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MONTEZUMA QUAIL IN THE EDWARDS PLATEAU OF TEXAS: DETECTION, OCCURRENCE, AND HABITAT

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ABSTRACT

Montezuma quail (*Cyrtonyx montezumae*) were historically found throughout nearly every county in the Edwards Plateau region of Texas, USA. Over the last century, shifting land use, reduction of fire on the landscape, and the subsequent encroachment of woody vegetation have constricted the distribution of Montezuma quail to a few counties in the southern portion of the Edwards Plateau. A renewed interest in management for Montezuma quail over the last decade has been met with a lack of information regarding their habitat requirements in this region. This lack of general information and increased sightings of this elusive species in areas where Ashe's juniper (*Juniperus ashei*) had been removed led to the initiation of this study to identify detection and site use. During April–August of 2015 and 2016, biweekly call-back surveys were conducted at 60 randomly stratified locations distributed across 9 properties in Edwards and Kinney counties, Texas. During each survey, weather conditions were recorded. Additionally, vegetation at each of the 60 survey locations was quantified. Montezuma quail were detected at 46% (28 of 60) of the survey locations during 6.7% of the total site visits during 2015 and 2016. Detection of Montezuma quail during call-back surveys was mostly explained by temperature. When temperatures exceeded 25 °C, probability of detection dropped below 70%. Site use by Montezuma quail was best explained by bunchgrass density as probability of site use exceeded 50% when bunchgrass density exceeded 0.63 plant/m^2. Future researchers may be more successful searching for Montezuma quail with an understanding of the environmental conditions under which they are most detectable. Furthermore, since relatively dense stands of bunchgrass were associated with site occupancy, this metric gives managers a management target to shoot for when restoring Montezuma quail habitat in the region.

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Key words: *Cyrtonyx montezumae,* Edwards Plateau, Mearns quail, Montezuma quail, Texas

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Montezuma quail (*Cyrtonyx montezumae*) are an elusive gamebird found throughout the montane regions of the southwestern United States and Mexico in oak-juniper (*Quercus* and *Juniperus* spp., respectively) savannahs (Leopold and McCabe 1957, Brennan et al. 2017). Montezuma quail are found in the Trans Pecos and Edwards Plateau regions of Texas, USA and are classified as a game species without an open hunting season. However, much of what we know about this species has come from populations in Arizona and New Mexico, USA; Mexico; and to a lesser extent, the Trans Pecos of Texas (Leopold and McCabe 1957, Brown 1982, Stromberg 1990). There is little information available to biologists, land managers, and quail enthusiasts in the Edwards Plateau of Texas regarding the habitat requirements of Montezuma quail. Once found in nearly every county throughout the Edwards Plateau, Montezuma quail populations have been constricted over the past century to an area encompassing portions of a few counties (Oberholser and Kincaid 1974, Harveson et al. 2007). This reduction in distribution has been attributed to antagonistic land use practices, the reduction of fire on the landscape and subsequent encroachment of Ashe's juniper (*Juniperus ashei*), red-berry juniper (*Juniperus pinchotii*), escarpment live oak (*Quercus fusiformis*), and other woody species (Leopold and McCabe 1957, Weniger 1988, Baccus and Eitniear 2007). Previous research has indicated that typical Montezuma quail habitat is characterized by a woody canopy of 25–50% (Brown 1982, Albers and Gehlbach 1990, Bristow and Ockenfels 2004). Today, much of the eastern portion of the ecoregion is dominated by juniper species with little herbaceous understory, presumably rendering large swaths within this region unusable. Across their entire geographic range Montezuma quail have suffered the greatest declines in the Edwards Plateau, underpinning the importance of understanding site use and habitat requirements in this area (Baccus and Eitner 2007).

