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Montezuma Quail (*Cyrtonyx montezumae*) foraging in a pinyon-juniper woodland

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ABSTRACT—Literature describing the ecology of Montezuma Quail (*Cyrtonyx montezumae*) is severely lacking. Their unique foraging strategy allows observers to study their foraging habitat selection without capturing them. We located 37 foraging sites in the pinyon-juniper (*Pinus-Juniperus*) woodlands of Lincoln County, New Mexico, over 2 years and analyzed the data using logistic regression analysis. The mean heights and the mean distances to the closest trees were the most significant factors in foraging site selection. Selection for a site increased by 19% for every 1 m increase in the mean distance to closest trees and decreased by 64% for every 1 m increase in the mean height of the closest trees. These findings support previous Montezuma Quail foraging site selection studies in oak (*Quercus* spp.) woodlands, which predicted Montezuma Quail select for relatively low (26%) canopy cover. Received 1 March 2020. Accepted 6 October 2021.

Key words: foraging, habitat selection, *Juniperus*, Mearns Quail, quail habitat.

Codorniz Moctezuma (*Cyrtonyx montezumae*) forrajeando en arbolados de piñón-junípero

RESUMEN (Spanish)—La literatura que describe la ecología de la codorniz Moctezuma *Cyrtonyx montezumae* tiene notables carencias. Su estrategia única de forrajeo permite a los observadores estudiar su selección de hábitat de forrajeo sin

necesidad de capturarlas. Encontramos 37 sitios de forrajeo en arbolados de piñón-junípero (*Pinus-Juniperus*) en el condado de Lincoln, New Mexico a lo largo de 2 años y analizamos los datos usando análisis de regresión logística. Las alturas y distancias medias a los árboles más cercanos fueron los factores más significativos en la selección de sitios de forrajeo. La selección de un sitio se incrementó 19% por cada metro de incremento en la distancia media a los árboles más cercanos y decreció 64% por cada metro de incremento en la altura media de los árboles más cercanos. Estos hallazgos dan soporte a estudios previos de selección de sitios de forrajeo de codornices Moctezuma en encinares (*Quercus* spp.), que predicen que estas codornices seleccionan una relativamente baja cobertura de dosel (26%).

Palabras clave: codorniz arlequin, forrajeo, hábitat de codornices, *Juniperus*, selección de hábitat.

Montezuma Quail (*Cyrtonyx montezumae*) are among the most understudied quail in the United States. This probably stems from researchers’ inability to capture sufficient sample sizes to draw statistically significant conclusions. Montezuma Quail use their large claws, feet, and legs to dig for starchy subterranean forage such as *Cyperus* spp., *Allium* spp., and *Oxalis* spp. (Albers and Gehlbach 1990). This unique foraging strategy seems to deter capture in Stoddard funnel traps.

Montezuma Quail foraging sites are conspicuous due to the aggregation of holes and disturbed soil (Leopold and McCabe 1957). Holes are crescent shaped, ~5 cm in diameter, and 2.5 cm deep (Leopold and McCabe 1957). Often, a triangle cut—created when Montezuma Quail use their bill to pull aside soil—is present, as well as footprints,

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feathers, and fecal matter, all of which help positively identify a Montezuma Quail foraging dig site and not a rodent site (Brown 1976).

Montezuma Quail inhabit wooded areas above about 1,000 m throughout Arizona, New Mexico, and Texas as well as several states in northern Mexico (Leopold and McCabe 1957). Previous studies identified the percentage of grass cover, tree density, and shrub density as significant habitat selection variables (Albers and Gehlbach 1990, Hernandez et al. 2006). Bristow and Ockenfels (2004) reported Montezuma Quail preferred 26–50% canopy cover in the oak woodlands of Arizona.

Montezuma Quail studies in pinyon-juniper woodlands comprise only a small percentage of the few published studies of this species (Brown 1976). Differences in tree structure and biology could affect Montezuma Quail habitat requirements in many ways from foraging to thermal cover. Thus, conclusions reached in oak woodlands may not translate directly to juniper woodland ecosystems (Robinson and Holmes 1982, Carroll et al. 2015). In this paper, we identify the influences of understory cover, woody tree cover, and topographical habitat components on Montezuma Quail foraging site selection in pinyon-juniper woodlands.

