ECOLOGY OF MONTEZUMA QUAIL IN THE DAVIS MOUNTAINS OF TEXAS

A Thesis

By

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Submitted to the School of Agricultural and Natural Resource Sciences

Sul Ross State University, in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2011

Major Subject: Range and Wildlife Management

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ABSTRACT

Montezuma quail (*Cyrtonyx montezumae*) occur throughout the desert mountain ranges in the Trans Pecos of Texas as well as the states of New Mexico and Arizona. Limited information on life history and ecology of the species is available due to the cryptic nature of the bird. Home range, movements, and preferred habitats have been speculated upon in previous literature with the use of observational or anecdotal data. With modern trapping techniques and technologically advanced radio transmitters, Montezuma quail have been successfully monitored providing assessments of their ecology with the use of hard data. The objective of this study was to monitor Montezuma quail to determine home range size, movements, habitat preference, and assess population dynamics for the Davis Mountains population. Over the course of two years (2009 – 2010) a total of 72 birds (36M, 35F, 1 Undetermined) were captured. Thirteen individuals with >25 locations per bird were evaluated in the home range, movement, and habitat selection analyses. Home ranges (95% fixed kernels) were calculated resulting in a mean home range size of 2,149.4 ha with ranges varying greatly (16.8 – 15,751.4 ha). Maximum straight-line distances between known locations within home ranges varied from 0.6 – 12.7 km. Home range size and distances of movements were greater than expected. Preferred habitats consisted of Canyon Mountain Savannah and Foothill Slope Mountain Savannah across 3 spatial scales. Montezuma quail (n=72) were found to have an even 50:50 sex ratio and an annual survival estimate of 12.8%. Further documentation is needed, but much of the general ecology has been addressed by my study for Montezuma quail in the Davis Mountains of Texas.

DEDICATION

I dedicate this thesis to my family, friends, and teachers. My grandfather L.D. "Dick" Greene inspired me throughout my life up to this point and had just recently passed during the final stages of my thesis. From a young age, he had taught me to work hard, try not to get discouraged, and in the face of adversity improvise to create the best outcome possible. With no more than an 8^{th} grade education and 40 years of working in the oil field, his never-ending support and inspiration has certainly helped me get to this point. Thank you and you are missed greatly.

ACKNOWLEDGEMENTS

I thank the Texas Parks and Wildlife Department for the primary funding of my project. I also thank Borderlands Research Institute for the technical guidance as well as the monetary contributions throughout the course of my project. The Texas Council of Quail Unlimited made a useful contribution by donating a four-wheeler.

I express great appreciation to my advisor Dr. Louis Harveson for the guidance and the opportunity to work on this project to obtain a M. S. in Range and Wildlife Management at Sul Ross State University. In addition to finding the sources of money to get the project going, he has allowed me countless opportunities of working with various species of wildlife here in the Trans Pecos and he has introduced me to many professionals within the wildlife management field.

I sincerely thank my technicians Justin Hoffman, Zach Criddle, Rebecca Stalling, and Michael Smith who all worked hard to collect the large quantity of telemetry data as well as work late hours on night captures. In addition to the technicians, I express my gratitude to the multiple volunteers for all of their efforts in making this project a successful one.

The support family and friends have provided throughout my study is insurmountable. If it wasn't for people like Dustin Hollowell and Jose de la Luz Martinez-Garcia along with many other great friends and family members my time at Sul Ross would not have been the same.

It would be foolish not to recognize my dad, Rodney Greene, for introducing me to the outdoors at a young age and supporting me in all of my adventures whether it be hunting, fishing, or schooling.

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INTRODUCTION

Montezuma quail (*Cyrtonyx montezumae*) are 1 of 4 species of quails found in Texas (Harveson 2007). Unlike northern bobwhite (*Colinus virginiana*), scaled quail (*Callipepla squamata*), and Gambel's quail (*Callipepla gambelii*), little is known about the general ecology of Montezuma quail likely due to their cryptic nature. This desert quail species is now restricted to scattered locations throughout the Trans-Pecos of Texas, but was thought to have a historic range of every county in the Trans-Pecos across much of the Edwards Plateau. Montezuma quail are considered an indicator species for the pine-oak woodlands (Leopold and McCabe 1957). Harveson et al. (2007) suggested that Montezuma quail are unique with respect to clutch size, diet, covey dynamics, and habitat use. However, there has been no recent detailed information on these aspects for Montezuma quail. Most literature regarding ecology of Montezuma quail is outdated and there is almost no data on their life history in Texas (Albers and Gehlbach 1990, Hernandez 2006, Garza 2007).

Answering questions about Montezuma quail life history such as covey dynamics, movement patterns, mating systems, nesting ecology, and survival rates becomes attainable via the use of radio telemetry. Radio telemetry data for Montezuma quail has been attempted by Stromberg (1990) and Hernandez et al. (2009) with little success. Lack of ecological information could be attributed to the secretive nature of the bird, lack of accessibility, and the difficulty of catching Montezuma quail by traditional means (Hernandez et al. 2006, Hernandez et al. 2009). Montezuma quail are ground--dwelling birds that rarely fly even when approached. They are cryptic and easily overlooked due to the camouflage provided by their intricate plumage (Harveson 2007). A major problem with successful monitoring in the Trans-Pecos is the rugged mountainous habitat in which they persist. Much of the land with appropriate habitat in Texas is privately owned with limited access. Common practices for capturing gallinaceous quail species involve walk in traps baited with grain (Stromberg 1990). However, Montezuma quail do not eat traditional grains (Hernandez et al. 2006).

Another advancement made is with regard to the ability of monitoring Montezuma quail using radio telemetry. Only 2 other studies (Stromberg 1990, Hernandez et al. 2009) have conducted radio telemetry work on Montezuma quail. Both of these studies demonstrated that typical neck loop transmitters, commonly used in tracking quail, resulted in abnormal mortality rates. Recently Sul Ross State University researchers worked directly with a telemeter manufacturer (ATS, Isanti, MN) in developing a backpack style radio transmitter for Montezuma quail. The new style of transmitter has the same capabilities of the neck loop but is mounted using shock cord with loops coming under the base of the wings. Preliminary studies have found that the new style of transmitter does not seem to affect survival rates as the neck loop transmitters did (L. Harveson, unpublished data). That study was carried out over a 5-month period, in which some radio-marked birds lasted the full length of time. The use of back pack radio transmitters has been successful in monitoring other avian species such as wild turkey (Kurzejeski et al. 1987). If backpack transmitters do indeed work for Montezuma quail, the opportunity exists to answer general ecology questions that have been addressed unsuccessfully in previous studies.

I conducted a radio telemetry study to obtain information on the life history of Montezuma quail with the use of 3 newly – acquired techniques: (a) night captures using

GPS tracking collars, (b) radio telemetry, and (c) ArcGIS for analysis. The main goal for this research project was to develop baseline ecological information on Montezuma quail in the Davis Mountains of Texas. My objectives were to (1) describe spatial patterns, (2) evaluate habitat use of Montezuma quail, and (3) determine population characteristics.

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CHAPTER 1:

SPATIAL ECOLOGY OF MONTEZUMA QUAIL IN THE DAVIS MOUNTAINS OF TEXAS

Quail species such as northern bobwhite (*Colinus virginiana*), scaled quail (*Callipepla squamata*), and Gambel's quail (*Callipepla gambelii*) have been studied throughout much of their ranges with literature describing movements and home ranges for each (Brennan 2007, Zornes and Bishop 2009). Montezuma quail (*Cyrtonyx montezumae*) however, have received little attention on their spatial ecology with only 1 radio-telemetry study (Stromberg 1990) providing limited information on home range and movements in Arizona. In that study, Stromberg (1990) radio-marked 15 Montezuma quail providing the basis for many aspects of life history on this species. Stromberg (1990) found fall through midwinter ranges to be small use areas (≤ 6 ha) that increased in size during late winter and early spring (<50 ha). Movements were restricted to ≤100 m between days (Stromberg 1990).

Other information on Montezuma quail movements and ranges are anecdotal (Brown 1976, 1978; Leopold and McCabe 1957). Brown (1978) speculated the home range of Montezuma quail were <6 ha. Large movements performed by Montezuma quail have been suspected, but were thought to be no more than a few miles (Leopold and McCabe 1957). The cryptic nature of Montezuma quail along with foraging strategy, terrain, and remoteness of areas limit the opportunity to capture and monitor radio-marked birds effectively (Hernandez et al. 2006).

Home range estimates for Montezuma quail are thought to be generally less than neighboring Gambel's quail or scaled quail. Estimates for home range size of Gambel's quail were similar to Montezuma quail with home ranges from 8–38 ha (Zornes and Bishop 2009). Scaled quail are typically thought to have larger home ranges varying from 10–882 ha (Zornes and Bishop 2009).

