2017

Ranges and Movements of Montezuma Quail in Southeast Arizona

Pedro M. Chavarria
New Mexico State University

Nova J. Silvy
Texas A&M University, College Station

Roel R. Lopez
Texas A&M University, College Station

Donald S. Davis
Texas A&M University, College Station

Angel Montoya
U.S. Fish and Wildlife Service

RANGES AND MOVEMENTS OF MONTEZUMA QUAIL IN SOUTHEAST ARIZONA

Pedro M. Chavarria
Department of Fish, Wildlife, and Conservation Ecology, New Mexico State University, Las Cruces, NM 88003, USA

Nova J. Silvy
Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843, USA

Roel R. Lopez
Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843, USA

Donald S. Davis
Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843, USA

Angel Montoya
U.S. Fish and Wildlife Service, Silver City, NM 88061, USA

ABSTRACT

Historical assumptions about Montezuma quail movements and home ranges at the population level are limited due to the lack of mark-recapture studies on this species from which solid conclusions can be derived. Such information is crucial for estimating population sizes, densities, and rate of emigration and immigration throughout the landscape. Our study examined home range size of 29 Montezuma quail and movements of 65 quail in southeast Arizona from 2008–2010. We used radio telemetry to follow radio-tagged birds in 3 study sites that varied in vegetation composition and topography. Mean home range size (MCP) was about was similar (51 ha) to the largest use area (50 ha) described in the literature for this species. The largest MCP home range estimate (206.7 ha) was far larger than what has been reported in the literature. Within a season, the largest mean maximum distance moved between 2 locations was 1,128.4 ± 619.5 m and the largest maximum linear distance between 2 locations for an individual was 2,375.5 m. Results from our research should help to address knowledge gaps about Montezuma quail home ranges and movements and provide a baseline to assist management of this species in the future.

Citation: Chavarria, P. M., N. J. Silvy, R. R. Lopez, D. S. Davis, and A. Montoya. 2017. Ranges and movements of Montezuma quail in Southeast Arizona. National Quail Symposium Proceedings 8:359–368.

Key words: *Cyrtonix montezumae, home* range, Mearn's quail, Montezuma quail, movements,

Understanding the home ranges and movements of wildlife populations is integral to their conservation. Ecological knowledge about the spatial-temporal dynamics associated with a species' life history, site use, and habitat requirements is especially important for management of game species in North America. Of North American gamebirds, much is known about northern bobwhite (*Colinus virginianus*) and scaled quail (*Callipepla squamata*), but few studies in the literature have evaluated the movements and home range of Montezuma quail (*Cyrtonyx montezumae mearnsi*). Knowledge gaps associated for this species have been in large part due to the difficulty of locating and monitoring wild populations of these secretive birds as well as a lack of more efficient and effective methods for their capture in mark-and-release studies. Much of what is known about Montezuma quail ranges in the literature is asserted from anecdotal evidence and casual field observations of wild populations.

Claims about abundances and population densities in a local area can be derived with some certainty through the dog-assisted flush-count method, but any other conclusions about covey home ranges lack considerable accuracy if those populations are not monitored through a mark-recapture method—of which radio-telemetry provides one such means. Of the few radiotelemetry studies attempted for this species, only Stromberg (1990) was successful in estimating, to some extent, the home range size of this species. Stromberg's (1990) limited sample size, however, reduces the power from which conclusions can be derived and hypotheses tested regarding this species' movements and home ranges throughout the landscape. A need exists, therefore, to address this knowledge gap to resolve management and conservation

[1]*Email: pedro.chavarria@nnmc.edu*

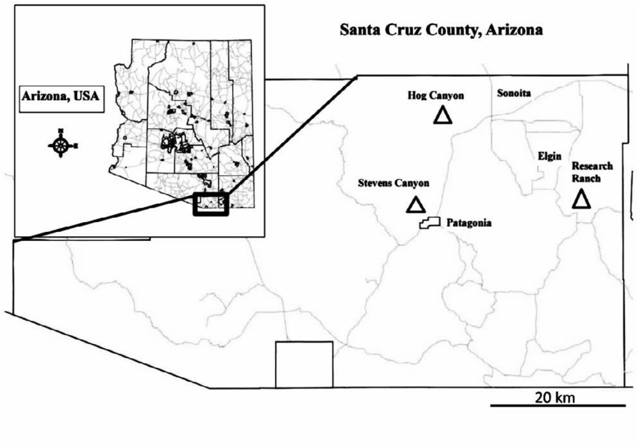

Fig. 1. Map of Montezuma quail study sites in Santa Cruz County, Arizona, 2007– 2010.

objectives for this species' distribution across the southeast Arizona region. Our goal in this study was to improve upon previous attempts at monitoring this species through radiotelemetry and to evaluate movements and seasonal ranges of Montezuma quail (Chavarria 2013). Our objectives were to verify the validity about previous conclusions made about this species' ranges and from comparison to our findings, provide meaningful conclusions, which could serve to facilitate the conservation and management of this species in the future.

METHODS

Study Site Selection

We conducted our study from 1 January 2008–31 May 2010 at 3 sites in southeast Arizona (Fig. 1), separated by 12.2 to 25.8 km from one another, to evaluate ranges and movements of spatially independent (quail did not move between sites) subpopulations across the landscape (Chavarria 2013). Diversity of habitat variables, particularly major vegetation types and topography, and how these could potentially affect home ranges and movements, were accounted for in study site selection. Of these sites, two were located in public lands managed by the Coronado National Forest (CNF). Steven's Canyon located along State Route 82 in Patagonia, Santa Cruz County and Hog Canyon along State Route 82, located closer to Sonoita, Santa Cruz County, were both within CNF boundaries. Hunting of Montezuma quail was permissible at both Steven's Canyon and Hog Canyon under legal Arizona Game and Fish (AZGF) permit, so those served as experimental treatments for evaluating potential impacts of hunting on their home ranges and their movements. The third site was at the Appleton-Whittell Research Ranch (AWRR) in Elgin, Santa Cruz County. AWRR was private land managed with an emphasis on research on native grassland communities in southeast Arizona. It was jointly managed by the National Audubon Society and Bureau of Land Management. AWRR was considered a "sanctuary" and, as such, did not permit legalized hunting. It served as a control site for evaluating home ranges and movements independent of impacts associated to hunting, grazing, and other sources of anthropogenic pressures realized in public lands across southeast Arizona.

