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INFLUENCE OF RAINFALL, TYPE OF RANGE, AND BRUSH MANAGEMENT ON ABUNDANCE OF NORTHERN BOBWHITES (*COLINUS VIRGINIANUS*) IN SOUTHERN TEXAS

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ABSTRACT—Assessing numerical response of northern bobwhites (*Colinus virginianus*) to habitat improvement in semi-arid rangeland often is confounded by responses of populations to highly variable patterns of rainfall. During 2 years of above-average rainfall, we investigated abundance of northern bobwhites relative to type of range and treatments to reduce brush on seven ranches in southern Texas. We expected response of populations to treatment of land to be more evident when northern bobwhites were released from constraints of low precipitation. However, main factors dominating abundance were rainfall during the previous growing season and type of range. Greatest numbers of calls were in mid-productivity rangeland (potential production of forage 2,000–3,900 kg/ha), especially sandy loam, clay loam, sandy, and gravelly ridge. Treatments to reduce brush increased abundance of northern bobwhites to a limited extent and were most effective when large blocks of land were treated. Techniques that kill brush (root-plowing) were more successful in increasing populations than top-removal methods (roller-chopping). Leaving strips or mottes (large clumps of living brush and trees) in cleared areas did not enhance populations, although we caution that retaining some brush cover may be important to survival of northern bobwhites in drier years and in situations where herbaceous cover is less abundant.

RESUMEN—Determinar la respuesta numérica de codornices norteñas (*Colinus virginianus*) a técnicas para mejorar el hábitat en pastizales semiáridos es confundido por las respuestas poblacionales a patrones altamente variables de precipitación. Durante dos años de precipitación más alta que la media, investigamos la abundancia de codornices con respecto al tipo de pastizal y tratamientos para reducir arbustos en siete ranchos en el sur de Texas. Esperamos la respuesta de la población al tratamiento de la tierra ser más evidente cuando las codornices fueron liberadas de los apremios de baja precipitación. Sin embargo, los factores más dominantes para determinar la abundancia fueron la precipitación durante la estación de crecimiento anterior y el tipo de pastizal. Más silbidos fueron registrados en los pastizales de productividad mediana (producción de forraje potencial de 2.000–3.900 kg/ha), especialmente en pastizales con suelos marga-arenosos, marga-arcillosos, arenosos, y pastizales en bordes pedregosos. Tratamientos para reducir arbustos aumentaron la abundancia de codornices a un grado limitado y fueron más eficaces cuando terrenos grandes fueron tratados. Los tratamientos de remoción de arbustos (remoción de raíces) fueron más exitosos para incrementar la población que los métodos de remoción superior (la eliminación de biomasa aérea). Dejando bandas o grandes grupos de arbustos y árboles en áreas despejadas no mejoró las poblaciones, aunque consideramos importante indicar que retener alguna cobertura arbustiva podría ser importante para la supervivencia de codornices en años más secos y en situaciones donde la cobertura herbácea es menor.

Habitat improvement for northern bobwhites (*Colinus virginianus*) in semi-arid, brush-dominated rangelands often involves large-scale reduction in brush to open up the habitat and push plant communities to an earlier seral stage. Early studies indicated that northern bobwhites required only 5–15% canopy cover of brush (Guthery, 1986) and favored vegetation communities in early seral stages (Rosene, 1969). This idea was challenged by Spears et al. (1993) who detected that northern bobwhites were associated only with early successional vegetation in mesic, high-productivity, rangeland. In habitats of medium-to-low productivity, such as the central and western Rio Grande plains of Texas, seral stage was not important. More recently, Hiller et al. (2005) determined that northern bobwhites in northern Texas can thrive in 30–60% mixed-shrub cover. In fact, northern bobwhites exhibit considerable habitat slack (Guthery, 1999), in that they can use a variety of habitats, provided there is a suitable distribution of microhabitats that comprise usable space (Guthery, 1997) for that species. For northern bobwhites, usable space requires fine-scale interspersion of brush for protective cover, open areas for forbs, and bare ground for foraging (Kuvlesky et al., 2002; Hiller et al., 2005). Thus, habitat improvement must include consideration of both vegetative structure and distribution.