During the 1970s and 1980s there was a renewed interest in Montezuma quail inhabiting the Edwards Plateau. Research conducted by Oberholser and Kincaid (1974), Sorola (1986), Albers and Gehlbach (1990), and Holderman (Texas Parks and Wildlife Department, personal communication) reported Montezuma quail in 5 counties: Edwards, Val Verde, Kinney, Uvalde, and Real counties. With sparse information regarding the general ecology and habitat requirement for Montezuma quail in this region, landowners, state biologists, and quail enthusiasts have been challenged when attempting to developing management strategies. In addition, the species' secretive nature has made study difficult. Monitoring such an elusive species with low detectability requires innovative methods. Call-back surveys during the breeding season have been useful in sampling elusive avian species (Johnson et al. 1981, Sanders 2012). To further our understanding of Montezuma quail in the Edwards Plateau of Texas, we attempted to 1) estimate site occurrence, 2) identify variables affecting the detection and site use of Montezuma quail in the Edwards Plateau, and 3) quantify the bounds of vegetation composition at sites where Montezuma quail were found.

STUDY AREA

We conducted this study on 9 properties in the Edwards Plateau ecoregion of Texas (Figure 1) (Gould 1975). These properties consisted of 8 privately owned ranches and 1 state park ranging in size from 40–5,754 ha located in Edwards and Kinney counties. The Edwards Plateau is centrally located in the state. Temperatures range from 18–31 °C in the warm season (Apr–Sep) and from 6–20 °C during the cool season (Oct–Mar; NOAA 2015). Average annual rainfall is 66.7 cm; this precipitation primarily occurs in a bimodal pattern during May–June and September–November. Ranging in elevation from 182 m to 1,638 m, the Edwards Plateau consists largely of limestone formations, covered by oak-juniper woodlands, upland savannahs, and native grass and shrublands (Gould 1975, Amos and Gehlbach 1988). Since the mid-1800s the Edwards Plateau has been utilized for livestock production including cattle, sheep, and goats. However, of the properties included in this study only 2 of the private ranches had domestic livestock (cattle and horses) grazing during the entire study. The primary soil types on the study sites were Dina, Eckrant, Ecktor, Oplin, Rio Diablo, and Tarrant series (NRCS 2009). These soil series are representative of relatively shallow soil horizons (<10 cm) with surface organic matter present. Sideoats grama (*Bouteloua curtipendula*), slim tridens (*Tridens muticus*), Hall's panicum (*Panicum hallii*), green sprangletop (*Leptochloa dubia*), purple threeawn (*Aristida purpurea*), silver bluestem (*Bothriochloa laguroides*), little bluestem (*Schizachyrium scoparium*), and King Ranch bluestem (*Bothriochloa ischaemum*) were common grasses on the study sites. Common forbs (in order of dominance) included Drummond's woodsorrel (*Oxalis drummondii*), one-seed croton (*Croton monanthogynus*), ten-petal anemone (*Anemone berlandieri*), knotweed leaf-flower (*Phyllanthus polygonoides*), and mealy sage (*Salvia farinacea*). Dominant woody and succulent species included Ashe's juniper, live oak,

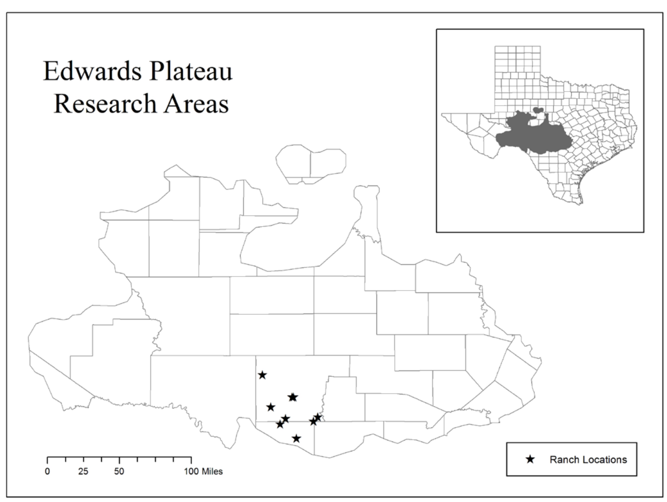

Fig. 1. Montezuma quail (*Cyrtonyx montezumae*) study area distribution in the southern Edwards Plateau ecoregion of Texas, USA.