Madrean Evergreen Woodland and Montane Meadow dominated Hog Canyon for vegetation and Caralampi gravelly sandy loam (22.2%) soils (Natural Resources Conservation Service [NRCS] 2012). Steven's Canyon also was dominated (52.8%) by Caralampi gravelly sandy loam soils (NRCS 2012) and had similar vegetative characteristics to Hog Canyon, but with a reduced over story canopy layer; Madrean Evergreen Woodland was sparser and intermixed with Desert Scrub mid story species (i.e., *Acacia* sp.; mesquite, *Prosopis* sp.). The AWRR consisted mainly of Plains and Great Basin Grasslands dominated by big sacaton (*Sporobolus wrightii*) bottomlands along Turkey Creek and Madrean Evergreen Woodlands sparsely dispersed among the sloping hills (Stromberg 1990), but were generally found in greater abundance and densities along the southern and eastern borders that neighbor the Coronado

National Forest (CNF). Dominant soils (52.5%) at AWRR consist of White House gravelly loam (NRCS 2012). Grazing of cattle was permitted seasonally at Hog Canyon and Stevens Canyon and was administrated by the CNF. Climate data from the nearest long-term weather station (Canelo, Arizona) indicated mean temperatures of 22.6^0 C in June, the hottest month, and mean temperature of 6.3^0 C in January, the coldest month, from 1981to 2010 for this region (Western Regional Climate Center 2012).

Capture and Handling

We captured quail from 1 January to 31 May 2008 in Stevens Canyon, from 6 December 2008 to 31 May 2009 in Hog Canyon, and from 12 February 2009 to 11 March 2010 on AWRR. The primary means of capturing Montezuma quail was by using large hoop-nets (Brown 1976) or throw-nets at night, when Montezuma quail were on their roosts. This required assistance of trained dogs, which would located birds by scent and hold point until the quail were cautiously approached and captured by researchers (Chavarria et al. 2012). A lightweight and transportable FLIR (Forward Looking Infra-Red) camera (FLIR Systems, North Billerica, Massachusetts) was sometimes used to narrow-down the location of quail by tracking their heat signatures after a dog had gone on point (Chavarria et al. 2012). Wire-cage funnel traps, baited with scratch seed, also were used with limited success. Other adaptations of audio (i.e., recorded callbacks) and visual lures (i.e., taxidermy mounts) also were sometimes used in conjunction with these funnel traps.

Captured birds were placed into individual cloth sacks, transported in a small, mobile field holding pen at the trap location, and later fitted with numbered aluminum leg bands and a mortality-sensitive, backpack radio-transmitter (about 5–9 g, less than 5% of bodyweight; 150.000-151.000 MHz; Wildlife Materials, Murphysboro, Illinois, USA; Telemetry Solutions, Concord, California, USA). We recorded gender and age for each individual. We determined approximate age of birds by examining fully developed presence of adult plumage on the facial feathers as well as the primary coverts using methods developed by previous researchers (Leopold and McCabe 1957, Stromberg 1990). Adult birds also were referenced as After-Hatch- Year (AHY) and juveniles and sub-adults were referenced as Hatch-Year (HY).

Most birds caught in night-trapping sessions were held overnight in a holding pen at the research station in Patagonia, Arizona or at the Appleton-Whittell Research Ranch and released before daybreak the following morning. Birds ($n = 5$) that were injured during the course of trapping were kept for 1–2 days in a holding pen at the research station and allowed time to recuperate and then relocated near their original covey. If a bird was non-releasable due to serious injury ($n = 2$) after 1–2 days, they were taken to a wildlife rehabilitation center (Liberty Wildlife Rehabilitation, Prescott, Arizona, USA) and treated for injuries. If treatment at the rehabilitation center was successful, birds ($n = 1$) were radio-tagged once again and released back into the wild near their original covey. If not ($n = 1$), the wildlife rehabilitation center became responsible for the care and oversight of non-releasable birds.

Radiotelemetry

We intended to fit at least 16 transmitters stratified by age class (i.e., juvenile or adult) and gender, among 3–4 coveys at each study site. This would allow for comparisons of home ranges and movements within these different classes and provide a moderate sample size for statistical evaluation. A 3-element Yagi antenna and ATS receiver (Advanced Telemetry Systems, Isanti, Minnesota, USA) were used to track individuals by vehicle from roads and off-road by foot.

Radio-tagged individuals, and the coveys with which they associated, were generally monitored at least 3–5 times a week at random times stratified by day (0700–1900 hours), when quail were most active, or night (1901–0659 hours), when quail were primarily on their roosts. An exception to this was the 2010 season where only the AWRR site were each quail was relocated each day at a random stratified times. All data collected, including quail sightings and quail sign (i.e., tracks, nesting sites, roosts, foraging sites), was entered into a database. Exact times and locations of visually relocated birds were georeferenced with a Garmin Legend GPS unit using Universal Transverse Mercator (UTM) coordinates in the NAD83 datum. Software programs ArcView 3.2a GIS (ESRI 2000) and QGIS (Quantum GIS Development Team 2011) were used to produce maps of location data using available 1:24,000 topographic maps [7.5-minute quadrangle, United States Geological Survey (USGS), Denver, Colorado, USA] and other available GIS layers.

