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Habitat Characteristics of Montezuma Quail Foraging Areas in West Texas

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Abstract

*Little information is known about the foraging habitat of Montezuma quail (*Cyrtonyx montezumae*) in Texas, USA. We compared habitat characteristics of foraging and nonforaging areas to identify trends in habitat attributes across sites with varying levels of quail use on Elephant Mountain Wildlife Management Area in Brewster County, Texas, USA, during May–August 2001. We delineated foraging and nonforaging areas using a system of parallel transects (100 m apart) that spanned the length of the grassland and covered the entire area. We walked transects every 3–5 days searching for signs of feeding (i.e., diggings). We documented a higher mean density of* Allium *spp. plants in foraging (95% CI: 12.1 ± 4.3 plants/m^2) than nonforaging areas (95% CI: 0.8 ± 0.6 plants/m^2). Foraging areas also exhibited a greater mean slope (95% CI: 22.6 ± 2.9% vs. 8.0 ± 2.1%). However, species richness, diversity, and equitability were similar between the foraging (23, 6.5, and 0.3, respectively) and nonforaging area (29, 7.6, 0.3). We observed a decreasing trend in density of* Allium *spp. plants, number of stones, and slope from high- to no-use sites. These 3 variables appear to be key habitat features associated with foraging areas of Montezuma quail in west Texas.* (WILDLIFE SOCIETY BULLETIN 34(3):856–860; 2006)

Key words

Cyrtonyx montezumae*, foraging habitat, Mearns quail, Montezuma quail, Texas.*

Montezuma quail (*Cyrtonyx montezumae*) inhabit pine–oak (*Pinus–Quercus*) communities at high elevations (>1,200 m) throughout much of the desert southwest (Leopold and McCabe 1957, Heffelfinger and Olding 2000). Montezuma quail are unique from other North American quail species in that they obtain most of their food requirements from subterranean bulbs and tubers (e.g., *Cyperus* spp., *Allium* spp., and *Oxalis* spp.; Bishop and Hungerford 1965, Albers and Gehlbach 1990). Miller (1943) noted that plants bearing bulb or tuber root systems often were associated with open spaces under oak trees and canyon bottoms. It is in these open pine–oak woodlands, with low shrubs and perennial bunchgrasses, that Montezuma quail attain their highest densities (Leopold and McCabe 1957). Montezuma quail have become adapted to a foraging strategy of digging for roots on steep slopes, and their morphological traits (large leg muscles, large feet and claws, strong beak) reflect such evolution (Miller 1943).

Few studies have been conducted on Montezuma quail ecology and life history. The research that does exist has focused primarily on a limited portion of its distribution, namely Arizona, USA (Wallmo 1954, Bishop and Hungerford 1965, Brown 1982) and Chihuahua, Mexico (Leopold and McCabe 1957). The species in general remains poorly understood (Albers and Gehlbach 1990), especially in Texas, USA, where Montezuma quail have declined in numbers and distribution over the past century (Oberholser 1974). Aside from the general association of Montezuma quail to pine–oak communities (Brown 1982, Albers and Gehlbach 1990), little is known regarding specific attributes of Montezuma quail habitat. To our knowledge, only 4 studies have quantified habitat for the species (Albers and Gehlbach 1990, Stromberg 1990, Bristow and Ockenfels 2002, 2004).

The unusual feeding habit of Montezuma quail results in characteristic diggings that have been useful for studying the species. A typical digging by Montezuma quail consists of a hole about 5.1 cm long, 2.5 cm wide, and 5.1–7.6 cm deep (Leopold and McCabe 1957). Previous studies have used diggings to index abundance and distribution of Montezuma quail (Holdermann 1992) and as indicators of habitat choice (Albers and Gehlbach 1990). Leopold and McCabe (1957) believed that lack of underground food reserves was the factor most frequently limiting Montezuma quail populations. Given the importance of foraging habitat for Montezuma quail, the practicality of using diggings to identify foraging habitat and the lack of empirical data on specific habitat attributes, we conducted a study to 1) quantify and compare habitat characteristics between foraging and nonforaging areas, and 2) identify trends in habitat attributes across sites with varying levels of quail use.