Improvised trapping techniques and modified backpack style transmitters allowed for assessing the following objectives: 1) determine home range size of Montezuma quail in the Davis Mountains and 2) describe movements for Montezuma quail. Meeting such objectives is progress towards the main goal to develop baseline ecological information on Montezuma quail in the Davis Mountains of Texas.

Study Area

My study took place on 8,760 ha in the central portion of the Davis Mountains in Jeff Davis County, Texas (Figure 1.1). The Davis Mountains Preserve was owned by The Nature Conservancy and served as the core study site but the study also included portions of neighboring ranches. The Davis Mountain Preserve was approximately 40 km northwest of Fort Davis on Texas Highway 118. The study site contained elevations ranging from 1,600 to 2,200 m with annual precipitation varying from 28.2 to 56.9 cm. Located in the northern portion of the Chihuahuan Desert, most rainfall occurs during the monsoon periods from June through August. The Davis Mountains represent 1 of 3 sky island communities in the Trans-Pecos region (DeBano and Ffolliot 2005). Range conditions varied throughout the study area ranging from deferment to extensive grazing.

Prescribed fire was used throughout the study site primarily for limiting brush encroachment.

Pine-oak woodlands and juniper-oak woodlands occur through out the study site. These mountain savannahs consisted of alligator juniper (*Juniperus deppeana*), emory oak (*Quercus emoryi*), gray oak (*Q. grisea*), Mexican pinyon pine (*Pinus cembroides*), rose-fruited juniper (*J. coahuilensis*), and red berry juniper (*J. pinchotii*) (Powell 1998). Stands of ponderosa pine (*P. ponderosa*) and southwestern white pine (*Pinus strombiformis*) were the dominant vegetation type in the higher elevations. Lower elevations of the study area were highland grasslands with blue grama (*Bouteloua gracilis*) being the dominant grass. Many other gramas, bluestems (*Bothriochloa* spp.; *Schizachyrium* spp.), threeawns (*Atrstida* spp.), and needlegrass (*Stipa* spp.) occurred throughout the study area.

In addition to Montezuma quail, many other species persist in the area creating superior wildlife diversity. Ungulates occurring in the area are Carmen Mountains white-tailed deer (*Odocoileus virginianus*), mule deer (*O. hemionus*), elk (*Cervus elephus*), collared peccary (*Pecari tajacu*), and feral pigs (*Sus scrofa*). Canids and felines such as coyote (*Canus latrans*), gray fox (*Urocyon cinereoargenteus*), bobcat (*Lynx rufus*), and mountain lion (*Puma concolor*) are known to reside there as well. Mesomammals of the area consist of skunks (*Mephitis* spp.), badgers (*Taxidea taxus*), ringtails (*Bassariscus astutus*), and raccoons (*Procyon lotor*).

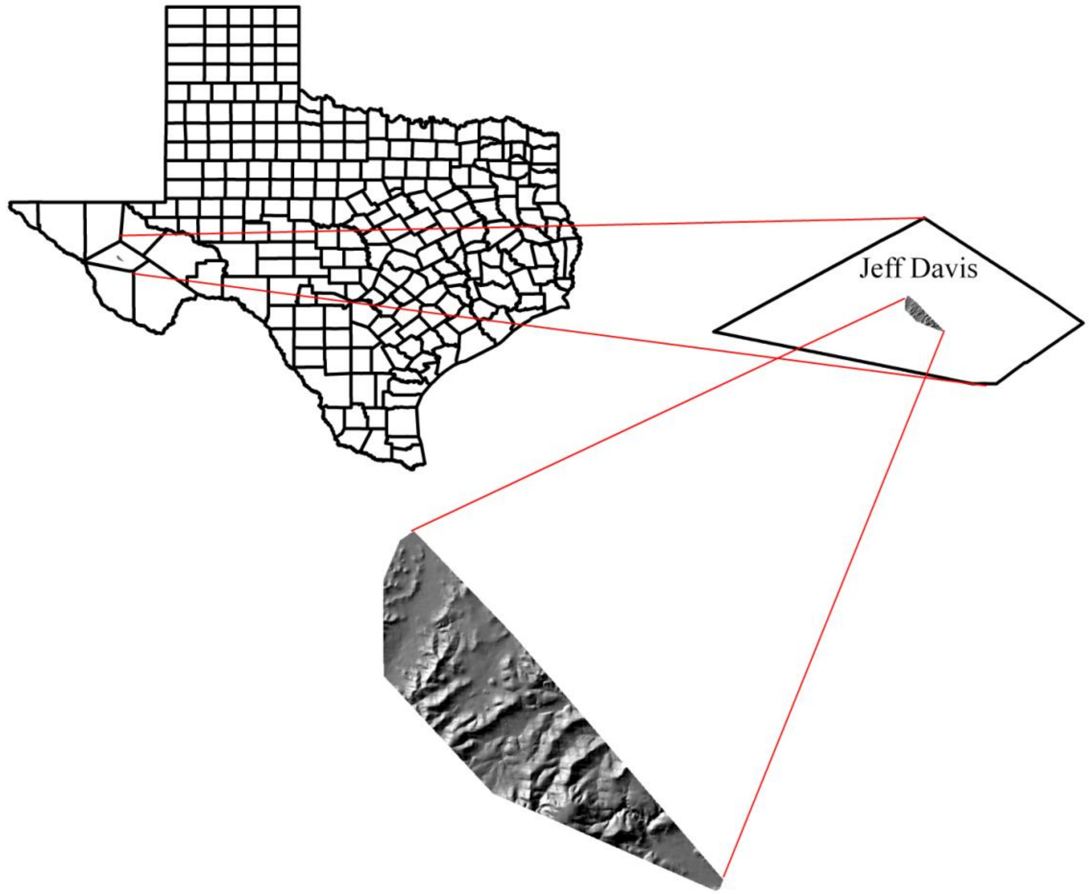

Figure 1.1. Location of the 8,760-ha study area used for monitoring Montezuma quail in the Davis Mountains of Texas.

Methods

Over the course of the study 2 methods of capture were employed. The first method was a modified version of the capture technique described by Brown (1976) using trained pointing dogs and hand nets. The dogs were worked in various locations throughout the study area focusing primarily on the Davis Mountain Preserve. The majority of dog searches took place within 4 hours of sunset. Once coveys were located during the day, a global positioning system (GPS) was used to mark the flush site of birds. The use of throw nets during the day was applied by casting in front of a pointing dog when habitat conditions allowed (e.g., free of brush).

The main trapping technique that was used for capturing Montezuma quail consisted of using trained hounds, large hoop nets, and throw nets at night. Capture crews revisited covey locations ≥half an hour after sunset accompanied by a bird dog. Search effort at night was focused in the general area of the original flush site. A lighted collar and tracking device (Astro 220 GPS, Olathe, Kansas) was used for monitoring the dog at night. Once the dog was on point, a research crew maneuvered a hoop net or cast a throw net down on top of a covey. Birds were carefully removed from the net, put in a small tote sack, and placed in a carrying device. Captured birds were then taken back to a lighted facility where sex, age, and other standard morphological variables were recorded. Captured birds were then fitted with a backpack style radio transmitter (4-6 g) and banded with a numbered aluminum leg band. The birds were then held in a small cage overnight and returned to the capture site the following morning for release.

Once a covey had ≥1 transmitted bird, the covey was relocated at night. Using a night-netting technique initially described by Labisky (1959, 1968), researchers homed-in on the radioed birds at night with telemetry equipment instead of using a dog to locate them. Using hoop or throw nets, a net was placed over as many birds in the covey as possible. Previously captured birds were examined and weighed, while newly captured individuals were aged, sexed, and measured. Birds were chosen at random to be transmitted until the covey had ≥3 transmitted individuals within a covey. All trapping activities were conducted in accordance with state (Texas Parks and Wildlife Department SPR-0592-525) and university laws (Animal Care and Use Committee).

Monitoring of transmitted birds was carried out with the use of a receiver (ATS R4000, Isanti, MN) and a yagi antenna. Locations of each individual were taken 2-5 times weekly using a ≥ 3 fixes per location. A GPS unit, compass, and handheld device (Palm T/X or Palm Tungsten E2) unit with Locate III (Tatamagouche, NS, Canada) software were used to ensure accuracy of each location. Accuracy considered acceptable was set to be <30,000 m^2 area of error ellipse (<100 m). Point coordinates along with azimuths were recorded on data sheets. Field data was then entered into a database. Files were saved as comma delimited and imputed into the Locate III software for usable locations.

Usable locations were then imputed to a database by individual. From there, locations were imported into ArcGIS 9.3 (ESRI, Redlands, California, USA) where shapefiles were created. I calculated composite home range to define my study area by combining locations from all birds and using Home Range Tools (HRT) to perform a 100% minimum convex polygon (MCP). HRT was also used for calculating home ranges for each Montezuma quail monitored with ≥25 locations. Ninety-five percent fixed kernel polygons and 95% MCP were placed around locations gathered to give defined home ranges for each individual.