Large-scale reduction of brush is achieved most commonly by mechanical means. Top-removal methods, such as roller-chopping, alter stature of brush, but because most species of brush resprout there is little effect on species composition. More intensive treatments, such as root-plowing, kill more brush so they have a greater effect on vegetative composition. Removal of brush may be followed by additional treatments including raking, stacking, and reseeding with grasses and forbs. Prescribed fire primarily is used to maintain cleared areas, but also may be used in initial clearance of brush-infested land; most species of brush resprout after fire. Within treated areas, strips or patches of untreated brush usually are left to create a patchwork of vegetative structure that provides a mixture of protective cover and open feeding areas.

Time and expense involved in implementing these land treatments necessitates that managers target those areas that are most capable of producing high populations of northern bobwhites. However, assessing success of land treatments in increasing abundance of northern bobwhites is difficult in semi-arid areas where annual quantity and timing of rainfall is highly variable. Fluctuations in annual precipitation greatly affect populations of northern bobwhites (Hernández et al., 2002*a*); this effect primarily is mediated by vegetative response to precipitation (Bridges et al., 2001).

In this study, we examined abundance of northern bobwhites in relation to type and productivity of range, and treatments to reduce brush, over a 2-year period of above average rainfall. We predicted that population constraints due to low precipitation would be minimized, making the underlying effects of type of range and reduction of brush on abundance of northern bobwhites more evident. This would allow us to identify optimal types of range and treatments to reduce brush to improve habitat for northern bobwhites.

Materials and Methods—We conducted the study on seven ranches in Frio, La Salle, Live Oak, Webb, and Zavala counties within the South Texas Plains ecoregion. These ranches have a cumulative holding of 64,000 ha and were 2,833–32,375 ha in size. All ranches have active brush-management programs and are managed for mixed production of white-tailed deer (*Odocoileus virginianus*), quail, and cattle. We mapped each ranch using the 2004 Natural Agricultural Imagery Program available from Texas Natural Resources Information System (http://www.tnris.state.tx.us/) using ArcGIS 9.1 (Environmental Systems Research Institute, Redlands, California), and overlaid soil-survey and range-type information available from the Natural Resource Conservation Service Soil Survey Geographic SSURGO Database (http://soils.usda.gov/survey/printed_surveys/state.asp?state=Texas&abbr=TX). Managers of these ranches provided information on type and time of treatment of land. Method and pattern of reduction of brush were not independent so we combined them in the term treatment. Root-plowing was used to create all three patterns of removal of brush; large open blocks, alternating strips of cleared and uncleared land, and cleared areas with scattered mottes (large clumps of living brush and trees). Roller-chopping was used only to create strips. All treatments were implemented 2–6 years before the study, allowing time for the land to revegetate. Most strips were created 1998–2000, most mottes were created in 2001, and most larger blocks were cleared in 2002. Width of strips were 10–120 m, and mottes were ca. 100 m apart. Replication of treatments within each type of range was not always possible because treatments were implemented by landowners and were not created specifically for this study.

Climate of the South Texas plains is semi-arid. Long-term annual precipitation for the five counties within the study area is 41 ± 32 cm, with large fluctuations in quantity and seasonal distribution. Soils in this region tend to be sandy; 13 range types were identified. Potential herbaceous production of these areas was <2,000 to >4,000 kg/ha of air-dried forage under cultivation (http://www.ncgc.nrcs.usda.gov/products/datasets/ssurgo/), although production is lower under natural vegetation. Vegetation was a diverse mixed-brush community dominated by honey mesquite (*Prosopis glandulosa*), blackbrush (*Acacia rigidula*), and annual grasses. Several ranches had areas planted with buffelgrass (*Cenchrus ciliaris*) to provide forage for cattle.

We surveyed abundance of bobwhites by counting the "bobwhite" whistle calls of males in spring 2004 and 2005. Whistle counts have been criticized as a poor predictor of productivity because unpaired males are believed to be the most active callers and do not represent the true breeding population (Guthery et al., 2001). However, we considered these counts to be a suitable comparative index of abundance in brush-dominated systems where road counts tend to be biased toward greater visibility of northern bobwhites on treated than on untreated areas. Auditory survey also allowed us to survey a larger area than could be achieved from road counts. We placed 10 count stations equidistantly along a 16-km route on each ranch. We determined the most obvious type of range and treatment in a 600-m radius around each station. During the last 2 weeks of April and first 2 weeks of May, we monitored each station for 5 min on 3 consecutive mornings, starting at a different station each day. Weather may affect frequency of calling (Hansen and Guthery, 2001), so we noted time of day and cloud cover, and recorded wind speed and minimum temperature using a Pocket Weather Station (Model 3000, Kestrel, Boothwyn, Pennsylvania). Following Robel et al. (1969), counts were not collected in rain or wind speed >16 km/h. We began counts at sunrise and continued until completion. At each site, we recorded number of calls given by each male and estimated his direction and distance from the observer. We used mean number of different birds calling per site rather than a density estimate because the exact distance over which birds could be heard in this habitat was unknown.