Triangulation of radio-tagged individuals was conducted 3–5 times per week to estimate the locations of birds when they could not be visually relocated. Flush relocations and visual re- sightings were conducted 1–2 times per month prior to the breeding and nesting season to determine covey sizes and potential nest sites. Triangulation was conducted more often than flushing and walks-ins to reduce impact of field tracking as a possible means of disturbing movements of radio-tagged individuals and their coveys. At least 3 location bearings, but generally 4–5, spaced apart about 5 minutes in interval between subsequent observations, were used to derive estimates of a position during triangulation. When fewer ($n < 4$) locations were taken, we optimized bearing angles, where possible, to be 120 degrees from one another to reduce error estimating a location (Saltz 1994). The Maximum Likelihood Estimator (MLE; Lenth 1981) function in software LOAS 4.0.3.7 (2010) was used to estimate locations of individuals for which triangulated positions were collected. The MLE function was set to estimate a location with an accuracy of 1.0×10^{-6}, using a total of 60 iterations. Where few bearings were provided and accurate estimates could not be derived with the MLE, we set program LOAS to automatically derive location estimates using the Harmonic Mean (HM) or Best Biangulation (BB) functions. The HM function is "far less sensitive to outliers than either the arithmetic mean or the geometric mean, but it is still a variation of the classical method of determining location of a signal" (LOAS 2000). The BB function is used automatically by LOAS when there are only two bearings available (LOAS 2000).

Home Range Analysis

Montezuma quail home ranges were estimated using both the fixed kernel range (Worton 1989) estimator and the minimum convex polygon (MCP) method (Jennrich and Turner 1969) function provided by the Home Range Extension (Rodgers and Carr 1998) in ArcView 3.2a (Environmental Systems Research Institute 2000). We determined the number of locations needed (18 locations) to describe a home range by graphing home range area by number of relocations. However, for Stevens Canyon in 2008, we used a minimum of seven locations to determine home range size. This was done to compare MCP home ranges as determined by Stromberg (1990) who had a maximum of seven (range 4–7) relocations during his study. We used both MCP and fixed kernel methods to be able to compare with previous Montezuma quail MCP ranges (i.e., Stromberg 1990) and to provide fixed kernel range data for future studies on Montezuma quail. For the MCP method, we used 100% of the points to estimate the area (ha) used. Using the fixed kernel range method, we estimated the total range (ha) utilized (95% probability area, FK95) and core areas (50% and 25% probability areas, FK50 and FK25) for each individual. The fixed kernel estimator allows evaluation of utilization distributions (UD) rather than just simple home range outlines (Kernohan et al. 2001) such as those produced by the minimum convex polygon method (Jennrich and Turner 1969). It has advantages over the adaptive kernel method in that it is less likely to overestimate a home range area (Powell 2000) and it is generally supported as the best method currently available (Seaman and Powell 1996;

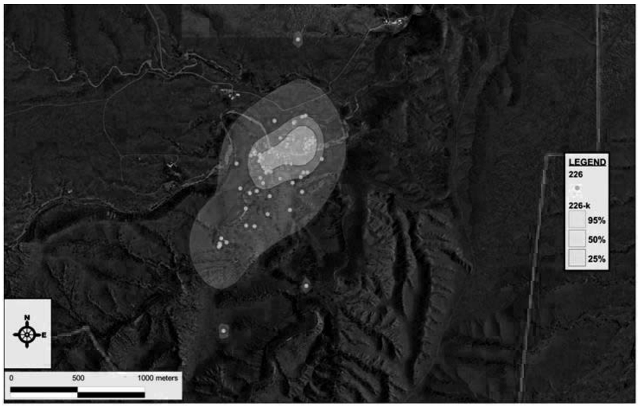

Fig. 2. Montezuma quail home range for HY female #226 showing 25%, 50%, and 95% Kernel utilization distributions at the Appleton-Whittell Research Ranch 2009.

Powell 2000; Kernohan et al. 2001). Home ranges (ha) and core areas (ha) were calculated for each individual and evaluated by study site, sex, age-class and season. Seasons were defined by the years in which field research was conducted at each individual site; these were generally from January–August each year, with some individuals surviving through December. Ranges for all radio-marked individuals, using FK25, FK50, and FK95 UD distributions, as seen in an example (Fig. 2), were plotted in ArcView 3.2a and QGIS.

Utilization distributions were derived using software JMP (SAS Institute Inc. 2007) and include mean hectares, range of hectares, mean days tracked, range of days tracked, mean number of locations, and range of number of locations for all individuals, as well as for the different age and sex classes, for each study site. The Adehabitat analysis package (Calenge 2006) for software R (R Development Core Team 2005) was used to evaluate other seasonal movement statistics including the following: mean maximum distance moved, maximum linear distance moved by an individual, the grand mean of distance moved between observations for all individuals, and the mean distance moved between first and last observation for all individuals.

RESULTS

Montezuma Quail Home Ranges

Stevens Canyon.—Home ranges and utilization distributions were evaluated for Stevens Canyon only for the 2008 field season (Tables 1 and 2). We tracked 10 individuals for a mean

31.1 ± 19.0 days, and mean 5.4 ± 2.3 for number of locations (Table 1Home ranges using the MCP method produced small mean home range size (24.6 ± 22.9 ha) for all quail at this site with the average MCP home range size being larger for males than females (Table 2). The mean FK50 UD (28.7 ± 20.9) for all quail was similar to

Table 1. Demographics of radio-marked Montezuma quail radio tracked in southeastern Arizona, 2008–2010. Ages: AHY = After-hatch-year (Adult), HY = Hatch-year (Juvenile).

Study area	Sex	Age	N	Locations (mean ± *SD*)	Locations range	Days (mean ± *SD*)	Days range
Stevens Canyon 2008	Male	AHY	4	5.3 ± 3.3	3–10	34.0 ± 23.3	6–60
		HY	0	-	-	-	-
	Female	AHY	5	5.4 ± 1.8	3–7	30.8 ± 19.3	16–60
		HY	1	6	6	21	21
	Total		10	5.4 ± 2.3	3–10	31.1 ± 19.0	6–60
Hog Canyon 2009	Male	AHY	1	5	5	34	34
		HY	7	23.9 ± 26.0	3–69	61.1 ± 49.9	7–145
	Female	AHY	1	53	53	97	97
		HY	3	27.3 ± 32.3	3–64	74.7 ± 61.3	10–132
	Total		12	25.6 ± 25.8	3–69	65.3 ± 47.5	7–145
Appleton- Whittell Research Ranch							
2009	Male	AHY	4	22.8 ± 23.0	8–57	60.0 ± 61.2	13–150
		HY	8	29.9 ± 23.6	6–63	57.6 ± 39.7	8–112
	Female	AHY	4	36.3 ± 17.9	14–57	112.0 ± 52.2	70–185
		HY	8	34.1 ± 31.6	4–92	78.9 ± 72.8	8–211
	Total		24	31.2 ± 24.6	4–92	74.2 ± 57.7	8–211
2010	Male	AHY	3	7.3 ± 2.1	5–9	9.0 ± 5.0	4–14
		HY	7	10.4 ± 5.7	7–22	10.4 ± 3.7	7–18
	Female	AHY	5	17.0 ± 10.9	10–36	20.0 ± 13.8	11–44
		HY	4	14.0 ± 4.9	10–21	13.8 ± 3.6	11–19
	Total		19	12.4 ± 7.3	5–36	13.4 ± 8.4	4–44
All sites combined	Male	AHY	12	11.6 ± 14.7	3–57	34.0 ± 23.3	6–150
		HY	22	21.8 ± 21.4	3–69	43.7 ± 42.2	4–145
	Female	AHY	15	20.9 ± 18.3	10–57	53.3 ± 49.4	11–185
		HY	16	26.0 ± 23.0	3–92	58.2 ± 62.3	8–211
	Total		65	20.7 ± 21.2	3–92	48.2 ± 48.7	4–211

