National Quail Symposium Proceedings

Volume 9 Article 36

2022

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ABSTRACT

Although Mexico has the greatest diversity of quail of any New World country, basic information on the ecology and life history of Mexican quails remains unknown. Our objective was to describe nest characteristics of the Montezuma quail (*Cyrtonyx montezumae montezumae*) in central Mexico. We searched for Montezuma quail nests within 8 counties in the state of México, Mexico during May–September 2003. We conducted nest searches along 66 transects (3–5 km × 40 m) distributed across 17 study sites. We recorded vegetation community, elevation, and nesting substrate for each nest. We measured nest characteristics: height, depth, nest entrance diameter, and orientation. If eggs were found, we recorded clutch size and egg mass, texture, color, and shape. We observed 324 quail and located 6 nests along a 254-km route. Nests were located at elevations ranging from 2,568–2,692 m above sea level. Mean (± standard deviation) nest height and depth were 122.2 ± 7.7 mm and 195 ± 61.8 mm, respectively. Nest entrance orientation for 5 of 6 nests was toward a southerly direction. Mean nest egg mass was 9.9 ± 0.1 g. Our study provides basic and descriptive information on a poorly known quail species in Mexico.

Citation: García-Solórzano, D., C. González-Rebeles Islas, G. D. Mendoza Martínez, E. Ávila González, and F. Hernández. 2022. Nesting of Montezuma quail in Mexico. National Quail Symposium Proceedings 9:159–163. https://doi.org/10.7290/nqsp09rQ8u

Key words: central Mexico, clutch, *Cyrtonyx montezumae*, egg, Montezuma quail, nest

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Mexico has the greatest quail diversity of any country in the New World, with 15 quail species, 5 of which are found in the state of México. This high diversity is due in part to the latitudinal location of the state, which is at the intersection of the Nearctic and Neotropical bioregions and the neo-volcanic belt mountain complex (Suárez-Mota and Téllez-Valdés 2014). The juxtaposition of these two biogeographic regions and mountain complexes results in a unique combination of wildlife from each region.

Despite Mexico's quail diversity, information on the basic life history, ecology, population status, and distribution of most Mexican quail species remains unknown (Carroll and Eitniear 2004). The Montezuma quail (*Cyrtonyx montezumae montezumae*) is one of the least studied species of pine-oak vegetation zones (Carroll and Eitniear 2000). Its cryptic coloration and reluctance to flush complicate field detection, and the species appears sensitive to most common tracking methods, such as radio-telemetry (Hernández et al. 2009). Thus, data on most aspects of its life history and ecology are limited (Stromberg 2000).

Montezuma quail are mostly restricted to the pine-oak vegetation zone; they reach their highest densities in open pine and oak woodland with an understory of low shrubs and perennial bunchgrasses (Leopold and McCabe 1957). Their primary distribution is in Mexico with a northern extension into the southern United States. Thus, their natural history and ecology can be best studied in this first country (Leopold and McCabe 1957). Our study objective was to collect basic nesting ecology information of Montezuma quail in central Mexico.

STUDY AREA

Our study covered an area of 3,156 km^2 in oak and pine-oak woodlands and grasslands in 8 northwestern counties (Acambay, Aculco, Almoloya de Juarez, Atlacomulco, Polotitlán, San Felipe del Progreso, Temascalcingo and Timilpán) of the state of México, and represents 1.4% of the total area for the state of México (INEGI 2000; Figure 1). Climate is temperate sub-humid with a mean annual precipitation of 1,000 mm (range 700–1500 mm), primarily occurring during summer (INEGI 2000). Local vegetation communities were composed primarily of woodlands (pine, oak, pine-oak, fir, fir-pine, pine-fir, and oak-pine) mixed with shrubs and native and nonnative grasslands (Espinosa-García and Sarukhán 1997). Pine-oak woodlands are common across the mountains at elevations of 2,800–2,950 m above sea level (Martinez and Matuda 1979). The tree stratum consists predominantly of 3 pine species (*Pinus occarpa, P. douglasina,* and *P. teocote*), 3 oak species (*Quercus crasifolia, Q. lauriana,* and *Q. conglomerata*), and 2 alder species (*Alnus jerullensis* and *A. firmifolia*). The shrub layer includes madroño (*Arbutus slandulosa*) and "escoba" (*Baccharis conferta*) with a herbaceous layer of muhly bunchgrasses (*Muhlenbergia* spp.; Rzedowski 1983, Rzedowski and Rzedowski 1985).