We measured density of potential nesting cover at alternating listening stations by walking a 500-m long by 2-m wide belt transect in a random direction. Tufts of grass ≥30 cm in diameter or cactus ≥60 cm were recorded as potential nest clumps (Lehman, 1984; Hernández et al., 2003). We gathered precipitation records from the nearest National Oceanographic and Atmospheric Administration recording station to each ranch.

We compared information on mean number of calling males per station to current weather variables (minimum temperature, wind speed, and cloud cover), seasonal rainfall (previous spring, summer, autumn, and winter), habitat variables (type of range, productivity ranking of range, and nest clumps/ha), and ranch-management variables (grazing pressure, presence of food plots and feeders, and treatment). We used SAS PROC GLM to identify and test significant variables because this procedure can assess both categorical and numerical variables (http://support.sas.com/91doc/docMainpage.jsp). Differences between means were tested by Tukey's test. We used nonparametric one-way ANOVA (SAS PROC NPAR1WAY) to test for differences in abundance of northern bobwhites relative to individual treatments of land. Significance of results was tested with the Kruskal-Wallis test. Significance was set at $\alpha \leq 0.05$.

Results—Effects of wind speed, cloud cover, and minimum temperature were successfully minimized by the procedure and did not influence counts of calls ($F_{3,35}$ = 1.76, P = 0.137). At the time of this study, vegetation was lush due to above-average rainfall, consequently management decisions including grazing and supplementation by food plots and feeders did not influence abundance of northern bobwhites ($F_{3,136}$ = 1.13, P = 0.338). Grazing pressure was low and nesting cover was abundant (≥600 clumps/ha; Hernández et al., 2003) and did not influence abundance ($F_{1,68}$ = 1.90, P = 0.172).

The most important factors affecting counts of calls were annual precipitation ($F_{1,101}$ = 11.48, P = 0.001), and type of range ($F_{12,101}$ = 2.22, P = 0.016). Compared to these over-riding factors, treatment ($F_{5,101}$= 0.64, P = 0.635) and interaction of treatment with type of range ($F_{13,101}$= 1.41, P = 0.179) were not important, although they did contribute to the overall best-fit model (r^2 = 0.410).

During the study, precipitation was well above the long-term average of 41.4 ± 32.1 cm/year for the five counties in the study area (http://www7.ncdc.noaa.gov/IPS/CDPubs?action=getpublication). In the year preceding counts in 2004, mean precipitation was 88.1 ± 7.5 cm, with rainfall relatively equally distributed between spring, summer, and winter, while autumn was relatively dry. In the year preceding counts in 2005, mean precipitation was 68.7 ± 12.2 cm and was more evenly distributed between autumn and winter than in the previous year (Table 1). The least difference in annual precipitation between the 2 years (8 cm) was recorded in Zavala County, and counts of calls on both ranches in this area were similar between years. Ranches further east in Frio and Live Oak counties, experienced a 21–25-cm decrease in precipitation in the second year, but only the ranch in Live Oak County had a decline in number of northern bobwhites (t_{18} = 6.44, P < 0.001). Although, vehicular disturbance due to initiation of mining-remediation work on this ranch may have affected distribution and activity of northern bobwhites. On the two southern-most ranches, rainfall in the second year decreased by 29 cm, much of this decrease was in spring, and abundance of northern bobwhites decreased by ca. 50% (La Salle County t_{18} = 2.08, P< 0.050, Webb County t_{10} = 2.93, P< 0.020). Over all ranches, rainfall in the previous growing season, especially summer, had a greater effect on subsequent counts of calls than rainfall later in the year (previous spring $F_{1,125}$ = 3.00, P = 0.086; previous summer $F_{1,125}$ = 5.12, P = 0.027; previous autumn $F_{1,125}$

= 0.02, $P = 0.888$; previous winter $F_{1,125} = 0.00$, $P = 0.972$). In the ANOVA model, replacing annual rainfall with rainfall for the previous summer increases r^2 from 0.40 to 0.45.