Study Area

We conducted our research on Elephant Mountain Wildlife Management Area (WMA) which was located approximately 40 km south of Alpine, Texas, USA, in Brewster County. Elephant Mountain WMA encompassed approximately 9,300 ha including the most prominent terrain feature, Elephant Mountain (Hughes 1993). Elephant Mountain has an elevation of 1,900 m and rises approximately 609 m above the surrounding table lands (Hughes 1993). Annual mean precipitation ranged from 38–51 cm with most of the precipitation occurring during July–August. Soils varied in texture and developed from outwash materials from the mountains (Correll and Johnston 1979). Typical range sites included stony hills, clay flats, sands, saline soils, gypsum flats, deep upland roughs,

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stony mountains, and gravelly outwashes (Gould 1975). The summit of Elephant Mountain was an alpine grassland dominated by native grasses and sparse patches of small shrubs including oak (*Quercus* spp.), mountain laurel (*Sophora secundiflora*), and fragrant sumac (*Rhus trilobata*). Elephant Mountain WMA was moderately grazed (1 animal unit/50 ha) using a high-intensity, low-frequency grazing system. Livestock grazing was restricted to the foothills and surrounding plains of Elephant Mountain with no grazing occurring on the alpine grassland.

Methods

We delineated foraging and nonforaging areas of Montezuma quail on the alpine grassland of Elephant Mountain using a system of parallel line transects (100 m apart) that spanned the length of the grassland and covered the entire area. During April–May 2001, we walked transects every 3–5 days visually searching for signs of feeding (i.e., diggings). Length of transects varied given the shape of the grassland on top of Elephant Mountain proper; however, search effort (distance walked/unit time) was approximately equal on all transects. We conducted searches by sequentially walking transects until the entire area had been searched. We obtained Universal Transverse Mercator coordinates for any foraging sites we detected from the transects using a hand-held global positioning system with $\pm$3-m accuracy (GARMIN International Inc., Olathe, Kansas). We defined a foraging site as a site consisting of $>$3 diggings or a cluster of diggings within a 0.5-m radius of each other.

We did not directly quantify visibility among transects that may affect the precision of our delineation of foraging and nonforaging areas. However, our intent was not to obtain a precise demarcation of the areas (an impractical task) but rather to compare general habitat characteristics between areas of relative high and low forage use. In this context what variation in visibility might have existed among transects would not invalidate our crude delineation of relative high- and low-use areas. In addition, vegetation data suggested similar visibility between the foraging and nonforaging areas because percent bare ground (the complement of percent vegetation canopy cover) was similar (see below).

To delineate the foraging area, we created a minimum convex polygon encompassing all foraging sites that were within 100 m of another using ArcView 3.2. (ESRI, Redlands, California) and the Animal Movement Extension (Hooge and Eichenlaub 1997). We termed the area encompassed by the polygon as the foraging area and the area outside the polygon as the nonforaging area. We note that use of the term nonforaging area does not imply the area was not used by Montezuma quail. Montezuma quail were observed in the nonforaging area; however, sightings were not common.

We quantified habitat characteristics within the foraging and nonforaging areas using 30 1-m^2 plots that were randomly established within each area. At each plot we recorded total number of diggings, plant species composition, percent exposure of bare ground, and slope. We also classified individual diggings as bulb (*Allium* spp.), grass, forb, or other, depending on the vegetation dug. Diggings classified as other consisted of diggings that could not be classified into the aforementioned categories or were diggings with no sign of vegetation matter.

To compare habitat characteristics across sites with varying levels of quail use, we categorized use into 3 levels (no, low, and high) based on spatial concentration of diggings. The no-use level occurred within the nonforaging polygon whereas the low- and high-use levels occurred within the foraging polygon. We crudely delineated low- and high-use areas by visually partitioning the foraging polygon into sub-polygons based on spatial concentration of diggings on the initial reconnaissance map. To ground-truth this crude delineation, we conducted several 5-minute searches (n = 5–7) within each use category from arbitrary starting points proceeding linearly in a random direction. As in our delineation of foraging and nonforaging areas, differences in visibility among search transects radiating out from starting points may have affected the precision of the delineation of low- and high-use areas. However, percent bare ground was similar between the low- and high-use areas (see below), thereby suggesting similar visibility.

We randomly established 2 100 $\times$ 100-m plots in each area of use (i.e., no, low, and high). We recorded total number of diggings in each plot by traversing the entire plot. We then established 2 50-m transects perpendicular to the side of the plot facing the slope at 25 and 75 m along the selected side. We determined slope (%) at these transects and documented the number of exposed stones that intersected the transects. We defined stones as rocks at least 25 $\times$ 25 $\times$ 25 cm. In addition, we recorded percent bare ground and density of *Allium* spp. plants using 1-m^2 quadrats set at 15, 30, and 45 m along each of the 50-m transects.