Hawths Tools in ArcGIS was used for measuring movements. For each individual with ≥25 locations, a distance matrix between points was performed. This accounted for the distance moved between successive locations. It also calculated the longest straight-line measurement across their home range.

Results

Seventy-two Montezuma quail were captured from January 2009 through September 2010. Of the birds captured, 68 were radio-marked and a total of 966 locations was collected. Thirteen individuals (8 M, 5 F) had ≥25 locations for home range estimates (Figure 1.2 through Figure 1.14). Only 2 birds (M21, F23) were monitored during both years of data collection.

Home ranges varied greatly in size (Figure 1.15). Using 95% fixed kernels, the smallest home range was 16.8 ha and the largest was 15,751.4 ha (Table 1.1). Mean home range size was 2,149.4 ha (SD = 4,736.8 ha). When using 95% MCP the smallest and largest home range was 11.5 ha and 1,486.6 ha, respectively. The mean 95% MCP home range 356.8 ha (SD = 454.4 ha). Large movements occurred such as a movement of 11.3 km from 29 June – 20 July by birds M62 and F65. Maximum straight-line distances across home ranges varied from 0.6 km to 12.7 km (1.1).

Discussion

Stromberg (1990) was the first to describe home range and movements of Montezuma quail. However, number of Montezuma quail radioed (15) and the number of relocations (<25) were very limited which provided the basis of the home range

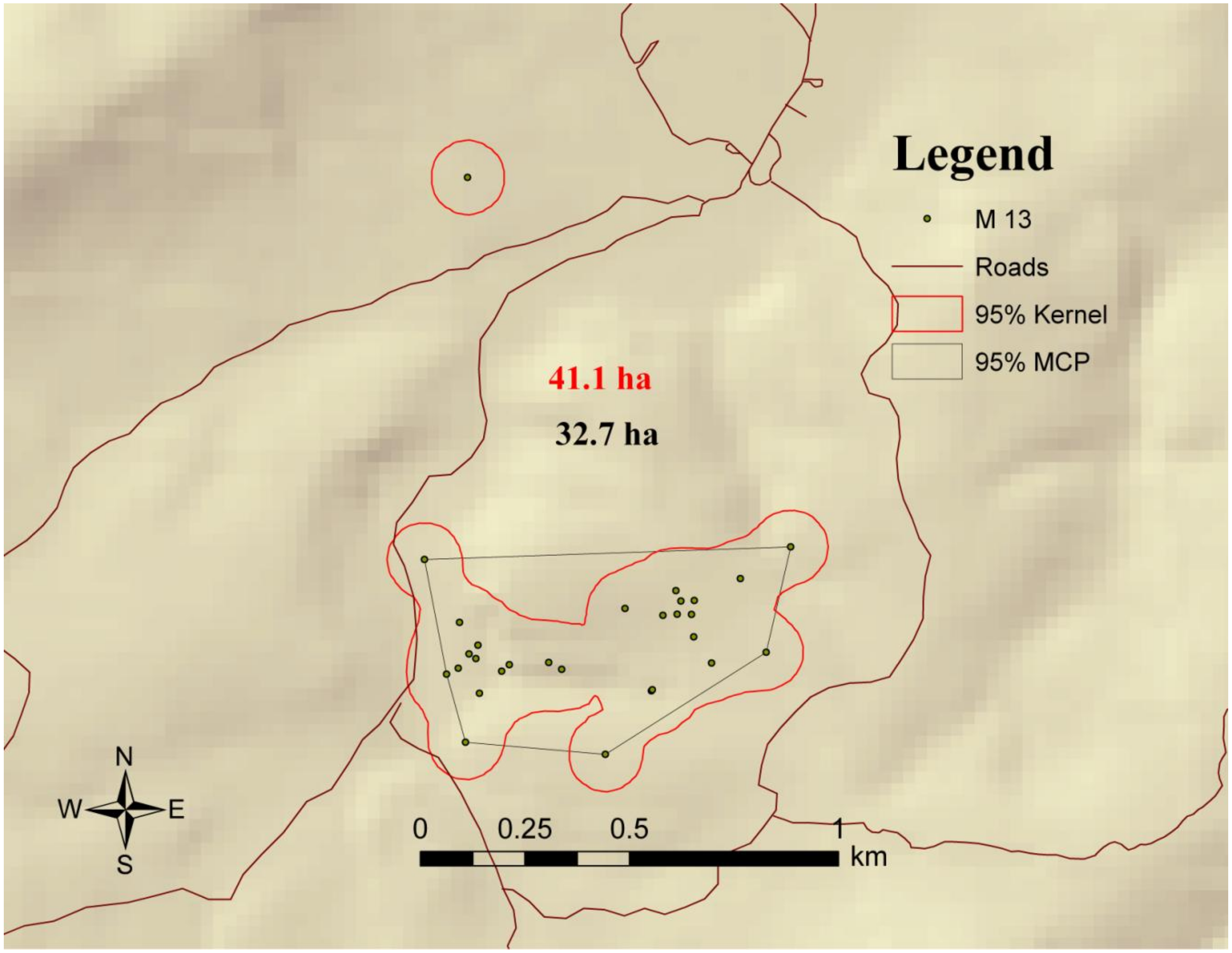

Figure 1.2. Home range size calculated using 95% MCP (32.7 ha) and 95% fixed kernel (41.1 ha) for Montezuma quail (M13) in the Davis Mountains of Texas, 2009 – 2010.

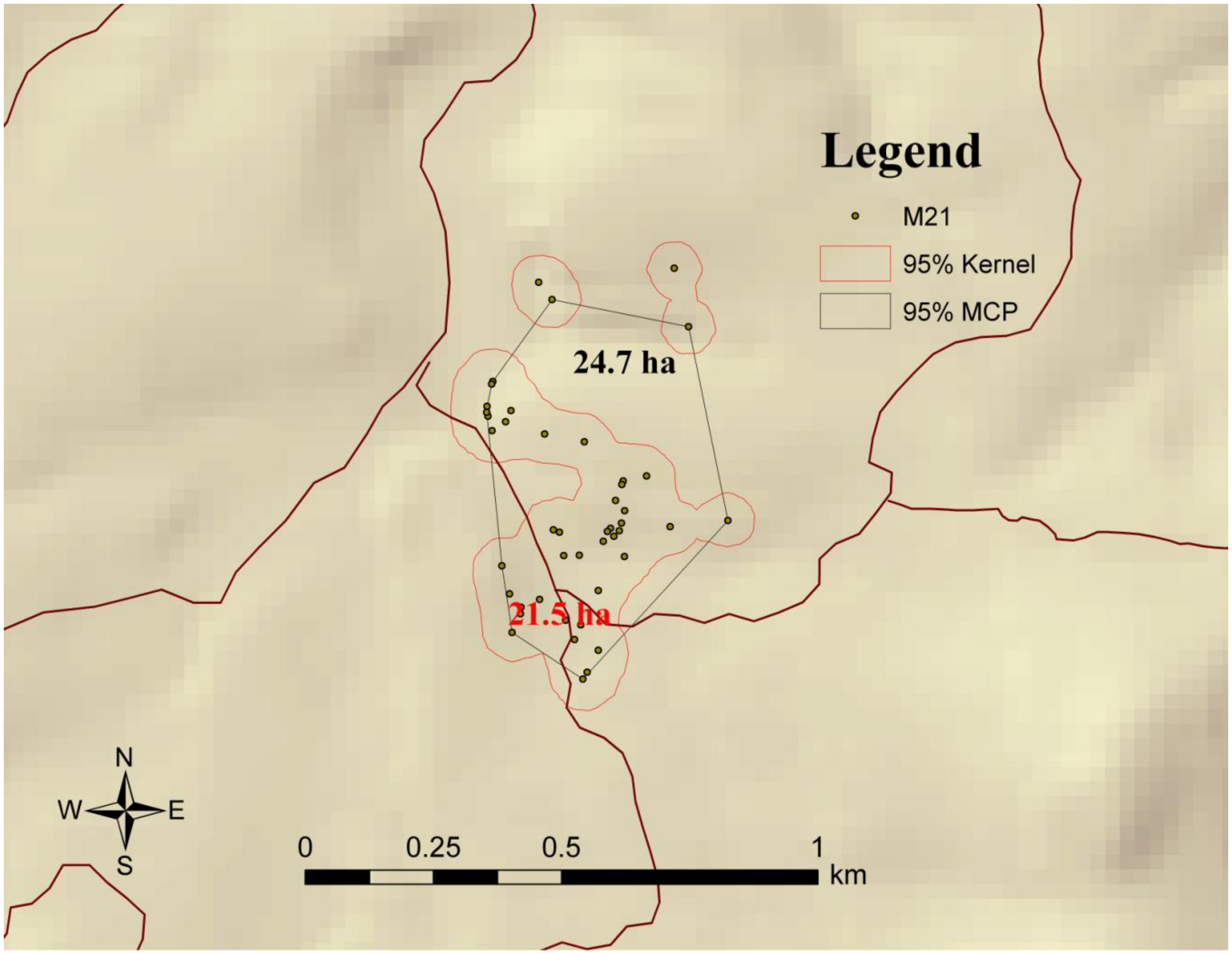

Figure 1.3. Home range size calculated using 95% MCP (24.7 ha) and 95% fixed kernel (21.5 ha) for Montezuma quail (M21) in the Davis Mountains of Texas, 2009 – 2010.