Texas persimmon (*Diospyros texana*), Texas sotol (*Dasylirion texanum*), various pricklypear species (*Opuntia* spp.), Texas mountain laurel (*Sophora secundiflora*), Texas oak (*Quercus buckleyi*), Mexican piñon (*Pinus cembroides*), evergreen sumac (*Rhus virens*), guajillo (*Senegalia berlandieri*), and Texas kidneywood (*Eysenhardtia texana*). Individual study sites were unique in their topographic diversity, soil series, and plant compositions.

METHODS

Call-back Surveys

We conducted call-back surveys at 60 stratified locations distributed across the 9 properties during April–August 2015 and March–August 2016. We created an 800 m × 800 m grid of points in ArcMap 10.5.1 (Esri Inc., Redlands, CA, USA) to guide selection of survey locations. These dimensions were modified from Sanders (2012), who used a 400-m × 400-m grid, and Bishop's (1964) finding that a Montezuma quail buzz call is generally audible to humans up to 200 m away. The larger grid was selected to reduce the probability of double sampling. Each location in the grid had a unique elevation, slope, relative juniper density, and topographic position. Selected survey locations were stratified between high, medium, and low elevation (low: <156 m; medium: 156.1–180 m; high: >180 m), slope (low: 0–7°; medium: 7.1–13.9°; high: ≥14°), relative juniper density coverage (low: 0–24%; medium: 25–49%; high: ≥50%), and between hill tops, hill sides, and valleys to ensure that a wide range of conditions were sampled. The 60 locations were also partitioned proportionally with the size of the property (i.e., smaller properties had fewer locations).

We surveyed locations 2 times per month between sunrise and 1200 hours on a rotational schedule so that the first location surveyed in period 1 was the last location surveyed during period 2. This rotation was implemented to ensure that survey locations were visited during all periods of the morning. At each survey location, prior to beginning the call-back survey, percent cloud cover, wind speed (km/hr) and direction (N, NE, E, SE, S, SW, W, and NW), temperature (°C), barometric pressure (mm Hg), and relative humidity (%) were recorded using a Kestrel 4500 hand-held weather station (Nielsen-Kellermen Co., Boothwin, PA, USA). Following this period, the call-back survey was conducted for 10 minutes based on a pilot study conducted by Grahmann and Moore (2013–2014; personal communication) using a recording of a male Montezuma quail buzz call and a descending 9-note covey call. Calls were played using a Bose SoundLink Mini speaker (Bose Corp., Framingham, MA, USA) and volume was calibrated so the recording of the buzz call could be heard from 200 m away on a calm day, on level terrain and with no woody cover. During each survey, we recorded 1) the presence of a Montezuma quail and noted if the observation was made visually or audibly, 2) the type of call heard (male buzz call or 9-note descending whistle), 3) the number of calls heard, and 4) the approximate distance and direction the call came from. All surveys were conducted by the same individual throughout the duration of this study.

Habitat Characterization

We measured vegetation at each of the 60 call-back survey locations at 1) plot (at the survey location) and 2) pasture-wide scales during May–June and October–November during both 2015 and 2016. At each location, 4 10-m transects radiated in the cardinal directions. During the May–June sampling period, percent exposed litter, bare ground, rock, and percent cover of forbs, subshrubs, and grass (by species) were estimated by using a 20-cm × 50-cm sampling frame at 5 m and 10 m along each of the 4 10-m transects (Daubenmire 1959). Additionally, bunchgrass density and food plant (*Allium* spp., *Oxalis drummondii*, *Cooperia* spp., *Nothoscordum* spp. and *Cyperus* spp.) densities were estimated using a 1-m^2 sampling frame at 5 m and 10 m centered on each of the 4 transects (Bishop and Hungerford 1965). Bunchgrass was tallied if it exceeded 22.4 cm wide by 22.4 cm tall in accordance with the minimum size preferred by northern bobwhite (*Colinus virginianus*) in the region (Arredondo et al. 2007). Woody plant cover at each of the call-back locations was estimated along the 4 10-m transects by species using the line intercept method to 5 cm (Canfield 1941). Herbaceous and woody canopy height were measured at the 5-m and 10-m marks along the 4 transects. During the October–November sampling period, only food plants were estimated following the same protocol as the May–June sampling.