We compared plant species richness, diversity, and equitability between the foraging and nonforaging areas using Shannon index (Hill 1973) and, for this publication, reported density only for plants $>$0.3 plants/m^2. We used 95% confidence intervals to compare habitat features between foraging and nonforaging areas (Johnson 1999). Because our intent was to identify patterns in habitat attributes across sites with varying levels of use, we plotted habitat features for no-, low-, and high-use areas to elucidate trends using confidence intervals.

Results

We recorded 27 detections (11 sightings + 16 calls) of Montezuma quail on top of Elephant Mountain proper during our study. Of these, we located only 4 (1 sighting + 3 calls) within the nonforaging area. Of the 23 detections within the foraging area, only 8 (4 sightings + 4 calls) were within the low-use area. In addition, we documented no diggings in the nonforaging area compared to 4.0 $\pm$ 1.1 diggings/m^2 (95% CI) in the foraging area. We located 2.0 $\pm$ 1.0 diggings/search period (95% CI) in the low-use area and 8.6 $\pm$ 1.6 diggings/search period in high-use area. Thus, our crude delineation of these areas of relative use appeared valid.

Bulbs comprised 75% of the quail diggings ($n = 121$) followed by grass (16%), other (8%), and forbs (1%). We also documented a higher mean density of *Allium* spp. plants in the foraging area (95% CI: 12.1 $\pm$ 4.3 plants/m^2) compared to the nonforaging area (95% CI: 0.8 $\pm$ 0.6 plants/m^2), as well as greater mean slope (95% CI: 22.6 $\pm$ 2.9% vs. 8.0 $\pm$ 2.1%). However, species richness, diversity, and equitability were similar between the foraging (23, 6.5, and 0.3, respectively) and nonforaging area (29, 7.6, 0.3; Table 1). Mean percent exposure of bare ground also did not differ (95% CI: 78.6 $\pm$ 4.7% [foraging]; 73.5 $\pm$ 5.2% [nonforaging]).

Table 1. Plant species, total count, and mean density (plant/m^2) within foraging and nonforaging areas of Montezuma quail, Brewster County, Texas, USA, May–Aug 2001. Thirty 1-m^2 quadrants were randomly sampled within each area.

			Foraging			Nonforaging		
Type	**Common name**	**Scientific name**	**Count**	**Density**	**SE**	**Count**	**Density**	**SE**
Forb								
	Wild onion	*Allium drummondii*	364	12.1	2.2	25	0.8	0.3
	Lazy daisy	*Aphanostephus riddellii*	0	0.0	0.0	12	0.4	0.2
	False nightshade	*Chamaesaracha* sp.	117	3.9	0.9	251	8.4	1.4
	Curlycup gumweed	*Grindelia squarrosa*	83	2.8	1.0	83	2.8	0.8
	Pepperweed	*Lepidium virginicum*	65	2.2	0.7	5	0.2	0.1
	Aster	*Machaeranthera* sp.	26	0.9	0.2	32	1.1	0.4
	Plantain	*Plantago* sp.	124	4.1	1.1	69	2.3	0.5
	Upright prairie coneflower	*Ratibida columnifera*	16	0.5	0.2	51	1.7	0.5
	Silverleaf nightshade	*Solanum elaeagnifolium*	0	0.0	0.0	15	0.5	0.3
Grass								
	Sideoats grama	*Bouteloua curtipendula*	62	2.1	0.5	23	0.8	0.4
	Black grama	*Bouteloua eriopoda*	100	3.3	1.0	295	9.8	1.8
	Tobosa	*Pleuraphis mutica*	22	0.7	0.5	36	1.2	0.5
	Bristlegrass	*Setaria* sp.	0	0.0	0.0	44	1.5	1.3
Shrub								
	Pink mimosa	*Mimosa boreales*	17	0.6	0.3	11	0.4	0.3

We observed a decreasing trend in density of *Allium* spp. plants, number of stones, and slope from high- to no-use sites (Fig. 1). Mean density of *Allium* spp. plants was the habitat feature that exhibited the most pronounced decreasing trend across the levels of use (Fig. 1). Percent bare ground was similar between the levels of low use (95% CI: 80.6 ± 9.2%) and high use (95% CI: 77.7 ± 13.0%).