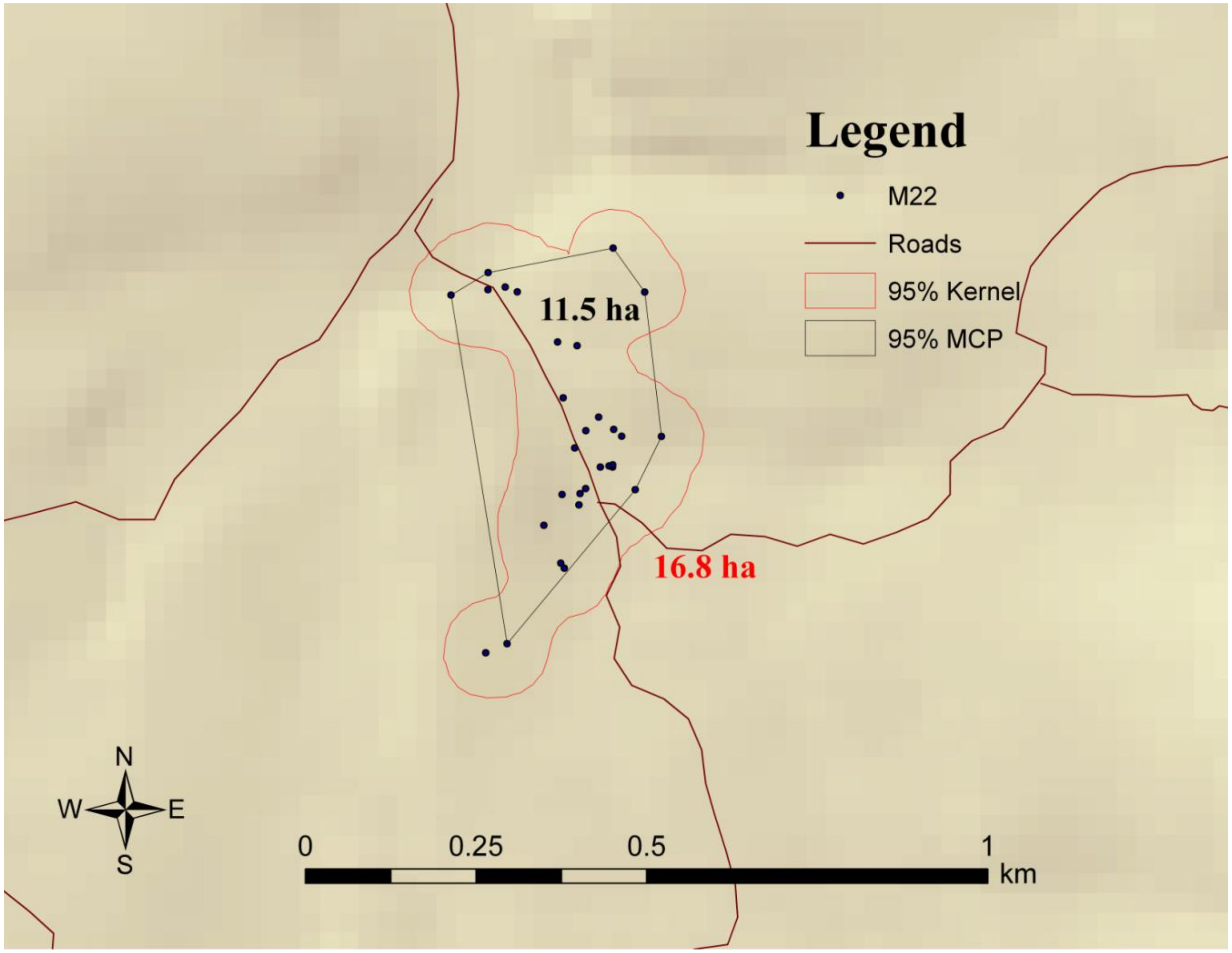

Figure 1.4. Home range size calculated using 95% MCP (11.5) and 95% fixed kernel (16.8 ha) for Montezuma quail (M22) in the Davis Mountains of Texas, 2009 – 2010.

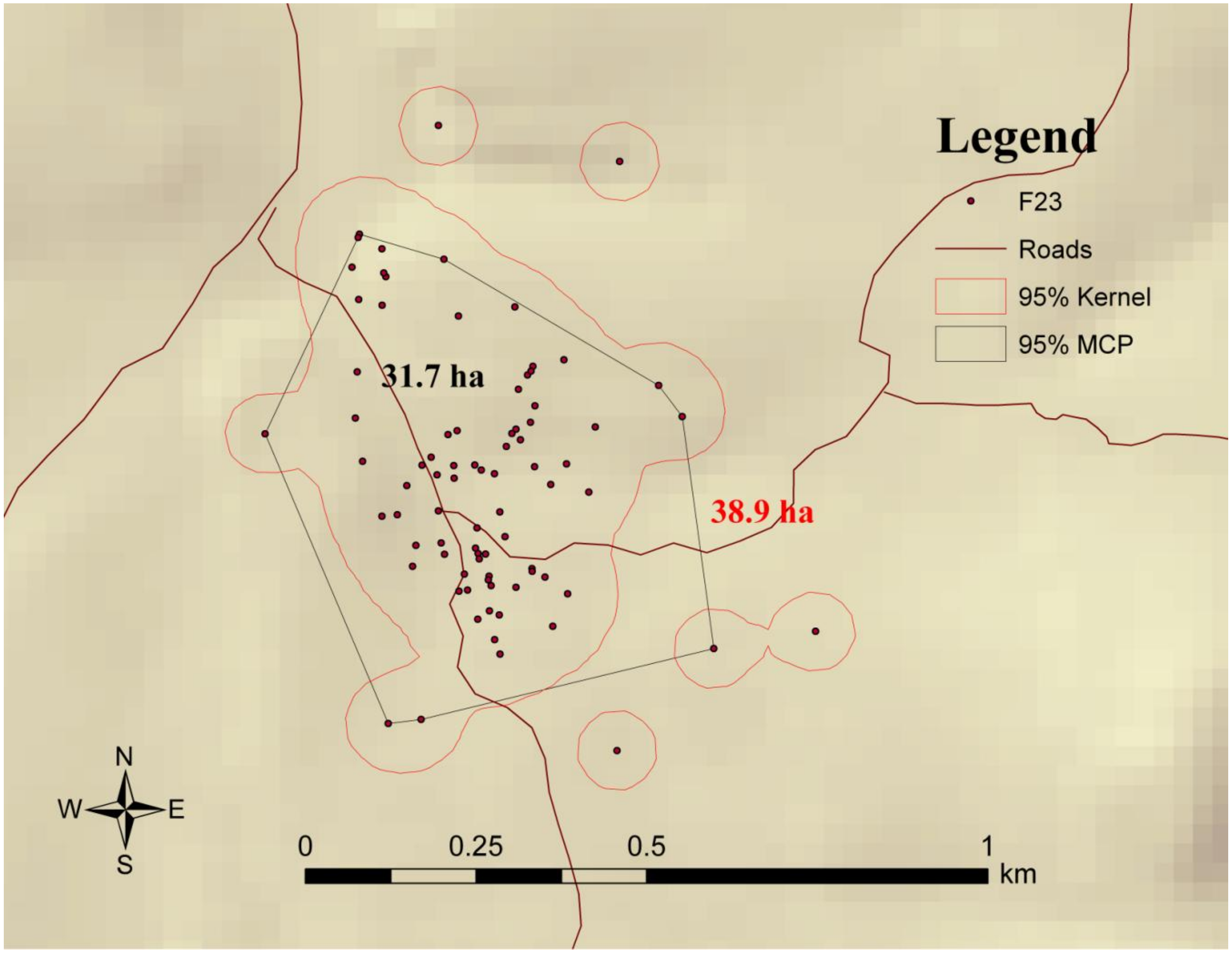

Figure 1.5. Home range size calculated using 95% MCP (31.7 ha) and 95% fixed kernel (38.9 ha) for Montezuma quail (F23) in the Davis Mountains of Texas, 2009 – 2010.