At the pasture scale woody cover was estimated from 2016 National Agriculture Imagery Program imagery using an unsupervised classification in the program to identify 1) woody cover, 2) herbaceous cover, 3) rock and bare ground, and 4) water cover classes within a 200-m buffer from each of the call-back locations.

Analyses

We examined means with standard errors (SE) and ranges of the weather variables affecting the detection of Montezuma quail and the vegetation characteristics at sites which showed use by Montezuma quail. To determine the effect of weather variables on detection and plant community effects on site use, stepwise logistic regressions were used with *a priori* selected variables. We ran a Pearson correlation analysis on all variables *a priori* to identify collinearity. Due to low observations, the data were pooled across years for analyses. The probability of observation was calculated using all site visits, while probability of detection was estimated following the occupancy when detection is less than 1 framework described by MacKenzie et al. (2006).

RESULTS

Observation

During the entire study 780 (2015: 360; 2016: 420) call-back surveys were conducted; of these, only 6.7% (52) of the surveys resulted in observation of at least 1 Montezuma quail. Detection was similar during the 2015 and 2016 survey season with 6.1% and 7.1% of surveys, respectively, resulting in observations. Of the locations where Montezuma quail were detected ≥ 1 time, the average probability of detection across both years was 17.9% during a single stand-alone survey.

Probability of detection was most influenced by temperature ($P < 0.0001$). As temperatures rose above 25 °C, the probability of detection dropped below 70% (Figure 2). While Montezuma quail were surveyed in a wide range of conditions, they were observed within distinct windows of environmental conditions. For example, wind speeds ranged from 0–14.7 km/hr during all surveys, while Montezuma quail calls were only observed within a window of 0.5–9.6 km/hr. Mean (± SE) wind speed averaged 3.4 ± 0.5 km/hr during visits resulting in observations. Temperature during all surveys conducted ranged from 4.5–36.3 °C, while Montezuma quail were observed during periods with temperatures ranging from 10.6–24.8 °C. Mean temperature during observations was 19 ± 0.5 °C. Humidity during surveys ranged from 41.3–100%, while observations were made when humidity was 61.4–100% and mean humidity during observations was 72.9 ± 5.4%. For cloud cover and barometric pressure, Montezuma quail responded to the call-back reel or were detected across the entire ranges sampled. For example, barometric pressure was 934.2–966.7 mm Hg during surveys and Montezuma quail responded from 934.4– 966 mmHg. Barometric pressure averaged 950.2 ± 1 mm Hg during sampling periods where a response was heard. Montezuma quail were observed during the full range of cloud coverages (0–100%); however, average cloud cover during observations was 72.9 ± 5.4%.

Site Use

During the 2015 and 2016 sampling periods, Montezuma quail were recorded at 30% (18 of 60 survey locations) and 43% (26 of 60 survey locations) of sites, respectively. Over the entire study 46% (28 of 60 survey locations) of the survey locations were used at least once and 27% (16 of 60 survey locations) were used during both years of the study. Due to a low sample size, site use data were pooled across years. Over this period, bunchgrass density ($P = 0.016$) was the most influential variable on site use by Montezuma quail. Probability of use exceeded 50% as bunchgrass density increased above 0.63 plant/m^2 (Figure 3).

