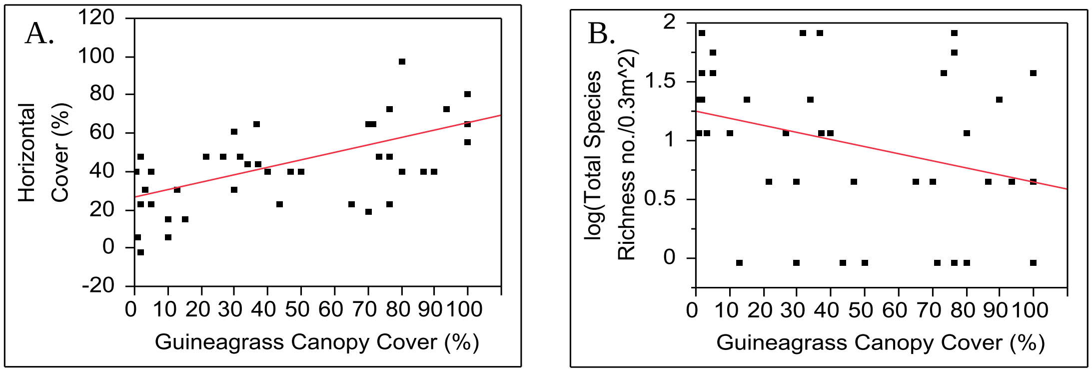

Figure 8. Linear relationship between guineagrass canopy cover and A) percent horizontal cover (horizontal cover = 26.72 + 0.38*guineagrass cover, r^2=0.35, *P*<0.001), and B) total species richness (log(total species richness = 1.25*guineagrass cover), r^2=0.10, *P*<0.046) , Kenedy County, Texas, USA, 2008 and 2009.

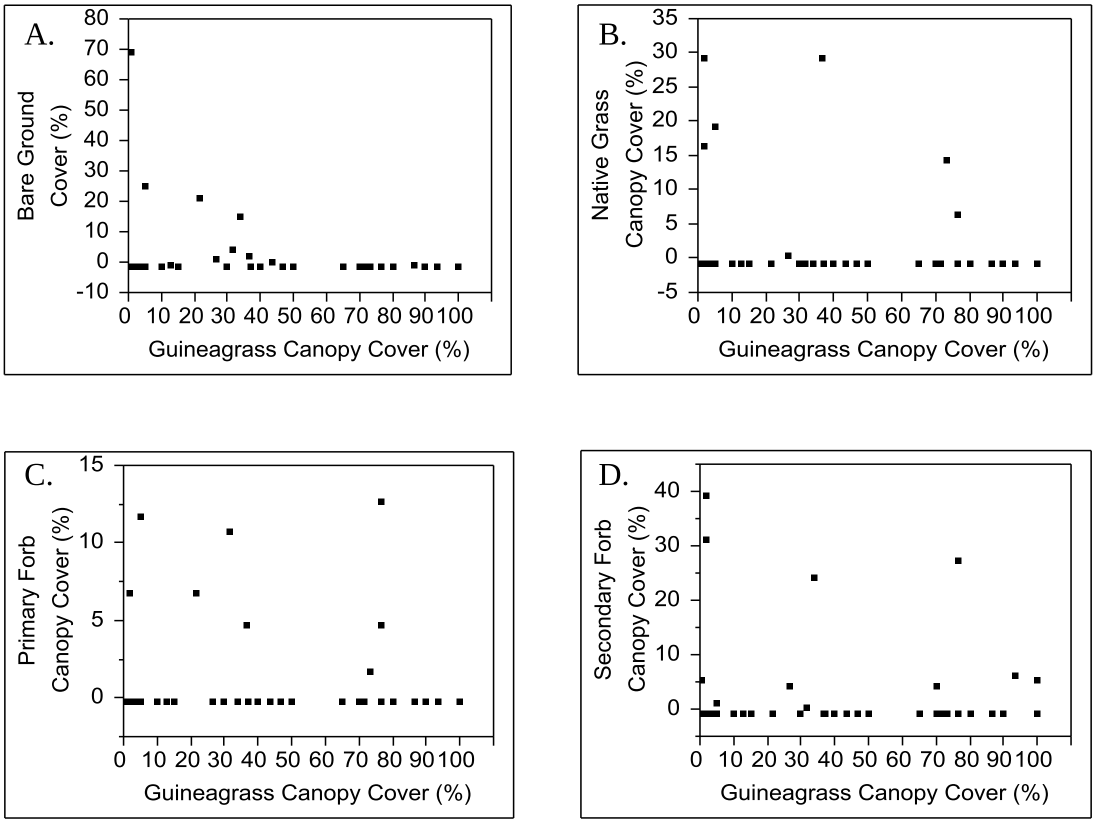

Figure 9 . Guineagrass canopy cover (%) versus A) bare ground cover (%), B) native grass canopy cover (%), C) primary forb canopy cover (%), D) secondary forb canopy cover (%), E) native grass density (no./m^2), F) litter cover (%), and G) vegetation height (cm), Kenedy County, Texas, USA, 2008 and 2009.