Table 2. Home ranges (ha; 100% minimum convex polygon [MCP], 50% fixed kernel distribution [FK50], and 95% fixed kernel distribution [FK95]) for radio-marked Montezuma quail in southeastern Arizona, 2008–2010. Ages: AHY = After-hatch-year (Adult), HY = Hatch-year (Juvenile).

				MCP		FK50		FK95	
Study area	Sex	Age	N	Mean ± *SD*	Range	Mean ± *SD*	Range	Mean ± *SD*	Range
Stevens Canyon[a] 2008	Male	AHY	1	49.3	49.3	15.7	15.7	183.6	183.5
		HY	0	-	-	-	-	-	-
	Female	AHY	2	12.2 ± 11.6	4.0–20.4	19.7 ± 19.6	5.8–33.5	95.5 ± 100.6	24.3–166.6
		HY	0	-	-	-	-	-	-
	Total	All	3	24.6 ± 22.9	4.0–49.3	28.7 ± 20.9	5.8–46.7	124.8 ± 87.5	24.3–183.6
Hog Canyon 2009	Male	AHY	0	-	-	-	-	-	-
		HY	3	46.3 ± 37.2	11.3–97.7	3.7 ± 2.2	1.5–5.8	71.0 ± 48.1	22.0–136.4
	Female	AHY	1	24.4	24.4	6.5	6.5	37.0	37.0
		HY	2	94.1 ± 48.8	45.3–142.9	9.4 ± 1.2	8.5–10.3	136.5 ± 5.6	131.0–136.5
	Total	All	6	58.6 ± 51.1	11.3–142.9	6.1 ± 3.1	1.5–10.3	87.2 ± 55.1	22.0–126.5
Appleton-Whittell Research Ranch 2009	Male	AHY	2	106.5 ±141.7	6.3–206.7	28.1 ± 33.6	4.4–51.9	153.6 ± 188.6	20.3–287.0
		HY	5	54.1 ± 41.9	11.7–98.3	27.3 ± 21.1	7.5–52.5	117.8 ± 90.1	32.4–219.2
	Female	AHY	3	41.8 ± 15.1	25.5–55.3	13.5 ± 14.5	5.0–30.3	66.3 ± 42.2	32.4–115.3
		HY	6	52.6 ± 56.1	5.6–150.2	33.0 ± 22.6	5.4–62.4	84.0 ± 131.0	19.1–228.9
	Total	All	16	64.2 ± 56.8	5.6–206.7	27.4 ± 20.7	5.0 ± 62.4	118.9 ± 88.3	19.1–287
2010	Male	AHY	0	-	-	-	-	-	-
		HY	1	19.0	19.0	5.1	5.1	33.1	33.1
	Female	AHY	2	6.2 ± 0.4	5.9–6.5	2.7 ± 0.2	2.6–2.9	14.4 ± 1.3	14.4–15.3
		HY	1	3.3	3.3	1.8	1.8	7.6	7.6
	Total	All	4	8.6 ± 7.0	3.3–19.0	3.1 ± 1.4	1.8–5.0	17.4 ± 11.0	7.6–33.1
All sites combined	Male	AHY	3	87.4 ± 105.5	6.3–206.7	24.0 ± 24.8	4.4–51.9	163.6 ± 134.5	20.0–287.0
		HY	9	47.6 ± 36.8	11.3–98.3	17.0 ± 19.3	1.5–52.5	92.8 ± 75.2	22.0–219.2
	Female	AHY	8	23.3 ± 18.7	4.0–55.3	13.7 ± 13.2	2.6–30.3	57.0 ± 54.7	14.4–166.6
		HY	9	56.3 ± 54.6	3.3–150.2	24.5 ± 22.1	1.8–62.4	87.2 ± 110.2	7.6–228.9
	Total	All	29	51.3 ± 51.8	3.3–206.7	19.8 ± 19.6	1.5–62.4	99.0 ±81.0	7.6–287.0

[a]For Stevens Canyon (2008), we used a minimum of 7 radio-telemetry locations to determine home ranges, but in all other study areas we use a minimum of 18 radio-telemetry locations to determine home ranges.

that of the MCP for all quail, but was the mean FK95 UD (125.8 ± 87.6) for all quail at this site were about 5.1 times larger than the mean MCP for this site (Table 2). The largest estimated home range for an individual using the MCP method was 49.3 ha and 183.6 ha using the FK95 UD method. Home ranges also were evaluated for different gender and age classes at Stevens Canyon (Table 2). Using the MCP method, the AHY male a larger home range size (49.3 ha) than the mean home range sizes (12.2 ha) for the two AHY females (Table 1). When using the fixed kernel method, both the FK50 and FK95 UDs ranges were larger for the male than the two females (Table 2). A comparison in mean home range size could not be made between HY females and HY males because no HY males were captured and marked and not enough location were obtained for HY females to calculate a home range.