Discussion

We begin by noting that differences in visibility could have affected the precision of our delineation of areas of relative foraging use. However, percent bare ground (the complement of percent vegetation canopy cover) was similar between the foraging and nonforaging areas, as well as between the low- and high-use areas within the foraging area. We also documented increasing numbers of foraging sites and quail detections with increasing level of foraging-use category. Given this data, our crude delineation of relative foraging-use areas appeared valid.

Species richness, diversity, and equitability were similar between the foraging and nonforaging area in our study. Bristow and Ockenfels (2002) reported that species richness of herbaceous plants was greater at used sites than randomly available habitat. They documented that Montezuma quail flush-sites contained an average of 5.3 grass and 6.1 forb species compared to random points, which averaged 4.1 and 4.3 species, respectively. Because of the small difference (1–2 species) in species richness between used and random points, it is uncertain whether the finding was biologically significant. However, we note that our study is not directly comparable to Bristow and Ockenfels (2002). Species diversity may be important in selection of use areas but not forage areas. We believe that species richness and diversity did not adequately characterize foraging habitat in our study because of the specialized diet of Montezuma quail. Bishop and Hungerford (1965) documented that 50–85% of the annual diet of Montezuma quail consisted primarily of bulbs and tubers from a select genera of plants (e.g., *Allium*, *Cyperus*, *Oxalis*). Given this specialized diet, it is intuitive to expect that habitat use by Montezuma quail would be influenced more by density of a few key food plants rather than species diversity at the community scale. Our data support this generalization. We documented that the foraging area differed from the nonforaging area in density of *Allium* plants but not in species diversity. *Allium* was the primary food plant for Montezuma quail at our study site, and its density was about 10× greater in the foraging area.

In addition to density of *Allium* plants, a second habitat feature that differed between the foraging and nonforaging area was % slope. Albers and Gehlbach (1990) also reported that slope was a major indicator of feeding habitat for Montezuma quail in central Texas. This link between slope and quail use had been noted in previous research (Fuertes 1903, Swarth 1909, Stromberg 1990), but no formal explanation had been offered.

Albers and Gehlbach (1990) proposed that Montezuma quail used steep slopes because the soil properties present therein afforded higher quantities of food plants. Soil depth and soil moisture differentiated between foraging habitat and unused areas in their study, with greater soil depth and lower soil moisture characterizing feeding sites. Albers and Gehlbach (1990) believed that wood sorrels (*Oxalis drummondii*) were more abundant on deeper soils and digging was easier on drier soils. Thus, increased precipitation runoff on steep slopes resulted in drier soils relative to more level terrain and, consequently, higher quail use.

The rationale of Albers and Gehlbach (1990) is somewhat faulty (or incomplete), however, because increased runoff on steep slopes would also increase soil erosion, thereby decreasing soil depth, a condition associated with unused sites in Albers and Gehlbach (1990). We observed an increasing trend in the amount of exposed stone from no- to high-use sites. Based on our data and field observations, we believe that considering amount of exposed stone can help strengthen Albers and Gehlbach's (1990) rationale.

During our field sampling, we noticed that relatively deep pockets of fertile soil formed on the uphill side of rock outcrops. These soil pockets appeared to hold moisture for longer periods of time and were less compact than surrounding, thinner soils. We also observed that higher densities of *Allium* plants generally were