Type of range was secondary to rainfall in influencing numbers of calling northern bobwhites. Greatest numbers of calling northern bobwhites were on sandy loam, clay loam, sandy, and gravelly ridge sites (Fig. 1). These range sites were of moderate vegetative productivity. Few northern bobwhites were in low-productivity, shallow-ridge sites or high-productivity sites such as ramadero (creeks) and loamy bottomlands (Fig. 2a).

Although ANOVA did not identify treatment as a major influence on abundance, counts of calls were higher on treated areas than on untreated rangeland (treated 3.34 ± 1.78 birds/site, untreated 2.63 ± 1.61 birds/site, $\chi^2_1 = 4.92$, $P = 0.027$). Comparing treatments within moderate-productivity types of range (Fig. 2b), the only treatment producing consistently higher counts of calls than untreated areas was root-plowed in large blocks ($\chi^2_1 = 7.69$, $P = 0.006$); this treatment also had more northern bobwhites than on roller-chopped strips ($\chi^2_1 = 5.34$, $P = 0.021$). Within root-plowed areas, leaving strips of residual brush did not improve size of populations of northern bobwhites ($\chi^2_1 = 1.92$, $P = 0.165$), and leaving mottes resulted in fewer northern bobwhites than in fully cleared blocks ($\chi^2_1 = 4.24$, $P = 0.040$).

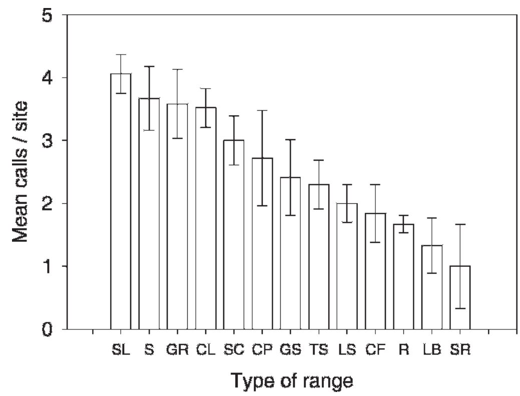

FIG. 1—Association of number of whistling male northern bobwhites per site with type of range (SL, sandy loam, $n = 8$; S, sandy, $n = 4$; GR, gravelly ridge, $n = 2$; CL, clay loam, $n = 16$; SC, saline clay, $n = 12$; CP, clay pan prairie, $n = 3$; GS, gray sandy loam, $n = 6$; TS, tight sandy loam, $n = 5$; LS, loamy sand, $n = 3$; CF, clay flats, $n = 3$; R, ramadero creeks, $n = 2$; LB, loamy bottomland, $n = 5$; SR, shallow ridge, $n = 1$) in southern Texas averaged over 2 years (spring 2004 and 2005).

DISCUSSION—Habitat improvement for northern bobwhites in brush-dominated rangelands

TABLE 1—Seasonal precipitation (cm) preceding surveys to count whistling calls of male northern bobwhites (*Colinus virginianus*) during April–May 2004 and 2005 in five counties in southern Texas.

	Precipitation (cm)			
Year	Zavala County	Frio County	Live Oak County	Webb and La Salle counties
2003 (year before count in 2004)				
Spring	34.85	33.55	25.53	26.67
Summer	22.12	26.37	41.07	26.49
Autumn	4.37	5.38	5.33	4.47
Winter	23.67	27.74	26.57	25.22
Total	85.03	93.04	98.50	82.85
Mean ± *SE* number of male northern bobwhites/site in 2004	2.70 ± 0.39	3.15 ± 0.31	4.87 ± 0.35	3.65 ± 0.48
2004 (year before count in 2005)				
Spring	32.72	28.40	25.81	7.34
Summer	18.78	15.34	21.39	27.08
Autumn	13.32	14.40	16.84	12.60
Winter	12.09	9.50	13.69	6.40
Total	76.91	67.64	77.72	53.42
Mean ± *SE* number of male northern bobwhites/site in 2005	3.03 ± 0.38	3.22 ± 0.49	3.22 ± 0.49	1.73 ± 0.43