Hog Canyon.—Home ranges and utilization distributions were evaluated for Hog Canyon only for the 2009 field season (Tables 1 and 2). We tracked 12 individuals for a mean of 65.3 ±

47.5 days and a mean 25.6 ± 25.8 for number of locations (Table 1). Home ranges using the MCP method produced moderate home range size (58.6 ± 51.1 ha) for the 6 quail with 18 or more locations at this site. The average MCP home range size was larger for HY females (94.1 ± 48.8 ha) than HY males (46.3 ± 37.2 ha) and both larger than the home range (24.4 ha) of the AHY female (Table 2). The FK50 and FK95 means were 9.6 times smaller and 1.5 times larger, respectively, than mean MCP ranges for quail at this site (Table 2). The largest estimated home range for an individual using the MCP method was 142.9 ha and 136.5 ha using the FK95 UD method. With the FK50 method, females of all age classes had substantially larger mean home range sizes when compared to HY males (Table 2).

Research Ranch: 2009.—Home ranges and utilization distributions were evaluated separately for the AWRR for the 2009 season (Tables 1 and 2). We tracked 24 individuals for a mean of 74.2 ± 57.7 days and a mean 31.2 ± 24.6 for number of locations (Table 1). Home ranges using the MCP method produced a moderate home range size (64.2 ± 56.8 ha) for quail with 18 or more locations at this site with the average MCP home range size being larger for AHY males (106.5 ± 141.7) than AHY females (41.1 ± 15.1; Table 2). The FK50 means were lower for all age and gender classes when compared to MCP (Table 2). FK95 means were larger within all age classes when compared to MCP. The largest estimated home range for an individual using the MCP method was 206.7 ha and 287.0 ha when using the FK95 UD method.

Table 3. Movement distances (meters ± *SD*) between successive observations for radio-marked Montezuma quail in southeast Arizona, 2008–2009. AHY = after hatch year (adult), HY= hatch year (juvenile). Statistics include number (N) of individuals, number of locations (mean ± *SD*, range), maximum distance moved, maximum linear distance, average distance moved between observations (mean ± *SD*), and distance between first and last observation (mean ± *SD*).

	Study site				
	Stevens Canyon	Hog Canyon	Appleton-Whittell Research Ranch		
Year	2008	2009	2009	2010	All Sites
N Individuals	10	12	24	19	65
N Locations (mean, range)	5.4 (3–10)	25.6 (3–69)	31.2 (4–92)	12.4 (5–36)	20.7 (3–92)
Maximum distance moved (mean)	678.4 ± 485.5	1,068.9 ± 741.2	1,128.4 ± 619.5	445.0 ± 179.3	848.5 ± 604.9
Maximum linear distance (individual)	1,339.6	2,375.5	2,250.4	894.8	2,375.5
Average distance moved between observations (mean)	302.8 ± 189.1	278.8 ± 106.0	239.2 ± 246.8	156.0 ± 61.8	232.0 ± 181.3
Distance between first and last observation (mean)	387.9 ± 297.5	373.3 ± 226.5	676.8 ± 533.7	227.4 ± 131.8	445.0 ± 405.2

Home ranges were evaluated for different gender and age classes (Table 2) with mean home range size for HY age classes (54.1 ± 41.9 ha and 52.6 ± 56.1 ha for males and females, respectively) were similar to AHY female ranges (41.8 ±15.1 ha), but about half the size of mean AHY male mean home range size (106.5 ± 141.7 ha; Table 2). In the FK50 estimates mean ranges were similar within all but AHY females which had a smaller mean home range size that all other. FK95 home range estimates had males with larger mean ranges sizes than females (Table 2).

Research Ranch: 2010.—Home ranges and utilization distributions were evaluated separately for the AWRR for the 2010 season (Tables 1 and 2). Nineteen individuals were tracked for a mean 13.4 ± 8.4 days and a mean 12.4 ± 7.3 for number of locations (Table 1). Home ranges using the MCP method produced small home range sizes (8.6 ± 7.0 ha) for the 4l quail at this site for which we had at least 18 locations, with a HY male having a larger home range size (19.0 ha) than the 2 AHY females (6.2 ± 0.4 ha) and the HY female (3.3 ha; Table 2). The FK50 means were smaller than those derived using the MCP method for all age and gender classes (Table 2). However, the FK95 mean home range estimates were larger when compared to MCP mean home range size (Table 2). The largest estimated home range for an individual using the MCP method was 19.0 ha and 33.1 ha using the FK95 UD method.

All Sites Combined: 2008–2010.—Home ranges and utilization distributions were evaluated for all site combined (Tables 1 and 2). We tracked 65 individuals for a mean of 48.2 ± 48.7 days and a mean 20.7 ± 22.2 for number of locations (Table 1). Home ranges using the MCP method produced a mean home range size (51.3 ± 51.8 ha) for 29 quail on the three study sites. The average MCP home range size was larger for AHY males (87.4 ± 105.5 ha) than HY males (47.6 ± 36.8 ha), AHY females (23.3 ± 18.5 ha), and HY females (56.3 ± 54.6 ha; Table 2). The FK50 and FK95 means were 2.6 times smaller and 1.9 times larger, respectively, than mean MCP ranges for quail at this site (Table 2).

Montezuma Quail Movements

Stevens Canyon.—Movement distances were calculated for 10 individual quail at Stevens Canyon for the 2008 season (Table 3). The mean maximum distance moved by all quail at this site was 678.4 ± 485.5 m. The maximum linear distance between two locations within the home range of an individual at this site was 1,339.6 m. The grand mean for average distance moved between successive observations for all birds at this site was 302.8 ± 189.1 m. Lastly, the mean distance between first and last observation was 387.9 ± 297.5 m. Movement statistics also were evaluated by gender and age class for the 2008 season (Table 4). The mean maximum distance moved was larger for females (AHY = 771.3 ± 519.1 m and HY = 867.6 m) than males (AHY = 515 ± 534.8 m), and the HY female had the largest mean. Both

Table 4. Movement distances (meters ± *SD*) by age class and gender between successive observations for radio-marked Montezuma quail at Stevens Canyon, southeast Arizona, 2008. AHY = after hatch year (adult), HY= hatch year (juvenile). Statistics include number (N) of individuals, number of locations (mean ± *SD*, range), maximum distance moved, maximum linear distance, average distance moved between observations (mean ± *SD*), and distance between first and last observation (mean ± *SD*).