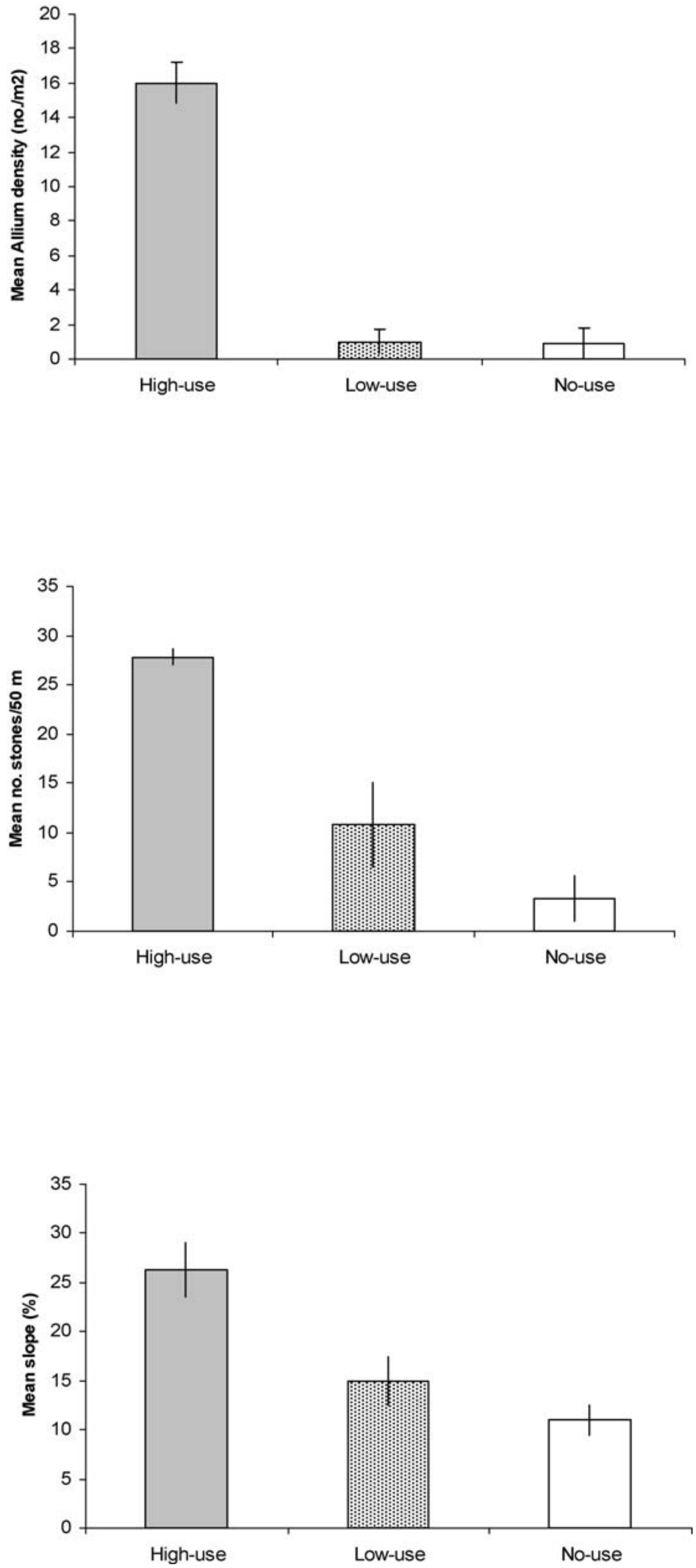

Figure 1. Estimated values ($\bar{x} \pm 1$ SE) for habitat characteristics of no-, low-, and high-use foraging areas ($n = 2$ 100 × 100-m plots/area) of Montezuma quail, Brewster County, Texas, USA, May–Aug 2001. High-use sites were defined as sites with high concentrations of quail diggings (>3 diggings within 5-min walking period) whereas low-use sites contained a lower concentration of diggings. No-use sites contained virtually no diggings.

Figure 2. Illustration of *Allium* plant establishment on soil pockets formed within rock outcrops, Elephant Mountain Wildlife Management Area, Brewster County, Texas, USA, 2001. Rock outcrops are thought to detain precipitation runoff on slopes and 1) allow time for soil sediments to settle, 2) form deep, moist soil pockets, and 3) result in a microclimate conducive for establishment of *Allium* plants.

associated with these steep slopes where rock outcrops existed. Moreover, many of these soil pockets exhibited sign of Montezuma quail use (i.e., diggings). Therefore, we presume that rock outcrops acted as runoff detainments and allowed time for soil sediment to settle, thereby creating soil conditions conducive for *Allium* establishment (Fig. 2). This scenario may help explain the slope-quail use association, at least in our study area. However, no study to date has quantified food availability relative to terrain or outcrop presence.

Management Implications

Montezuma quail are habitat and foraging specialists. In our study habitat use by Montezuma quail was associated with habitats that had high densities of *Allium* plants, moderate slopes (20–30%), and rock outcrops. Habitats that had the same species composition but lacked the physical characteristics to support high *Allium* densities had fewer signs of use by Montezuma quail. Little information exists regarding management practices that may promote primary food resources for Montezuma quail. However, given the apparent interrelationship among rock outcrops on slopes, soil pockets, and *Allium* presence, management should minimize practices that could disrupt such relationship (e.g., practices that could dislodge rock outcrops and increase soil erosion).

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