Methods

Study area

The Fort Stanton Snowy River Cave National Conservation Area (Conservation Area hereafter)—an approximately 10,149 ha protected area in Lincoln County, New Mexico—served as our study site. The Conservation Area is at 1,770–2,170 m elevation and is in an area of public use. The Conservation Area received a mean of 24 cm of rain per year from 2015 to 2016, mostly during the monsoon months of July–September (NOAA 2017).

The Conservation Area is topographically composed of rolling hills and ecologically a pinyon-juniper savanna. Grama grasses (*Bouteloua* spp.) dominate the understory with thick patches of wavy-leaf oak (*Quercus undulata*) on some of the steeper slopes. Common forbs include Apache plume (*Fallugia paradoxa*), yarrow (*Achillea millefolium*), and prairie rocket (*Erysimum capitatum*). Soil types consist of sandy to heavy clay loams: lithic argiustolls, cumulic

hapiustolls, and aridic calciustolls (NRCS 2017). The Bureau of Land Management conducted a thinning project to reduce juniper cover throughout the study site during 2015–2016.

Field methods

We created nineteen 100 m north–south line transects to search for foraging sites. Transects were spaced 150–300 m apart to cover the 140 ha thinning site and surrounding areas where we observed Montezuma Quail. The centroid of the transect area was located at 33°28'59.2"N, 105°34'00.5"W at about 2,000 m in elevation. We slowly walked transects while visually searching 10 m to each side of the line. We confirmed Montezuma Quail foraging sites by the presence of feathers, fecal matter, tracks, or flushing quail. Sites were omitted from analysis without such corroborating evidence (Brown 1976). At each confirmed site, GPS locational data and vegetation analysis were conducted.

The center point of the foraging site was determined by drawing a straight-line measurement of the widest diameter of the collection of digs, then intersecting it with a perpendicular line in the widest point available. Measurements of the closest woody vegetation in the 4 cardinal directions were recorded as follows: distance (m), height (m), species, and tree canopy cover. We recorded herbaceous vegetation diversity and cover using a Daubenmire (1959) frame, along with the heights of 10 random herbaceous plants. Tree cover width was used as a substitute for basal diameter (diameter at breast height was not applicable due to the shrub-like nature of junipers on this site). Cover width was defined as the distance from the farthest outside branches, 0.5 m from the ground parallel to where the Daubenmire frame was placed. Trees were only measured if they were 0.5 m or greater in height. Aspect and slope were analyzed using GIS.

Transects were surveyed during times when birds were in coveys (Nov–Mar) as single digs were difficult to locate. Selected foraging locations were compared to twice as many random locations (1:2 ratio). Random locations were generated using the Create Random Points tool in ArcGIS 10.3 (ESRI software, Redlands, California, USA).

Statistical analyses

We used a backwards stepwise regression analysis to identify which habitat variables were most informative. Logistic regression analyses use variables to predict binomial outcomes and are typically used to predict habitat selection (Jones 2001, Keating and Cherry 2004). Outcomes possible for this analysis were either “used” or “random” sites coded as 1 or 0, respectively.

Results

Thirty-seven positively identified Montezuma Quail foraging sites were located during the study and compared to 74 random points. Transects were not searched for during times of snow cover (1–15 Jan) to avoid biasing data for sunny areas. Three of 37 sites were found while searching transects, 6 were accidentally found by flushing birds while they were foraging, and the remaining 28 were located during other aspects of the larger telemetry study.

A logistic regression analysis was used to identify significant habitat components including % grass cover, % forb cover, % bare ground, aspect, slope, mean height of closest tree (m), mean distance to closest tree (m), mean canopy cover of closest tree (cm), richness of vegetation within the Daubenmire frame, vegetation species, aspect \times slope, and mean distance of closest tree \times percentage of grass \times slope.