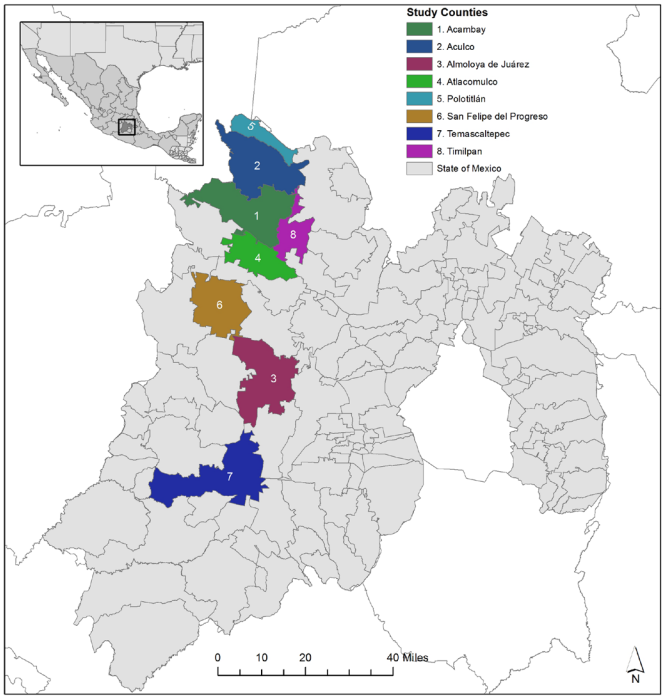

Fig. 1. Location of counties in the state of México, Mexico that were surveyed for Montezuma quail (*Cyrtonyx montezumae montezumae*) in 2003.

METHODS

We established 66 40-m wide transects of variable length (3–5 km) at 17 study sites. Study sites were selected because some of them contained the highest densities of Montezuma quail in the state of México (Tapia et al. 2002).

We conducted searches for quail along transects beginning at sunrise, continuing through mid-day, and resuming near sundown (0600–1200, 1600–1800), from May–September 2003. Search teams consisted of 4 observers and 2–3 bird dogs with >5 years' experience searching for Montezuma quail. The observers were spaced 10 m apart and walked 5–8 m behind the bird dogs (Bishop and Hungerford 1965, Brown 1978). Bird dogs have proven useful in studies estimating Montezuma quail densities in this region of the state (Tapia et al. 2002). When a bird dog located quail, observers slowly approached the pointing dog to locate the birds. We searched for nests within a 50-m radius of each quail point and conducted subsequent nest searches in locations with frequent quail sightings. We geo-referenced all nests found using a Global Positioning System device (Garmin® GPS 12XL™; Garmin, Olathe, KS, USA). We recorded vegetation community (i.e., oak woodland, pine-oak woodland, or grassland), nesting substrate, date found, and elevation (meters above sea level) for each nest. In addition, we measured nest height and depth and the diameter and orientation (the 4 cardinal directions) of the nest entrance. If eggs were found, we recorded clutch size and egg mass, texture, color, and shape. We calculated relative abundance as the number of quail observed per km.

RESULTS

We walked 254 km, observed 324 quail, and located 6 nests. We observed quail at 14 of 17 study sites and mean (± standard deviation) abundance was 1.1 ± 0.9 quail/km (range: 0.0–3.1; Table 1). We found nests at 4 of 17 study sites (Table 2). Mean abundance of nests was 0.02 ± 0.06 nests/km (range: 0.0–0.2). We found nests during July and August. Nests were located at elevations ranging from 2,568–2,692 m above sea level. Four nests were found in grassland-oak woodland, and the remaining 2 were found in grassland. The grass *Muhlenbergia* spp. was the most common nesting substrate. All nests were shaped like a lab flask, with a small oval entrance increasing in space to form an internal conical chamber with its base larger than the entrance (Figure 2). Mean nest height and depth were 122.2 ± 7.7 mm and 195 ± 61.8 mm, respectively. The nest entrance of 5 of 6 nests had a southern orientation. The mean smallest and largest diameter of the nest entrance were 136.0 ± 37.7 mm and 154.3 ± 46.5 mm, respectively (Figure 2). Clutch size (n = 4) ranged from 2–16 eggs and mean egg mass was 9.9 ± 0.1 g. All eggs were smooth in texture, white in color, and oval shaped with an elongated apical point. Mean egg length and width were 32.2 ± 0.2 mm and 24.6 ± 0.2 mm, respectively (n = 13).