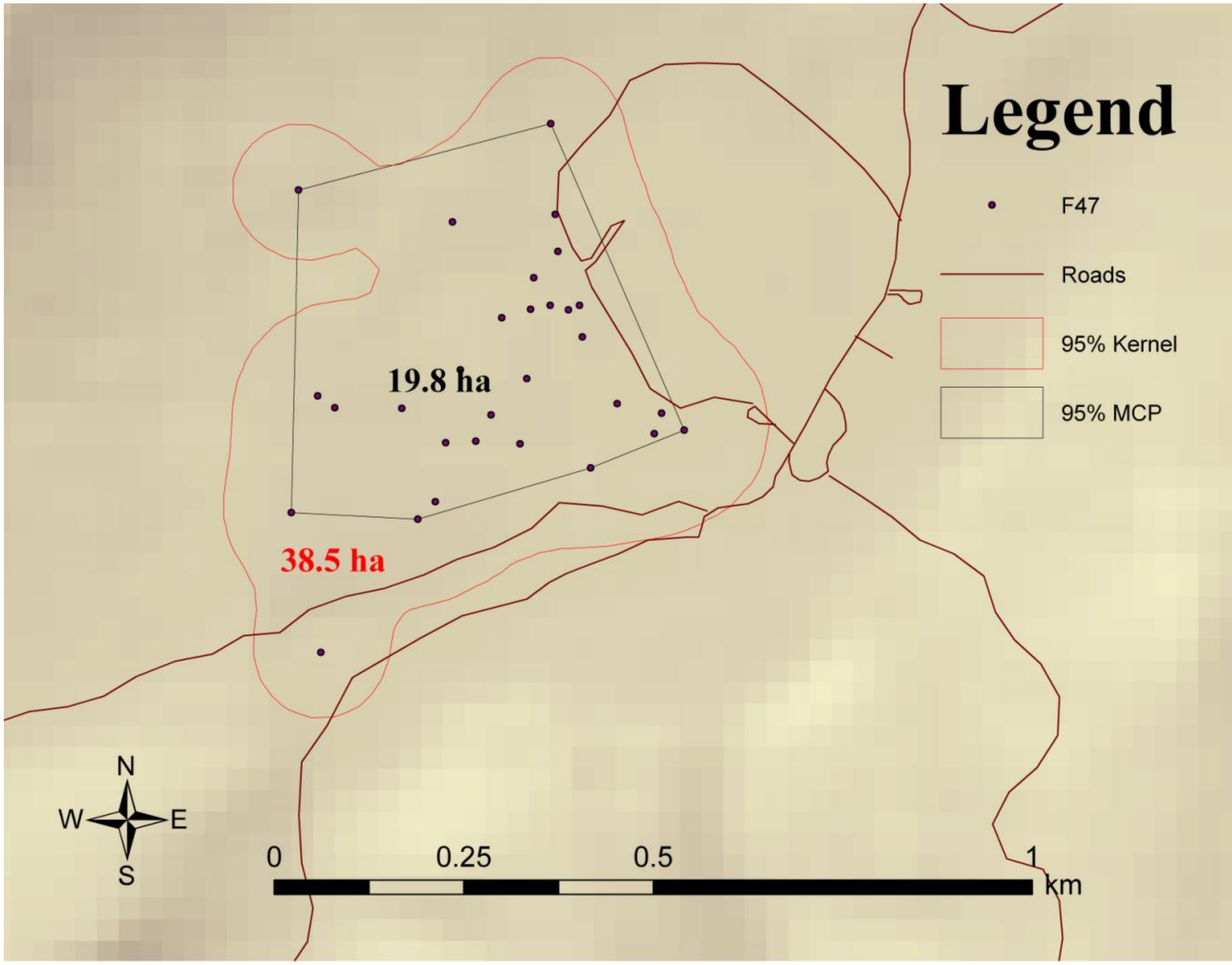

Figure 1.6. Home range size calculated using 95% MCP (19.8 ha) and 95% fixed kernel (38.5 ha) for Montezuma quail (F47) in the Davis Mountains of Texas, 2009 – 2010.

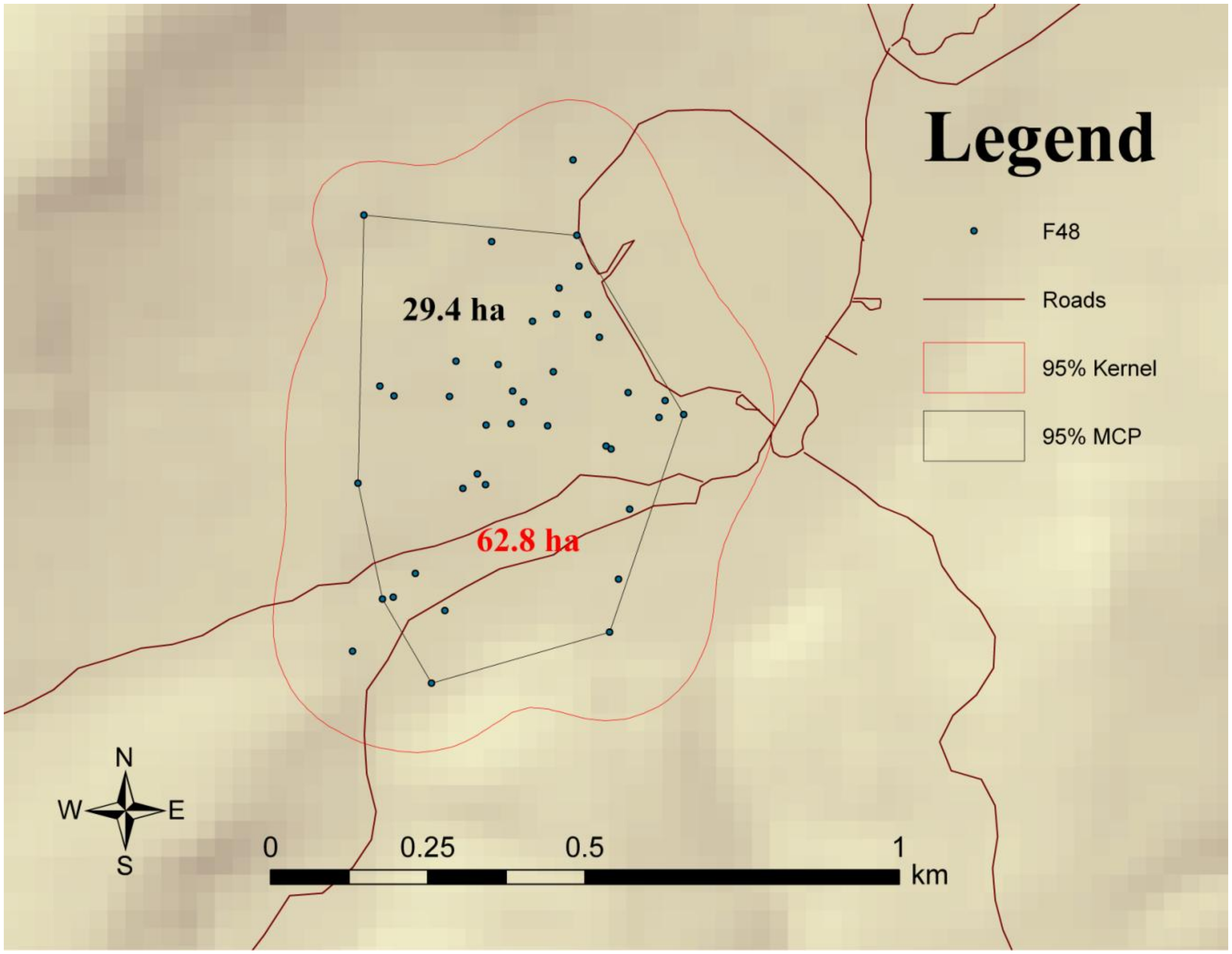

Figure 1.7. Home range size calculated using 95% MCP (29.4 ha) and 95% fixed kernel (62.8 ha) for Montezuma quail (F48) in the Davis Mountains of Texas, 2009 – 2010.