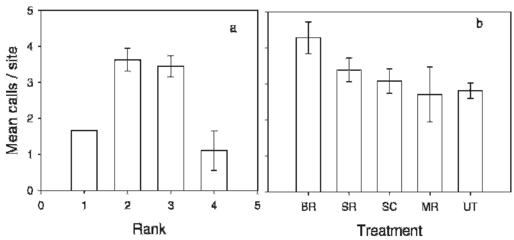

Fig. 2—Association of number of whistling male northern bobwhites per site with a) potential productivity of range (Rank 1, <2,000 kg/ha, $n = 1$; rank 2, 2,000–2,999 kg/ha, $n = 23$; rank 3, 3,000–3,999 kg/ha, $n = 34$; rank 4, >4,000 kg/ha, $n = 7$) of air-dried herbage) and b) pattern and method of brush clearance in mid-productivity rangeland (BR, blocks were root-plowed, $n = 6$; SR, strips were root-plowed, $n = 16$; SC, strips were roller-chopped, $n = 8$; MR, strips were root-plowed, $n = 4$; UT, untreated, $n = 27$) in southern Texas averaged over 2 years (spring 2004 and 2005).

often involves expensive, large-scale treatments to reduce brush over extensive areas. Yet quantifying response of populations to treatments in semi-arid regions often is confounded by considerable annual fluctuations in quantity and timing of precipitation. Rainfall and the subsequent effect on vegetation greatly affects population dynamics of northern bobwhites (Rice et al., 1991; Bridges et al., 2001; Hernández et al., 2002*a*), and can mask effects of habitat treatments. During this study, the South Texas plains experienced 2 years of above-average precipitation, which we hypothesized would reduce weather-induced constraints on populations of northern bobwhites. This would allow us to evaluate effectiveness of various treatments to reduce brush on abundance of northern bobwhites. Nevertheless, even in these wet years, precipitation during the previous summer, and to a lesser extent in the previous spring, was the dominant factor impacting abundance of northern bobwhites. Breeding success is sensitive to variation in rainfall during spring and summer (Lusk et al., 2002). In semi-arid areas, positive effects of additional precipitation in the growing season include increased growth of vegetation for nesting cover and shelter, and more food in the form of vegetation, insects, and seeds. In comparison, productivity in more mesic regions tends to decrease as rainfall in summer increases. Excessive precipitation can chill eggs and young chicks (Newton, 1998), even in arid areas (Hernández et al., 2002*b*). Several studies have indicated that, in South Texas, precipitation in the previous autumn often correlates best with abundance of northern bobwhites in the following year (Bridges et al., 2001; Lusk et al., 2001, 2002); however, late-season rainfall was not identified as an important factor in our study.

Type of range was secondary to rainfall as an influence on abundance of northern bobwhites. Types of range with largest populations were sandy loam, clay loam, sandy, and gravelly ridges. These sites are of moderate productivity for the area, although they would be considered of low productivity in more mesic regions (Spears et al., 1993). Few northern bobwhites were heard in the most productive types of range. In semi-arid rangeland, lack of moisture often limits productivity, and the most productive sites are often low-lying areas that are subject to inundation during rainstorms. These areas are unsuitable nesting habitat. Abundance of northern bobwhites also was low on lowest-productivity sites with thin soils, such as shallow-ridge sites. Herbaceous cover and density of potential grassy nesting clumps on these sites was low even during wet years. In this study, the number of shallow-ridge sites was small, but counts collected over the same time on shallow-ridge sites on the northern edge of the South Texas plains support the observation that this is unfavorable habitat for northern bobwhites (mean birds/site 1.10 ± *SE* 0.15, $n = 20$).

This study suggests that in semi-arid regions, reducing brush will not improve habitat for northern bobwhites in areas prone to inundation or low-productivity types of range, but in mid-productivity rangeland, abundance can be increased by treatments to reduce brush, with variable response. Although Spears et al. (1993) suggested that the best land-management procedure for northern bobwhites in central and western South Texas plains may be to protect later seral stages that tend to have more ground cover, the most successful treatment in increasing populations was intensive clearing of large blocks of land by root-plowing, which kills much of the brush. There was no evidence that leaving strips and mottes of brush to create a mosaic of protective cover and open feeding areas was advantageous. However, this study was conducted in a period of abundant rainfall when optimal growth of herbaceous vegetation provided ample cover. In drier years, or under heavier cattle-grazing regimes, cover provided by remaining brush strips and mottes might be critical to survival of northern bobwhites.

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