Age Class	AHY Female	HY Female	AHY Male	HY Male	All quail
N Individuals	5	1	4	0	10
N Locations (mean, range)	5.4 (3–7)	6 (6)	5.3 (3–10)	-	5.4 (3–10)
Maximum distance moved (mean)	771.3 ± 519.1	867.6	515.1 ± 534.8	-	678.5 ± 485.5
Maximum linear distance (individual)	1,339.6	867.6	1,316.4	-	1,339.6
Average distance moved between observations (mean)	328.7 ± 196.8	305.2	269.8 ± 230.4	-	302.8 ± 189.1
Distance between first and last observation (mean)	388.8 ± 357.8	640.6	323.6 ± 260.7	-	387.9 ± 297.5

Table 5. Movement distances (meters ± *SD*) by age class and gender between successive observations for radio-marked Montezuma quail at Hog Canyon, southeast Arizona, 2009. AHY = after hatch year (adult), HY= hatch year (juvenile). Statistics include number (N) of individuals, number of locations (mean ± *SD*, range), maximum distance moved, maximum linear distance, average distance moved between observations (mean ± *SD*), and distance between first and last observation (mean ± *SD*).

Age Class	AHY Female	HY Female	AHY Male	HY Male	All Quail
N Individuals	1	3	1	7	12
N Locations (mean, range)	53 (53)	27.3 (3–64)	5 (5)	23.86 (3–69)	25.2 (3–69)
Maximum distance moved (mean)	754.3	1,531.4 ± 908.1	312.9	1,023.6 ± 714.9	1,068.9 ± 741.2
Maximum linear distance (individual)	754.3	2,375.5	312.9	2043.9	2043.9
Average distance moved between observations (mean)	163.8	377.9 ± 69.9	140.0	272.5 ± 92.8	278.8 ± 106.0
Distance between first and last observation (mean)	268.7	362.4 ± 22.0	259.8	409.2 ± 297.3	373.3 ± 226.5

the AHY females (1,339.6 m) and AHY males (1,316.4 m) had similar maximum linear distance moved, but this was lower for the only HY female (867.6 m) observed (Table 4). The average distance moved between observations was similar between AHY females (328.7 ± 196.8 m) and AHY males (269.8 ± 230.4 m; Table 4). No HY males were monitored so those movement data are unavailable for that age-gender class.

Hog Canyon.—Movement distances were calculated for 12 individuals at Hog Canyon for the 2009 season (Table 3). The mean maximum distance moved by quail at this site was 1,068.9 ± 741.2 m (Table 3). The maximum linear distance between two locations within the home range of an individual at this site was 2,375.5 m. The grand mean for average distance moved between successive observations for all birds at this site was 278.8 ± 106.0 m. Lastly, the mean distance moved between first and last observation was 373.3 ± 226.5 m. Movement data also were evaluated by gender and age class for the 2009 season (Table 5). The mean maximum distance moved was larger for HY males (1,023 ± 714.9 m) and HY females (1,531.5 ± 908.1 m) than for AHY males (312.9 m) and AHY females (754.3 m; Table 5). Maximum linear distance moved also was considerably larger for HY males and females than AHY males and females, with the largest distance moved (2,375.5 m) pertaining to a HY female (Table 5). The average distance moved between observations also was larger for HY males and females than AHY males and females (Table 5).

Research Ranch: 2009.—Movement distances were calculated separately for the 2009 and 2010 seasons at the AWRR. Movements for 24 individuals were evaluated for the 2009 season (Table 3). In 2009, the mean maximum distance moved by all quail at this site was 1,128.4 ± 619.5 m. The maximum linear distance between two locations within the home range of an individual at this site was 2,250.4 m. The grand mean for average distance moved between successive observations for all quail at this site was 239.2 ± 246.8 m. Lastly, the mean distance moved between first and last observation was 676.8 ± 533.7. Gender and age class also evaluated movement distances for the 2009 season (Table 6). The mean maximum distance moved was larger for females than males when comparing within age classes (Table 6). Within gender, means were larger in AHY females (1,336.7 ± 217.7 m) than HY females (1,175.6± 841.7 m) and larger in HY males (1,070.2 ± 422.2 m) than AHY males (942.1 ± 840.9 m).

Maximum linear distance moved by an individual was larger in HY females (2,250.4 m), followed by AHY males (2,188.3 m). The average distance moved between observations also was larger in HY females (214.6 ± 22.1 m) and second largest in HY males (316.6 ± 420.2 m).

Research Ranch: 2010.—Movement statistics for 19 individuals were evaluated for the 2010 season (Table 3). In 2010, the mean maximum distance moved by all quail at this site was 445.0 ± 179.3 m. The maximum linear distance between two locations within the home range of an individual at this site was 894.8 m. The grand mean for

Table 6. Movement distances (meters ± *SD*) by age class and gender between successive observations for radio- marked Montezuma quail at the Research Ranch, southeast Arizona, 2009. AHY = after hatch year (adult), HY = hatch year (juvenile). Statistics include number (N) of individuals, number of locations (mean ± *SD*, range), maximum distance moved, maximum linear distance, average distance moved between observations (mean ± *SD*), and distance between first and last observation (mean ± *SD*).

Age Class	AHY Female	HY Female	AHY Male	HY Male	All Quail
N Individuals	4	8	4	8	24
N Locations (mean, range)	36.3 (14–57)	34.1 (4–92)	22.8 (8–57)	29.9 (6–63)	31.2 (6–92)
Maximum distance moved (mean)	1,336.7 ± 216.7	1,175.6 ± 841.7	942.1 ± 840.9	1,070.2 ± 422.2	1,128.4 ± 619.5
Maximum linear distance (individual)	1,582.8	2,250.4	2,188.3	1,546.3	2,250.4
Average distance moved between observations (mean)	198.7 ± 22.1	214.6 ± 107.1	174.3 ± 48.6	316.5 ± 420.2	239.2 ± 246.8
Distance between first and last observation (mean)	535.8 ± 398.8	803.3 ± 702.0	510.3 ± 549.1	704.2 ± 446.7	676.9 ± 533.8

Table 7. Movement distances (meters ± *SD*) by age class and gender between successive observations for radio- marked Montezuma quail at the Research Ranch, southeast Arizona, 2010. AHY = after hatch year (adult), HY = hatch year (juvenile). Statistics include number (N) of individuals, number of locations (mean ± *SD*, range), maximum distance moved, maximum linear distance, average distance moved between observations (mean ± *SD*), and distance between first and last observation (mean ± *SD*).