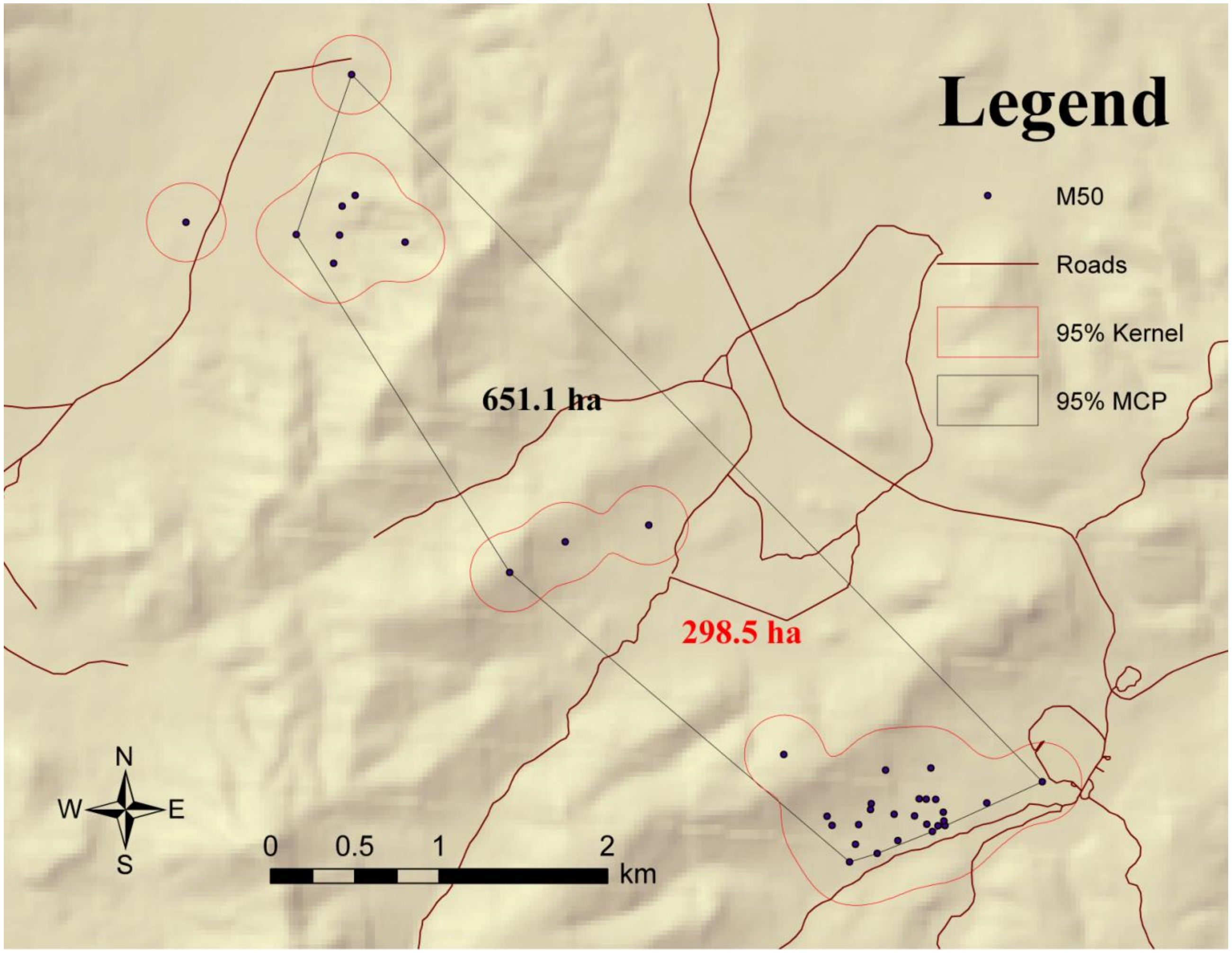

Figure 1.8. Home range size calculated using 95% MCP (651.1 ha) and 95% fixed kernel (298.5 ha) for Montezuma quail (M50) in the Davis Mountains of Texas, 2009 – 2010.

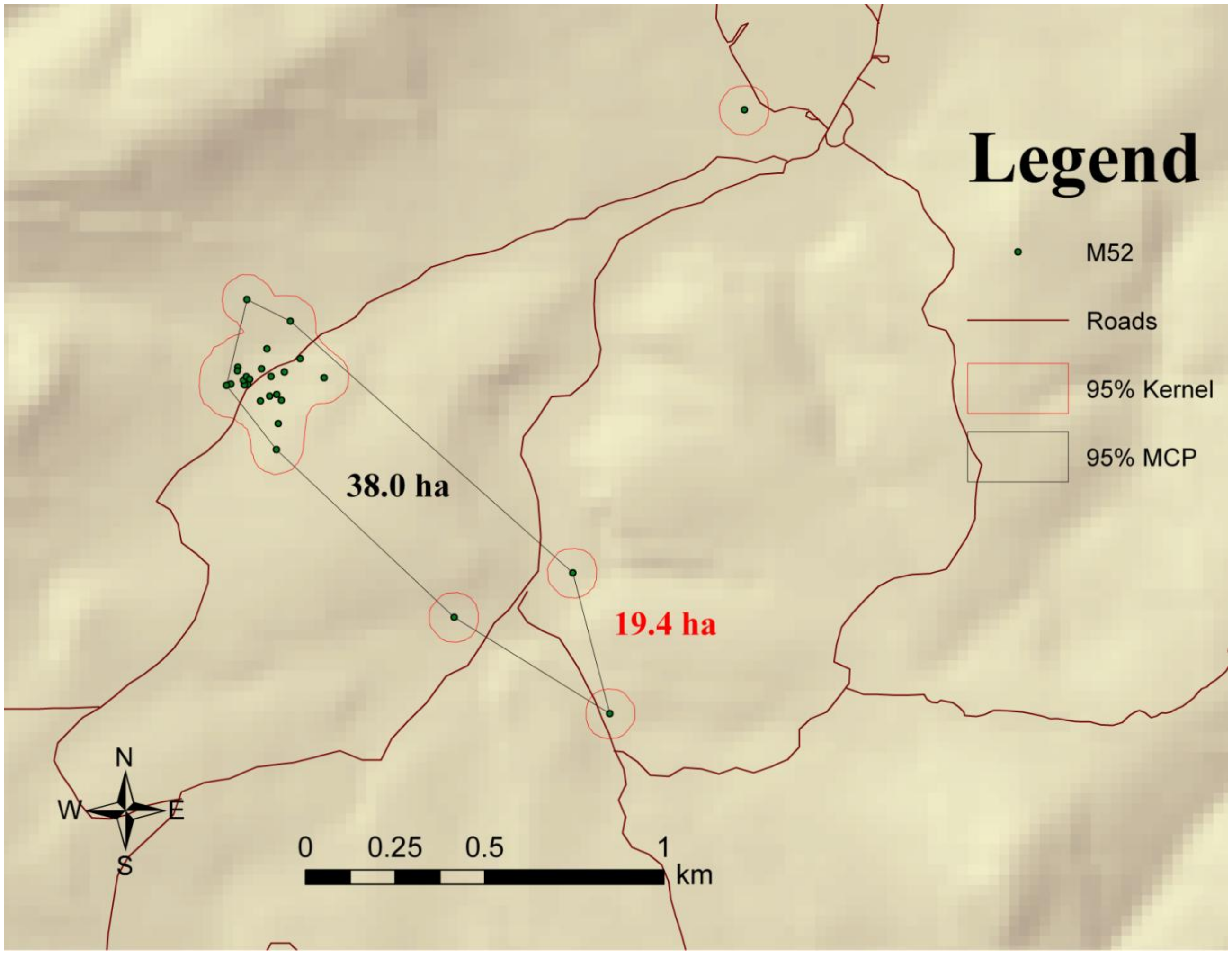

Figure 1.9. Home range size calculated using 95% MCP (38.0 ha) and 95% fixed kernel (19.4 ha) for Montezuma quail (M52) in the Davis Mountains of Texas, 2009 – 2010.