The ranges of litter cover, bare ground, forb cover, grass cover, and bunchgrass density sampled at locations where Montezuma quail were observed represented the complete range that was sampled across all sampling locations regardless of site use. Litter coverage ranged from 2.3–90% with a mean of 30.8 ± 3.1% at used sites. Bare ground ranged from 0–34.4%, with a mean of 5.8 ± 0.9% used sites. Forb coverage ranged 0–61.6% with a mean of 11.5 ± 1.65% at used sites. Grass cover ranged from 0–87.5% with a mean of 29.8 ± 3% at used sites. Bunchgrass density ranged from 0 –1.1 plants/m^2, with an average abundance of 0.3 ± 0.04 plant/m^2 at used locations. Rock coverage was similar at used (0–66.9%) and unused sites (all-sites range: 0–77.1%) with an average of 27.4 ± 2.4% at used sites. Subterranean food plant density ranged 0–16.8 plants/m^2 among all locations; used locations had a mean of 1.1 ± 0.31 plants/m^2 with a range of 0–8.6 plants/m^2. Montezuma quail were detected at locations with a wide range of woody cover. Among all locations regardless of site-use status, woody cover ranged 5.8–82.6%. The mean woody coverage at used sites was 49.3 ± 3.1% with a range of 5.8–74.8%. Woody height among all locations ranged 0–5.8 m, while at used locations average woody height was 1.4 ± 0.2 m with a range of 0–5.1 m. Herbaceous height ranged 0–36.9 cm at all surveyed locations, while at used locations the mean

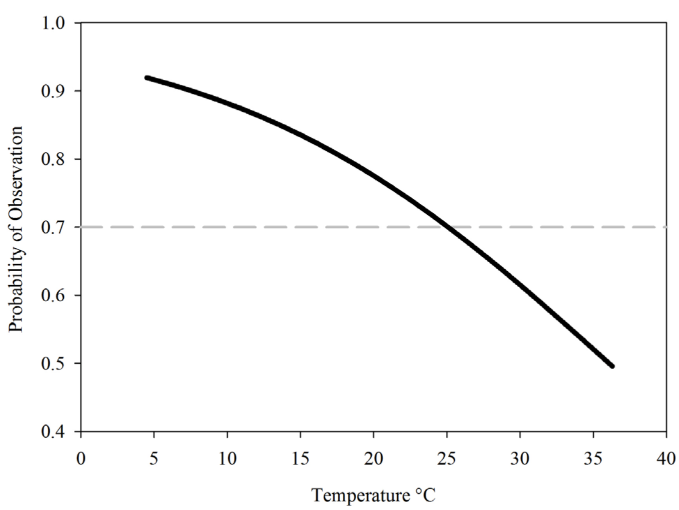

Fig. 2. Probability of observation of Montezuma quail (*Cyrtonyx montezumae*) in relation to temperature in the Edwards Plateau, Texas, USA.

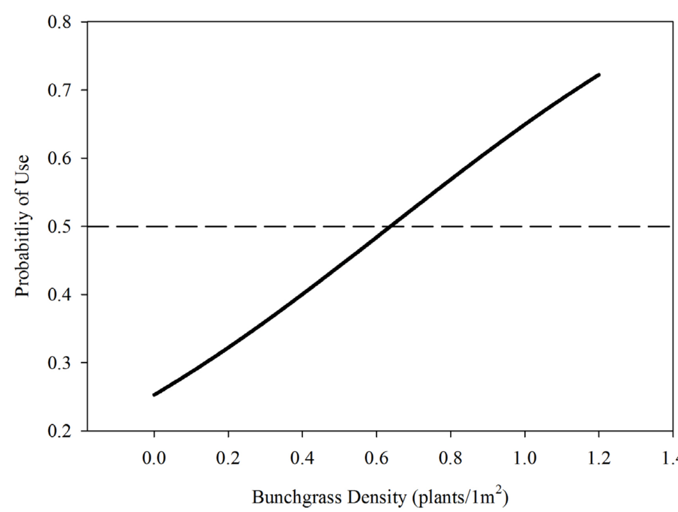

Fig. 3. The relationship between the probability of use by Montezuma quail (*Cyrtonyx montezumae*) and bunchgrass density (plants/m^2) in the Edwards Plateau, Texas, USA.

was 12.1 ± 1.4 cm and ranged 0–31.3 cm. Regardless of site use, juniper coverage varied greatly, from 0–87.5%, with an average of 26.8 ± 4.2% at used locations. Woody coverage estimated using remotely sensed imagery within the 200-m buffer was estimated among all locations and ranged 5.8–82.5%, while at used locations it ranged 8–81.3% with a mean coverage of 45.2 ± 4.7%.