Although no eggs were found at Nest CC, we observed a female leaving the nest. When Nest SnF3 was located, we found a female incubating the eggs. We subsequently visited the nest site from afar once a week. Hatching occurred 21 days after the nest was found. We determined a clutch size of 16 eggs based on the number of eggshells in the nest. We were fortunate to be able to observe the emergence of the hatchlings. Chicks pecked out small holes in the eggshells, began producing vocalizations immediately upon emerging, and promptly left the nest. Nests Yeb1 and Yeb2 were located within 1.5 m of each other. We found only 2 eggs in Nest Yeb1. We speculate that egg laying was not yet complete at the time of discovery. We found an egg on bare ground on July 23 at Tito's Ranch study site (San Felipe del Progreso County). We searched for a nest within a 50-m radius without success.

Table 1. Number of Montezuma quail (*Cyrtonyx montezumae montezumae*) and nests observed on transects in the state of México, Mexico, 2003.

			Observations		Relative abundance	
County, site		Accumulated transect length (km)	No. of quail	No. of nests	Quail/km	Nests/km
Acambay						
	Arroyo Zarco	20	18	0	0.9	0.0
	Peña Ñadó	6	0	0	0.0	0.0
Aculco						
	Cerro del Comal	18	30	1	1.7	0.1
	El 120	20	12	0	0.6	0.0
	La Cofradía	40	69	0	1.7	0.0
	San Francisquito	16	35	3	2.2	0.2
Almoloya de Juárez						
	Ocoyotepec	12	15	0	1.3	0.0
	San Lorenzo Toxico	16	12	0	0.8	0.0
	Yebucivi	12	37	2	3.1	0.2
Atlacomulco						
	Diximoxi	6	5	0	0.8	0.0
Polotitlán						
	Casas Viejas	6	0	0	0.0	0.0
San Felipe del Progreso						
	Rio Hoyo Buenavista	20	11	0	0.6	0.0
	San José del Rincón	16	20	0	1.3	0.0
	Tito´s Ranch	24	53	0	2.2	0.0
Temascalcingo						
	Puente Andaró	6	0	0	0.0	0.0
	Santa María Canchesdá	10	4	0	0.4	0.0
Timilpan						
	Buenavista	6	3	0	0.5	0.0
Total		254	324	6	1.28	0.02

Table 2. Characteristics of Montezuma quail (*Cyrtonyx montezumae montezumae*) nests in the state of México, Mexico, 2003.

County, Site	Nest ID	Date found	Vegetation community	Elevation (m a.s.l.)	Nesting substrate (mm)		Nest entrance			Clutch size
							Diameter (mm)			
					Height	Depth	Smallest	Largest	Orientation	
Aculco										
Cerro del Comal	CC	31 Aug 2003	Grassland-oak woodland	2692	121	162	90	105	SW	0
San Francisquito	SnF1	20 Jul 2003	Grassland-oak woodland	2589	121	280	90	101	SE	11
	SnF2	30 Jul 2003	Grassland-oak woodland	2568	111	143	162	184	SW	12
	SnF3	31 Aug 2003	Grassland-oak woodland	2570	135	134	140	140	E	16
Yebucivi	Yeb1	05 Jul 2003	Grassland	2650	121	261	156	180	SW	2
	Yeb2	05 Jul 2003	Grassland	2650	124	190	178	216	SW	0