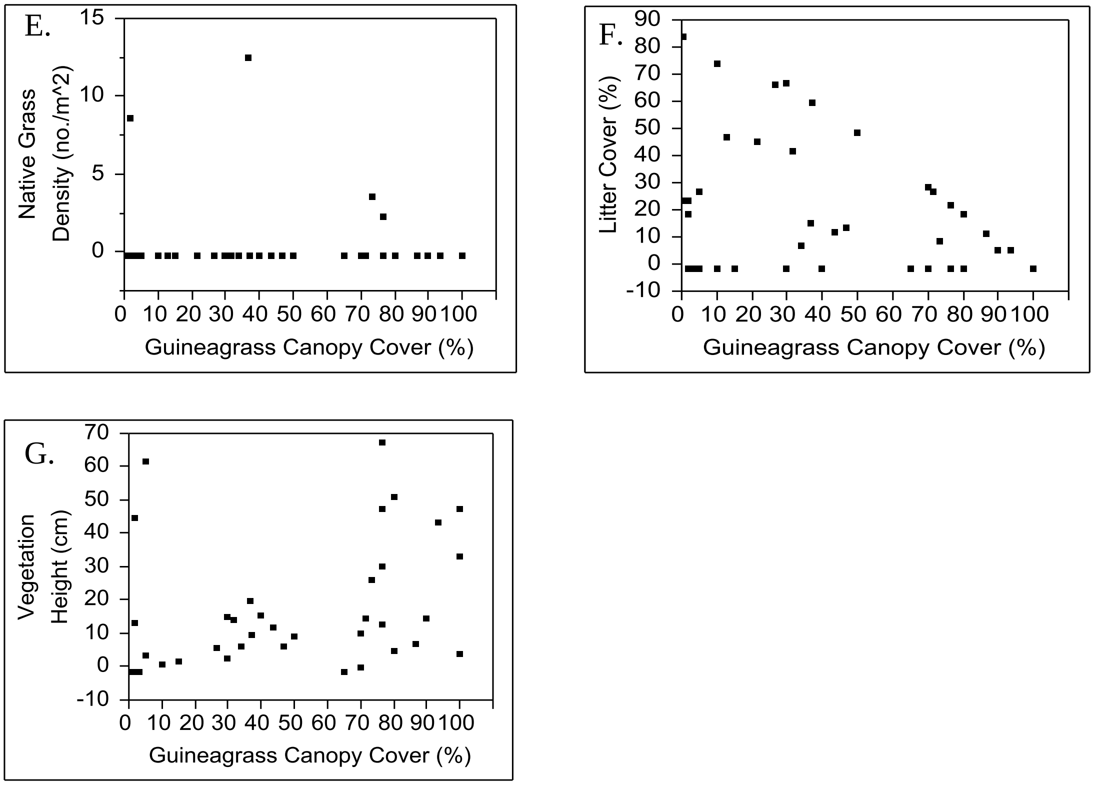

Figure 9 . Continued.

Discussion

Guineagrass may hinder habitat characteristics that are important for bobwhite foraging and brood rearing habitat, such as forb cover and species richness, but improved characteristics important for nesting habitat, such as grass canopy cover and percent horizontal cover, are associated with guineagrass. Structural and floristic characteristics of vegetation communities are essential components of grassland bird habitat, and the influences of exotic grasses like guineagrass on these characteristics can be detrimental to bobwhites (Rotenberry 1985, Vitousek 1990, Block and Brennan 1993, Flanders et al. 2006). Based on the results of my study and others, as guineagrass increases and forms dense near-monocultures, plant community structure becomes simplified (Calvert 1999, Ramirez et al. 2007). This results in reduced diversity and abundance of forage plants, such as seed-producing forbs and grass (Guthery 1986, Kuvlesky et al. 2002, Flanders et al. 2006, Sands et al. 2009). There is evidence that birds are more dependent on plant community composition, by way of specific food resources, than on habitat structure (Lovejoy 1974, Maurer and Whitmore 1981, Robinson and Holmes 1984, Rotenberry 1985). Based on these findings, guineagrass abundance may be detrimental to bobwhite foraging and brooding habitat. Effects of this grass on forage insects, which are essential food items for bobwhites, need to be investigated because impacts of the grass on plant community structure and composition may affect these species (Flanders et al. 2006).

Presence of guineagrass, in contrast to foraging and brood rearing, may be beneficial to bobwhite nesting habitat. As was found in this study (see Chapter I, page 29) and others, bobwhite hens tend to select nest sites that have greater structural complexity, specifically nest sites that provide greater nest concealment through taller vegetation and greater structural complexity such as greater horizontal cover (Townsend et al. 2001, Hernández et al. 2003, Tjemeland 2007). Guineagrass provides suitable nesting cover because it offers tall, dense bunchgrass cover for nest concealment, even when present as dead culms from the previous growing season. The fact that dead guineagrass culms from the previous growing season provide adequate nesting cover for bobwhites may be important during years of drought when growth of native grasses is minimal and may not meet nesting cover requirements. Similar effects have been found with buffelgrass and tanglehead, which is a native grass that acts like an invasive grass (Sands 2007, Tjemeland 2007, Buelow 2009).

Stands of guineagrass of the size in my study area (0.15 ha ±0.02) that are scattered about within a mosaic of native grassland are not detrimental to bobwhite nesting, foraging, and loafing. Bobwhites utilize mottes of woody plants with an understory of guineagrass for loafing in preference to those in grassland (chapter III). Large-scale invasions of guineagrass may be detrimental to bobwhite populations, however, because of the associated reduction in abundance and diversity of native forbs.

Management Implications

Because guineagrass can outcompete important quail forage plants and reduce plant diversity, it is not a desirable plant for livestock or erosion control in areas where landowners desire to maintain bobwhite forage and brooding habitats. Prescribed fire and grazing increase diversity and abundance of native plants essential to bobwhites for foraging (Ramirez et al. 2007). Creating mosaics of native-plant dominated patches within extensive areas invaded by guineagrass using patch burning and grazing is a possible management practice to improve these areas for bobwhites. Prevention of guineagrass invasion, however, is the best management tool. Exotic grasses can spread quickly as their seeds are transported by livestock and vehicles (Groom et al. 2006). Therefore, care should be taken to avoid dispersing guineagrass seeds, for example, by keeping livestock and vehicles out of guineagrass infested areas while seeds are present.

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VITA

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