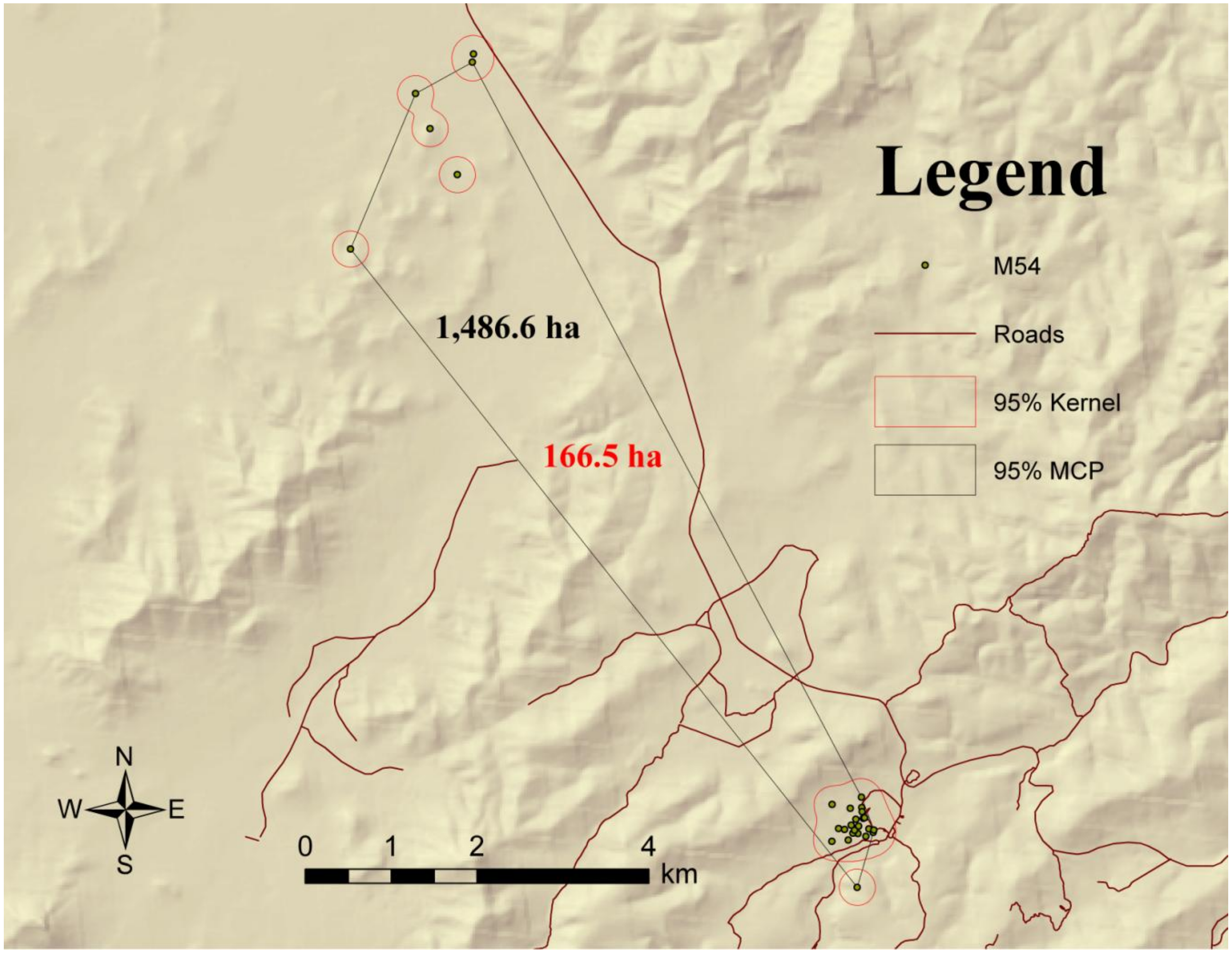

Figure 1.10. Home range size calculated using 95% MCP (1,486.6 ha) and 95% fixed kernel (166.5 ha) for Montezuma quail (M54) in the Davis Mountains of Texas, 2009 – 2010.

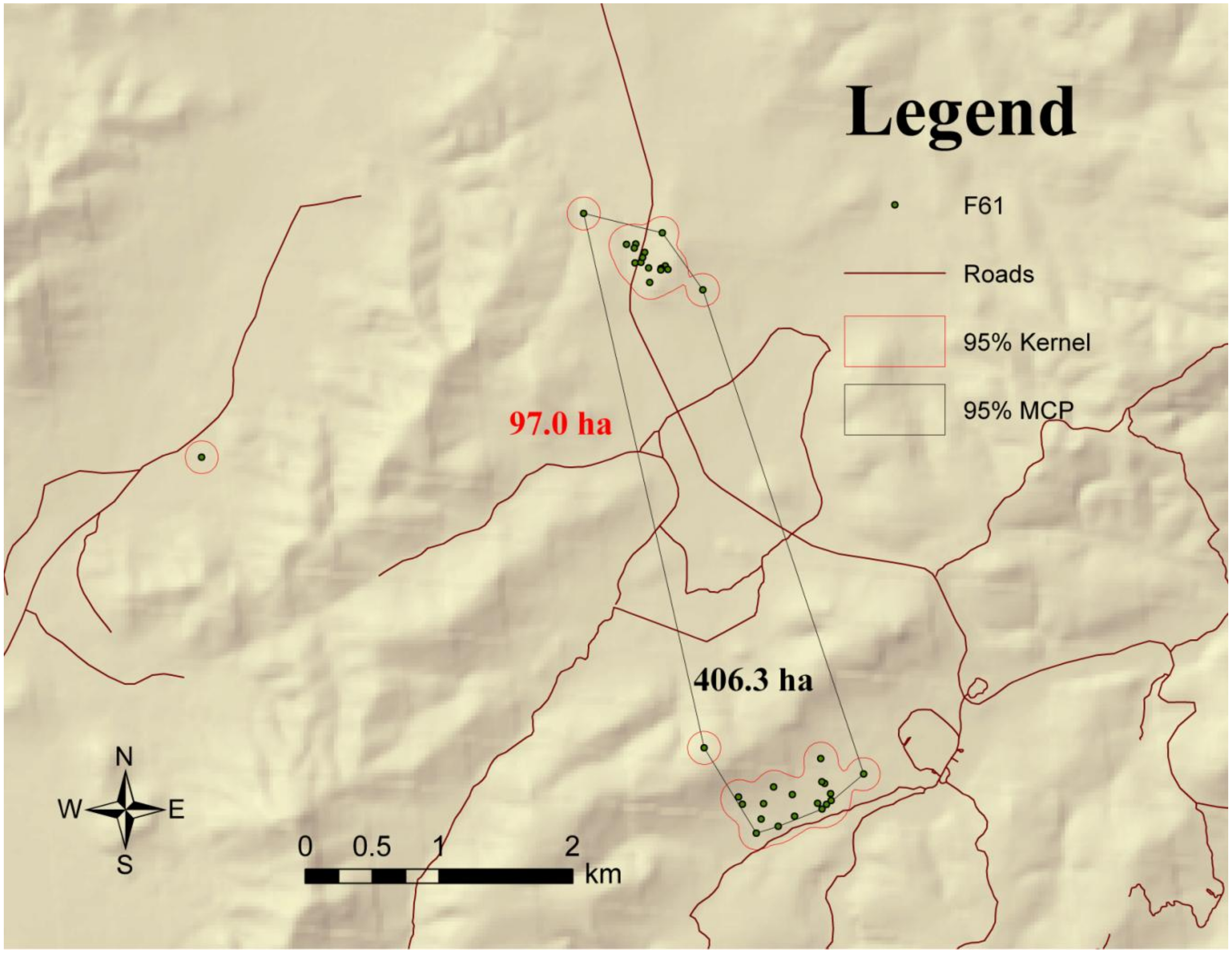

Figure 1.11. Home range size calculated using 95% MCP (406.3 ha) and 95% fixed kernel (97.0 ha) for Montezuma quail (F61) in the Davis Mountains of Texas, 2009 – 2010.

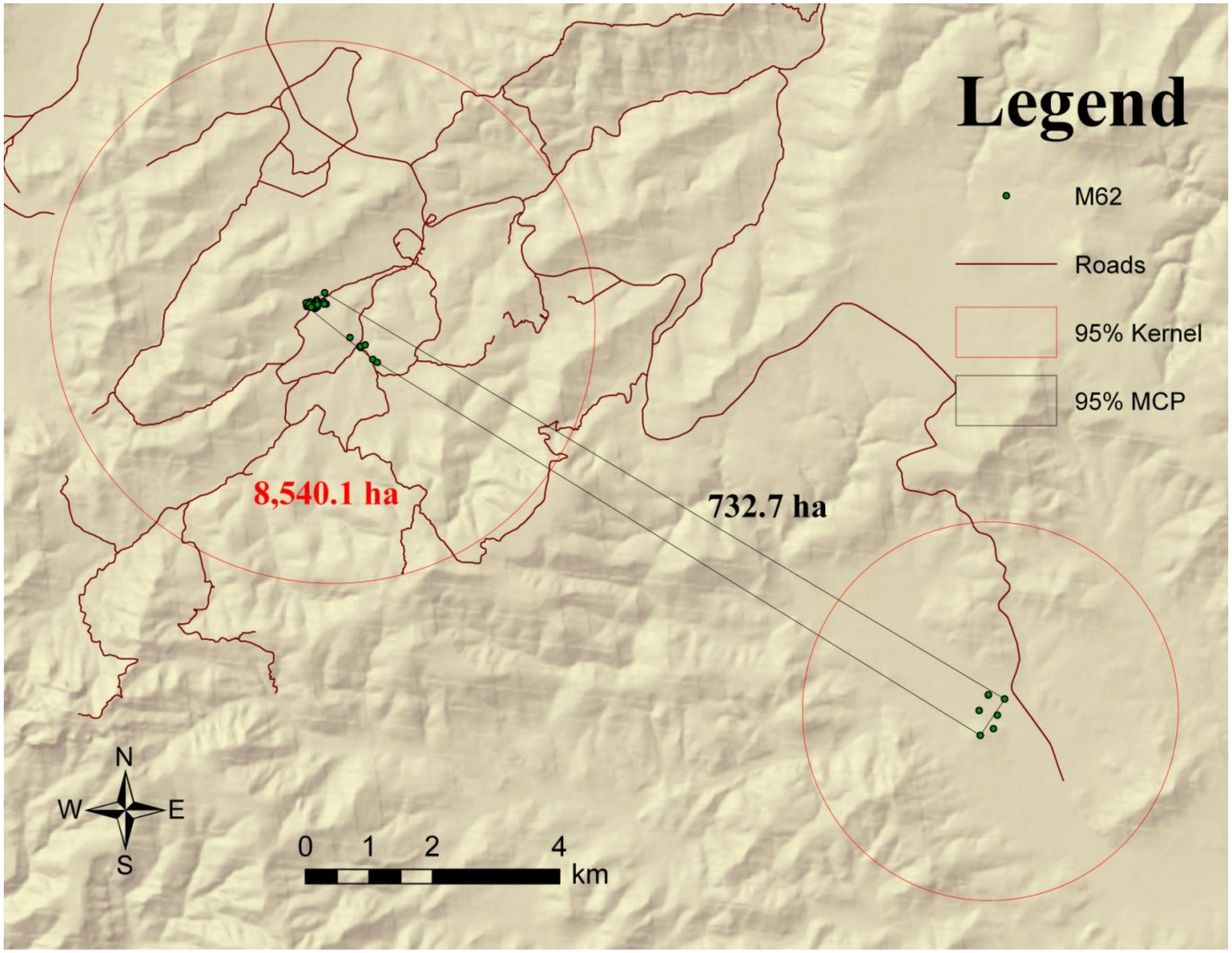

Figure 1.12. Home range size calculated using 95% MCP (732.7 ha) and 95% fixed kernel (8,540.1 ha) for Montezuma quail (M62) in the Davis Mountains of Texas, 2009 – 2010.