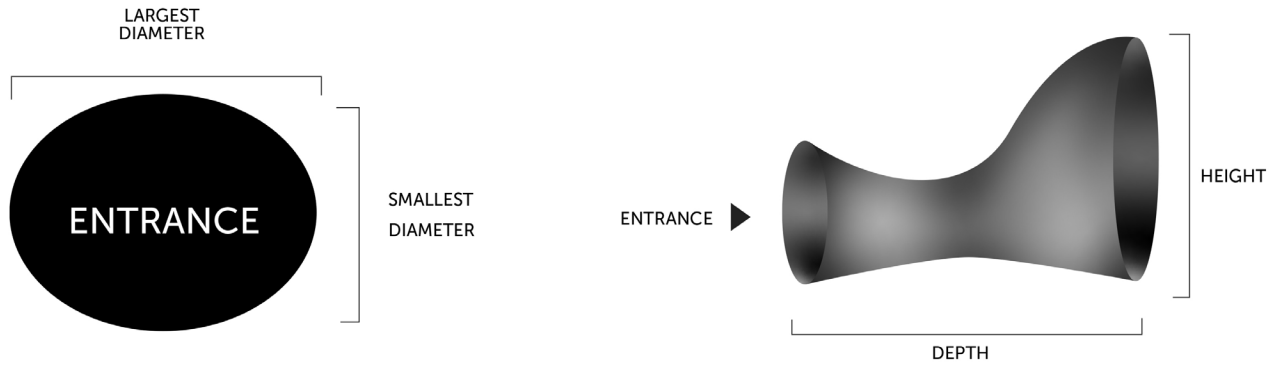

Fig. 2. Dimensions of Montezuma quail (*Cyrtonyx montezumae montezumae*) nests measured in the state of México, Mexico in 2003.

DISCUSSION

Our study adds basic descriptive information to a limited database of Montezuma quail nesting ecology. Data related to nest characteristics of Montezuma quail in central Mexico were not previously available. Thus, comparisons to other studies are limited.

We observed the first evidence of Montezuma quail forming pairs at the beginning of June. This timing differs slightly from pair formation documented during March–April in Arizona, USA (Wallmo 1954, Bishop 1964). However, the breeding phenology of Montezuma quail is closely tied to precipitation (Leopold and McCabe 1957). Thus, this slight difference in breeding phenology between studies could be due to variation in timing of precipitation. The nesting season (Jun–Aug) in our study corresponds to prior studies (Falvey 1936, Leopold and McCabe 1957).

The grass *Muhlenbergia* spp. was the most commonly used nesting substrate, probably due to its availability at our study sites. Nests were located within a narrow elevational range (2,568–2,692 m), and this grass is dominant at these elevations in our study area. Our general description of nests appears to be similar to prior research, but no other studies provide dimensions of Montezuma quail nests for comparisons.

The physical characteristics (mass, texture, color, and shape) of eggs for *C. montezumae montezumae* were similar to those reported for *C. montezumae mearnsi* in northwestern Chihuahua, Mexico (Bent 1932) and southeastern Arizona (Leopold and McCabe 1957). We observed that eggs had a smooth shell and were white. Bent (1932) noted that Montezuma quail eggs were smooth and somewhat glossy, ranging in color from pure white to creamy white. He described egg shape as short ovate or ovate pyriform.

Leopold and McCabe (1957) noted that Montezuma quail abundance in the pine-oak zone of Mexico was inversely related to the local abundance of livestock. Grazing removes important escape and nesting cover for Montezuma quail (Brown 1982). Our findings provide general support for the sensitivity of this species to grazing. All 6 nests that we found

were located in grassland and grassland-oak habitat in areas with little grazing. Because overgrazing is an occurrence widespread throughout the state of México (Herrera et al. 1998), grazing is likely to be limiting the distribution and abundance of Montezuma quail in this state.

MANAGEMENT IMPLICATIONS

Nest characteristics of Montezuma quail in central Mexico were previously not available. This information helps us understand in general the breeding biology and ecological function of this species (Mainwaring et al. 2014), but in particular its nesting habitat requirements. High-quality habitat for Montezuma quail depends on appropriate proportions of pine and oak woodland interspersed with low shrubs and perennial bunchgrasses (Hernández et al. 2019). We suggest cover provided by *Muhlenbergia* spp. is important for breeding habitat and nesting substrate. Current habitat for the species is at risk of deterioration and loss due to grazing, agriculture, and mismanagement of fire. In addition to conventional management practices (e.g., population and habitat monitoring, improvement, and protection), remote sensing imagery and spatial analysis within geographic information systems technology are critical to model potential habitat distribution, suitability, and management requirements. We suggest this study should be continued to 1) better understand the role of Montezuma quail nesting characteristics in this type of environment and the evolution of nesting morphology and its function (Mainwaring et al. 2014, Medina 2019, Perez et al. 2020) and 2) generate information on the species' persistence under current challenges from climate change.

ACKNOWLEDGMENTS

We thank the National Autonomous University of México (UNAM) and the Graduate College (CP) for field assistance and support. This project was funded by the National Council for Science and Technology of México (CONACyT).

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