Age Class	AHY Female	HY Female	AHY Male	HY Male	All Quail
N Individuals	5	4	3	7	19
N Locations (mean, range)	17 (10–36)	14 (10–21)	7.3 (5–9)	10.4 (7–22)	12.4 (5-36)
Maximum distance moved (mean)	425.5 ± 109.4	487.1 ± 228.5	450.8 ± 98.6	432.3 ± 239.6	445.0 ± 179.3
Maximum linear distance (individual)	486.1	758.1	542.6	894.8	894.8
Average distance moved between observations (mean)	135.7 ± 50.4	157.9 ± 47.5	230.7 ± 96.7	137.3 ± 44.5	156.0 ± 61.8
Distance between first and last observation (mean)	201.2 ± 123.6	278.1 ± 248.4	272.9 ± 26.7	197.7 ± 80.3	227.4 ± 131.7

average distance moved between successive observations for all birds at this site was 156.0 ± 61.8 m. Lastly, the mean distance moved between first and last observation was 227.4 ± 131.8 m. Movement statistics also were evaluated by gender and age class for the 2010 season (Table 7). The mean maximum distance moved was similar (range = 425.5 ± 109.4 m for AHY females to 487.1± 228.5 m for HY females) amongst all age and gender classes, but larger for HY females (Table 7). Maximum linear distance moved by an individual was larger for HY males (894.8 m) and second larger for HY females (758.1 m). The average distance moved between observations was similar for AHY females (135.7± 50.4 m), HY females (157.9± 47.5 m), and HY males (137.3± 44.5 m), but larger for AHY males (230, 7± 96.7 m).

All Sites Combined: 2008–2010.—Movement distances were calculated for 65 individuals for all sites combined (Table 3). The mean maximum distance moved by quail at all sites was 848.5 ± 604.7 m (Table 3). The maximum linear distance between two locations within the home range of an individual at this site was 2,375.5 m. The grand mean for average distance moved between successive observations for all birds was 232.0 ± 181.3 m. Lastly, the mean distance moved between first and last observation was 445.0 ± 405.2 m. Movement distances also were evaluated by gender and age class for all sites combined (Table 8). The mean maximum distance moved was larger for HY females (1,050.9 ± 769.7 m) than for HY males (852.4 ± 555.5 m), AHY males (624.5± 575.1 m) and AHY females (787.7± 474.6 m; Table 5). Maximum linear distance moved also was similar for HY males, AHY females and AHY males with the largest distance moved (2,375.5 m) pertaining to a HY female (Table 8). The average distance moved between observations was largest (245.5± 260.7 m) for HY males (Table 8).

DISCUSSION

Ranges (n = 29) and movement distances for 65 Montezuma quail were determined in southeast Arizona from 2008–2010. We encountered problems with radio-transmitter failure at the start of the 3-year study at Stevens Canyon, which limited the number of locations recorded for individual quail. At this site only we used a minimum of 7 locations to determine home range size, for without doing so we would not have been able to calculate home ranges for quail at this site. We justify doing so for this site because Stromberg (1990) used a maximum of seven locations to determine home range size during his study. For the other two sites, we used a minimum of 18 locations to determine home ranges. We calculated both MCP and fixed kernel home ranges for two reasons. First, we needed MCP home ranges data to compare to the only other study (Stromberg 1990) on home ranges for this species. In addition, we calculated 50% and 95% fixed kernel home ranges so as future researchers could use our results in their presentations.

For Hog Canyon and the AWRR, we were able to track some individuals for as long as 145 and 211 days,

Table 8. Movement distances (meters ± *SD*) by age class and gender between successive observations for radio- marked Montezuma quail for all sites combined, southeast Arizona, 2010. AHY = after hatch year (adult), HY = hatch year (juvenile). Statistics include number (N) of individuals, number of locations (mean ± *SD*, range), maximum distance moved, maximum linear distance, average distance moved between observations (mean ± *SD*), and distance between first and last observation (mean ± *SD*).

Age Class	AHY Female	HY Female	AHY Male	HY Male	All Quail
N Individuals	15	16	12	22	65
N Locations (mean, range)	20.7 (3–57)	26 (3–92)	7.3 (5–57)	10.4 (3–69)	12.4 (3–92)
Maximum distance moved (mean)	787.7 ± 474.6	1,050.9 ± 769.7	624.5 ± 575.1	852.4 ± 555.4	844.3 ± 605.5
Maximum linear distance (individual)	1,582.81	2,375.5	2,188.3	2,043.9	2,375.5
Average distance moved between observations (mean)	218.7 ± 137.9	236.7 ± 112.6	217.4 ± 138.2	245.5 ±260.7	232.0 ± 181.3
Distance between first and last observation (mean)	357.5 ± 306.2	579.2 ± 550.4	367.8 ± 335.4	449.2 ± 374.2	445.0 ± 405.2

respectively. These results surpass those found by Stromberg (1990) where the mean number of days captured birds were known to be alive was 28.4 days (*SE* = 8.9 days) and the longest time a radio-tagged bird was monitored was about 140 days.

We found Montezuma quail to be sedentary with small home range sizes. However, we documented wider variation by gender and age classes in the home range sizes and movements of Montezuma quail from our study sites. Stromberg's (1990) noted that coveys used small areas (0.09–6 ha) in the winter, non-overlapping areas as large as 50 ha in early spring and from June to October, pairs remained sedentary in small areas, often smaller than two ha. Coveys in his study were consistently relocated in the same small areas and usually within the same 50 m^2 area.

Home range estimates in our study spanned from late winter to late summer, with exception to the 2008 season at Stevens Canyon and 2010 season the AWRR where data were limited to only late winter and early spring. Mean seasonal home range size (MCP) for all sex and gender classes in our study averaged 51.3 ± 51.8 ha which was similar to largest use area (50 ha) derived by Stromberg (1990).