DISCUSSION

The elusive behavior of Montezuma quail makes them a difficult species to study, especially in areas of relatively low abundance like that experienced in the Edwards Plateau region of Texas. In this study we experienced a low probability of detection (18%) across both years of sampling. Rates of detection were similar between the 2 consecutive years, even with increased sampling effort from 2015 to 2016. Sanders (2012; mean call/point on 2 routes: 0.01 and 0.18) and Stewart et al. (2021; 0.06 detection/hour) found similar results in the Edwards Plateau, with higher rates of detection and relative abundance of Montezuma quail in the Trans Pecos ecoregion of Texas. The low levels of detection and observation may support the idea that Montezuma quail populations exist at lower levels in the Edwards Plateau than in other areas of their Texas distribution. To give insight into the probability of detection at a single location without prior sampling, we estimated the probability of observation. This rate is what could be expected in an exploratory search where occupancy is unknown. The probability of observation was most associated with temperature; however, wide ranges and small standard errors of environmental conditions in which Montezuma quail were observed suggest that it was likely a collective influence of different environmental conditions. This result differs from the findings of Sanders et al. (2017) as they found no correlation between calling rate and maximum daily temperature in the Edwards Plateau. Optimal conditions to sample for Montezuma quail during exploratory searches may be described as having moderate temperatures and barometric pressures, higher cloud cover percentages, lower wind speeds, and higher humidity. Other quail scientists have previously described this range of conditions on searches for Montezuma quail in the Edwards Plateau while conducting call-back surveys (Holderman, personal communication, Texas Parks and Wildlife; E. Grahmann, personal communication, Caesar Kleberg Wildlife Research Institute).

The history of overgrazing by sheep (*Ovis* spp.), goats (*Capra* spp.), cattle (*Bos* spp.), and nonnative wildlife in the Edwards Plateau exceeds a century. This pattern of intense herbivory has been suggested as a direct factor contributing to the decline of Montezuma quail in the Edwards Plateau (Texas Game, Fish, and Oyster Commission 1945, Baccus and Eitner 2007). Lockwood (2001) suggested intensive herbivory that removes 40–50% of tall grass cover leads to extirpation of Montezuma quail. The study sites used in this investigation had low to no grazing pressure by domestic livestock for at least 5 years prior to the study. We found bunchgrass density to be the most influential habitat feature on occupancy of Montezuma quail, with occupancy increasing as bunchgrass density increased. However, similar to patterns influencing detection, site use by Montezuma quail can likely be explained by a combination of habitat variables. At the local scale, sites with the highest rates of occupancy were savannah shrublands and grasslands, and on hillsides. Sampling the habitat variables at the sampling point may not have been the best method to identify fine-scale patterns in site use. Occupancy status was determined if a Montezuma quail was detected, audibly or visually, in ≥1 sampling period. Bishop (1964) suggested the male buzz call can be heard from up to 200 m away. Thus, the sampling location which was defined by the 4 10-m transects was not completely representative of the area actually used by the birds. Trapping, radio-telemetry, and associated vegetation sampling at quail locations were not possible using current technology and known means of capture under the low densities of birds found in the area.

Another attribute regarding habitat variables at occupied sites is the wide range used for each variable or metric sampled. For example, Montezuma quail were found in areas near the extremes of each sampled metric. These findings may suggest that at least some level of habitat plasticity exists in their site use. This potential conclusion conflicts with the commonly cited notion of Montezuma quail being habitat or site specialists (Leopold and McCabe 1957).

MANAGEMENT IMPLICATIONS

Renewed interest in management for Montezuma quail by landowners and scientists is hampered by a lack of general information on the species. We recommend the maintenance of savannah-like shrublands and grasslands, especially along hillsides, through the select removal of juniper and reduction of grazing pressure to ensure adequate amounts of bunchgrasses for cover.

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