The final, and only, significant model included % grass cover, % forb cover, aspect in degrees, % slope, mean height of the closest tree, mean distance to closest tree, an interaction of slope and aspect, and an interaction of grass cover, slope, and distance to closest tree. The logistic regression model was statistically significant, $\chi^2 = 53.90$, $P < 0.0005$ (Omnibus test), the Nagelkerke $R^2 = 0.576$. The Hosmer and Lemeshow value was not significant at 0.261. The model correctly classified 86.1% of sites, meaning this percentage of used and random sites were placed in the correct category, used or random, based on the included variables. The mean height of the closest trees and the mean distance to closest trees were determined to be the most significant of the 8 predictor variables (Table 1).

The likelihood of foraging site selection increased by 19% as mean distance to closest trees

Table 1. Predictor variables for logistic regression predicting foraging site selection for Montezuma Quail in Fort Stanton Snowy River National Conservation Area, Lincoln County, New Mexico. Forb = percentage of forb cover, Grass = percentage of grass cover, aspect = aspect of point, slope = slope of point, mean height = mean height of the 4 closest trees in each cardinal direction, mean distance = mean distance of the 4 closest trees in each cardinal direction, aspect by slope = interaction of aspect and slope, and distance by slope by grass = interaction of slope, mean distance to closest trees, and percentage of grass in the plot.

Variable ^a	Standard error	P	β	DF
Grass	0.021	0.964	1.001	1
Forb	0.038	0.116	0.942	1
Aspect	0.008	0.309	0.992	1
Slope	0.202	0.746	0.357	1
Mean height	0.294	<0.001	0.357	1
Mean distance	0.066	0.008	1.193	1
Aspect \times Slope	0.001	0.233	1.001	1
Distance \times Grass \times Slope	0.001	0.059	1.000	1

^a $n = 111$, Nagelkerke $R^2 = 0.565$, $\chi^2 = 53.75$, Percent Predicted = 86.1%.

increased by 1 m. We were unable to identify a maximum selected distance to closest tree because the maximum distance to closest tree was not sufficiently different than random sites (46.2 m selected, 46.8 m random). The likelihood of site selection decreased by 64.3% for each 1 m increase in the mean height of the closest tree. The most commonly selected tree height was 5 m with a mean of 3.07 m and the most commonly selected mean distance to closest tree was 10–20 m with a mean of 20.08 m.

The 2 interaction terms were not significant for these data; however, one was near to the significance value of 0.05. The interaction of % slope, % grass cover, and distance to closest tree had a near significance value of 0.059. The likelihood of foraging site selection increased as each unit of slope and distance to the closest tree increased, and percentage of grass decreased. The strength of the influences of these interactions is unclear since logistic regressions are sensitive to scale (Hilbe 2014).

Discussion

Two significant attributes of foraging site selection were found for this population of Montezuma Quail, mean height of closest trees

and mean distance to closest trees. These findings support previous Montezuma Quail research regarding tree density (Stromberg 1990, Bristow and Ockenfels 2004, Chavarria et al. 2017). The extent to which these variables affect selection remains unknown because of available onsite habitat.

One interaction term, mean distance to closest tree \times % grass cover \times % slope, approached significance ($P = 0.059$) and was of special interest. Stromberg (1990) reported the same interaction as a significant factor in Montezuma Quail habitat selection in a very different vegetative community, dominated by oak trees. He speculated that oak litter may have prevented understory cover from growing, therefore removing foraging material in those areas. Although quail on our site used habitats with wavy leaf oak shrubs, we did not find any evidence of digging, therefore these sites fell out of the scope of the study. Due to the lack of litter-producing oak tree species onsite, we suggest a different mechanism explaining this interaction. Studies have shown that in arid pinon-juniper woodlands, tree and bare patches act as nutrient and water sources for more vegetated patches (Reid et al. 1999). These grassless areas might create opportunities for thermal regulation, increased forage, or ease of access to that forage; more studies are necessary to determine the true mechanisms for this interaction.

Montezuma Quail have a specialized diet. Their large feet and claws are exceptionally out of proportion with their bodies and enable them to dig for nutrient-rich forage that is otherwise inaccessible. This implies foraging for specific tuberous plant materials affects habitat selection in foraging areas. More research into which tuberous subterranean plant materials or root nodes they consume may be the key to understanding the mechanisms behind habitat selection.

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