We did not track radio-tagged birds hourly or at 30-minute intervals, because we felt such intensive tracking could be intrusive and affect the behavior of birds being monitored.

Montezuma quail, especially those using open grasslands on arroyo bottoms, could often detect us from over 50 m and would flush into dense cover. Such aversive behavior has undesired impact on observing natural movements and determining accurate home ranges. Our method, therefore, allowed us to improve the accuracy of estimating home range areas with less worry that our monitoring activities artificially affecting estimates of their utilization distributions.

Large-scale migrations were not observed in our study and the mean distance between relocations, on sequential days, for all quail we observed, averaged 844.3± 605.5 m. Stromberg (1990) observed mean distance moved to be 97.8 m (*SE* = 15.1) from January to March, but increased to 194.9 m (*SE* = 56.8) for some birds from March to May. From July to October, Stromberg (1990) reported the mean distance moved between successive days to be 79.2 m (*SE* = 47.4).

Comparison between genders and different age classes, and the interaction of these, also revealed some important differences that occur in both home range size and movements. These differences need to be examined further in future studies with larger sample sizes of radio-marked birds that also account for diverse landscape features. In summary, home range size and movements varied by study site and may be explained by differences in features at the landscape and microhabitat level. Differences in range size between gender and age classes were observed between two study sites, but similarities within age classes were observed between the two sites. Our data corroborates historical assumptions about relatively small home range sizes for this species, but our estimates are much larger than those presented in the literature.

MANAGEMENT IMPLICATIONS

Understanding the home ranges and movements of wildlife populations is integral to their conservation. Our study of home range and movements of Montezuma quail on three study areas in southeast Arizona provided us an opportunity to add to the knowledge of this important species.

Based on our study, the following conclusions were drawn:

1. Montezuma quail are sedentary with small home range sizes.
2. Mean home range size for our three study areas was similar to that found in a previous study of the species.
3. Age and gender classes had similar ranges and movements.
4. Montezuma quail did not make large-scale migrations.
5. Montezuma quail in our study had much larger movements between sequential relocations than observed from a previous study.

Further research throughout the species is recommended to lend more support to conclusions drawn from our study in southeast Arizona. Such research is warranted for developing better management and conservation strategies for this species throughout its range.

ACKNOWLEDGMENTS

Several volunteers, including, Alison Kocek, Lily Ng, Richard Chasey and Lindsey Reifl assisted with this research. A Sloan Foundation Fellowship, Ariel- Appleton Fellowship, and a National Audubon Society Apacheria Fellowship provided generous support. We thank our graduate assistant dogs Blanca, Chico, and Choco for putting in countless hours in the field from the earliest hours of the day to the latest hours at night searching for birds in the field. Much thanks also to Dr. Linda Kennedy, Dr. Christine Hass, and Roger Cogan for logistical and moral support at the Appleton-Whittell Research Ranch. Dr. Mark Stromberg's mentoring and previous work with this species served to inspire our success with this project.

LITERATURE CITED

Calenge, C. 2006. The package adehabitat for the R software: a tool for the analysis of space and habitat use by animals. Ecological Modelling 197:516–519

Chavarria, P. M., A. R. Kocek, N. J. Silvy, and R. R. Lopez. 2012. Use of portable infrared cameras to facilitate detection and capture success of Montezuma quail. National Quail Symposium Proceedings 7:333–338

Chavarria, P. M. 2013. Ecology of Montezuma Quail in Southeast Arizona. Dissertation, Texas A&M University, College Station, Texas, USA.

Environmental Systems Research Institute (ESRI). 2000. Arcview 3.2A GIS software. Redlands, California, USA

Jennrich, R.I, and F.B. Turner. 1969. Measurement of the non-circular home range. Journal of Theoretical Biology 22:227–237

Kernohan, B. J., R. A. Gitzen, and J. J. Millspaugh. 2001. Analysis of animal space use and movements. Pages 469–474 *in* J. J. Millspaughand J. M. Marzluff, editors. Radio tracking animal populations. Academic Press, San Diego, California, USA.

Lenth, R. V. 1981. On finding the source of a signal. Technometrics 23:149–154. Leopold, A. S., and R. A. McCabe. 1957. Natural history of the Montezuma quail in Mexico. Condor 59:3–26.

LOAS. 2010. Ecological Software Solutions LLC. Version 4.0.3.7, Hegymagas, Hungary. Natural Resources Conservation Service (NRCS). 2012. Web soil survey. U.S. Department of Agriculture, Washington, D.C., USA. <http://websoilsurvey.nrcs.usda.gov/>. Accessed 28 October 2011.

Powell, R. A. 2000. Animal home ranges and territories and home range estimators. Pages 65– 110 *in* L. Boitani, and T. K. Fuller, editors. Research techniques in animal ecology. Columbia University Press, New York, New York, USA.

Quantum GIS Development Team. 2011. Quantum GIS geographic information system. Version 1.7.0. Open Source Geospatial Foundation Project. <http://qgis.osgeo.org>. Accessed 10 September, 2011.

R Development Core Team. 2005. R: A language and environment for statistical computing, reference index. Version 2.2.1. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Rodgers, A. R. and A. P. Carr. 1998. HRE: the home range extension for ArcView. Users Manual. Ontario Ministry of Natural Resources, Thunder Bay, Ontario, Canada.

Saltz, D. 1994. Reporting error measures in radio location by triangulation. Journal of Wildlife Management 58:181–184.

SAS Institute. 2007. JMP. Version 9.0, Statistical software manual. SAS Institute, Cary, North Carolina, USA.

Seaman, D. E., and R. A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. Ecology 77:2075–2085.

Stromberg, M. R. 1990. Habitat, movements and roost characteristics of Montezuma quail in southeastern Arizona. Condor 45:57–65.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home range studies. Ecology 70:164–168.

Western Regional Climate Center. 2012. Arizona climate summaries. Western Regional Climate Center, National Oceanic and Atmospheric Administration, Reno, Nevada, USA. <http://www.wrcc.dri.edu>. Accessed 28 October 2011.