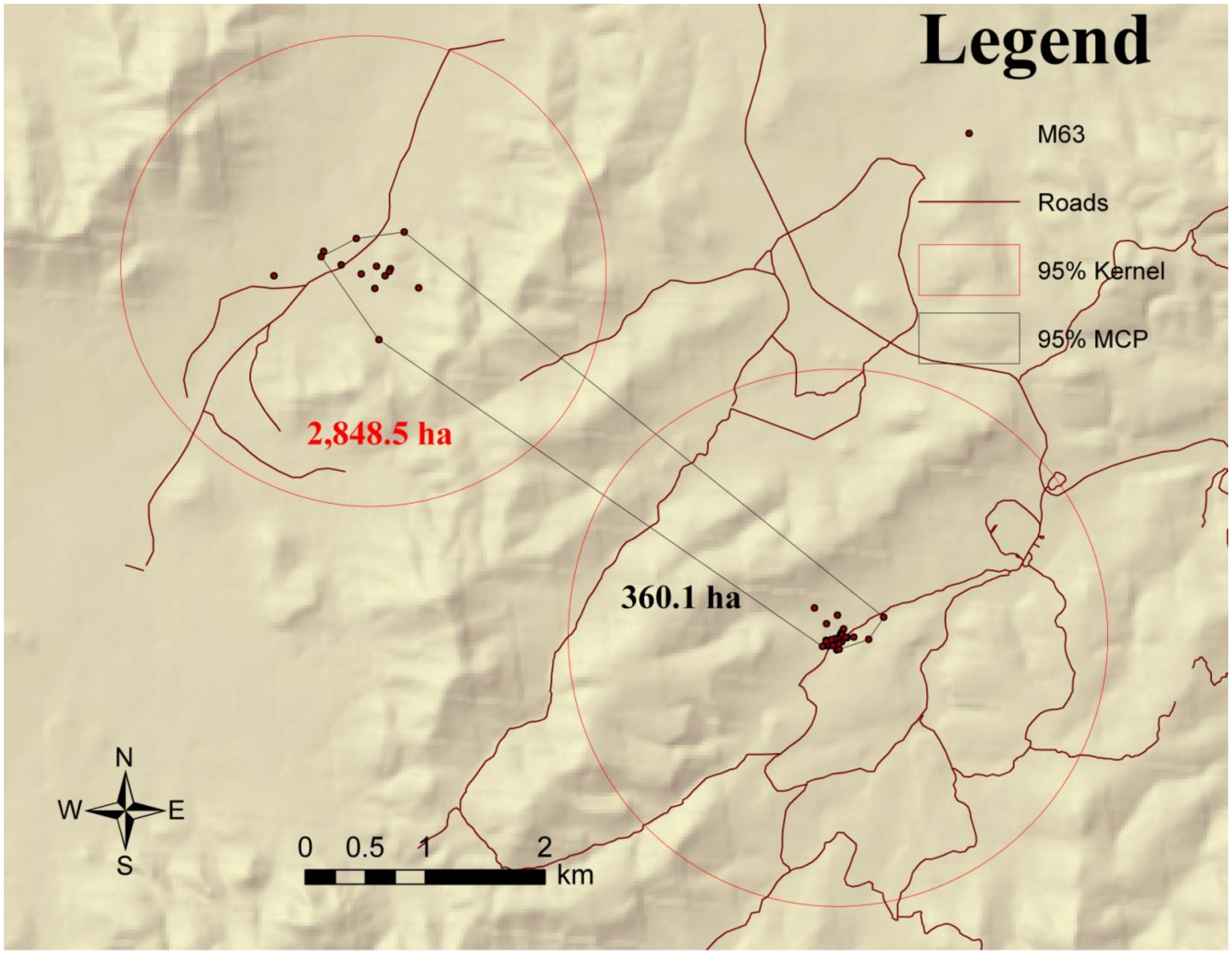

Figure 1.13. Home range size calculated using 95% MCP (360.1 ha) and 95% fixed kernel (2,848.5 ha) for Montezuma quail (M63) in the Davis Mountains of Texas, 2009 – 2010.

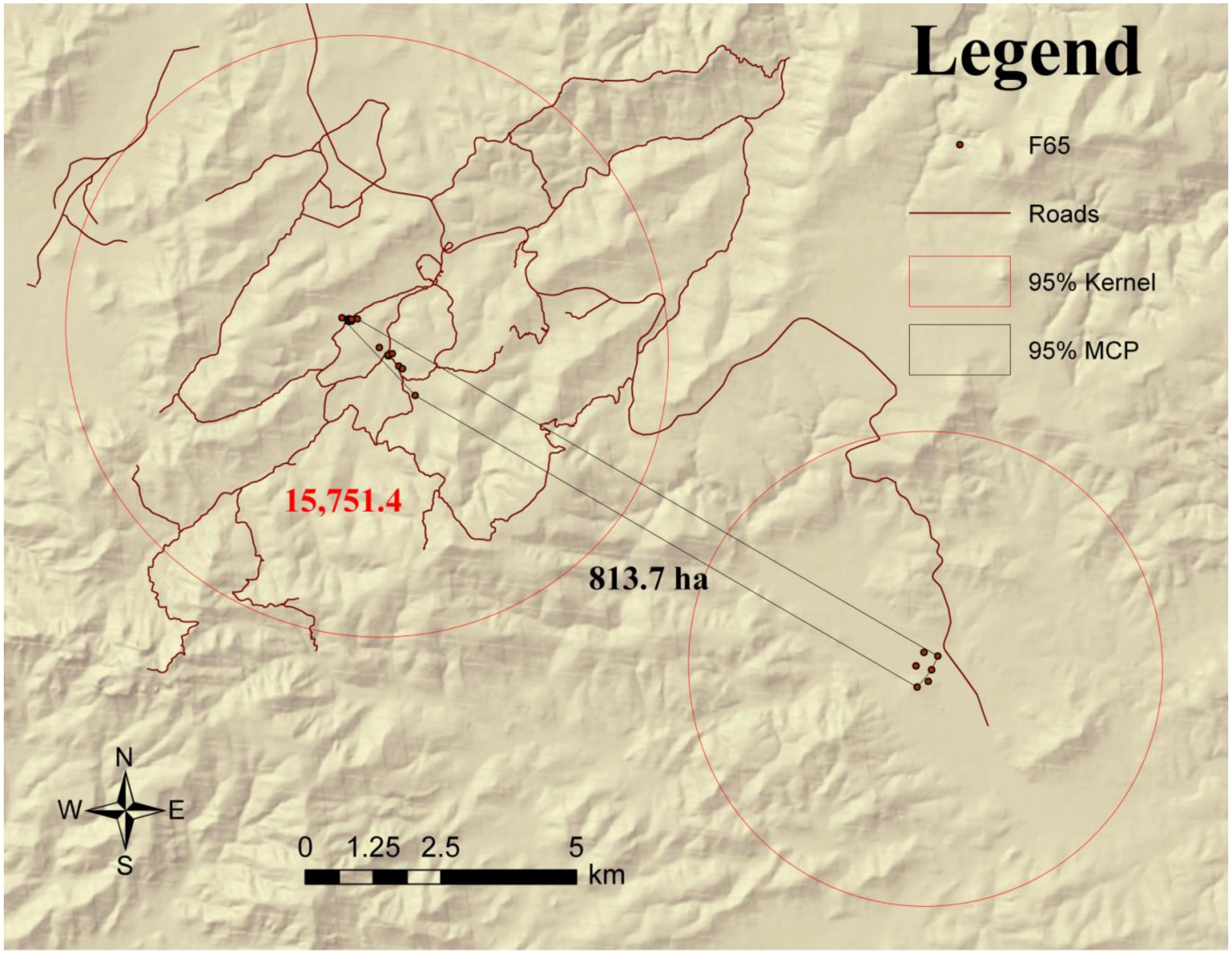

Figure 1.14. Home range size calculated using 95% MCP (813.7 ha) and 95% fixed kernel (15,751.4 ha) for Montezuma quail (F65) in the Davis Mountains of Texas, 2009 – 2010.

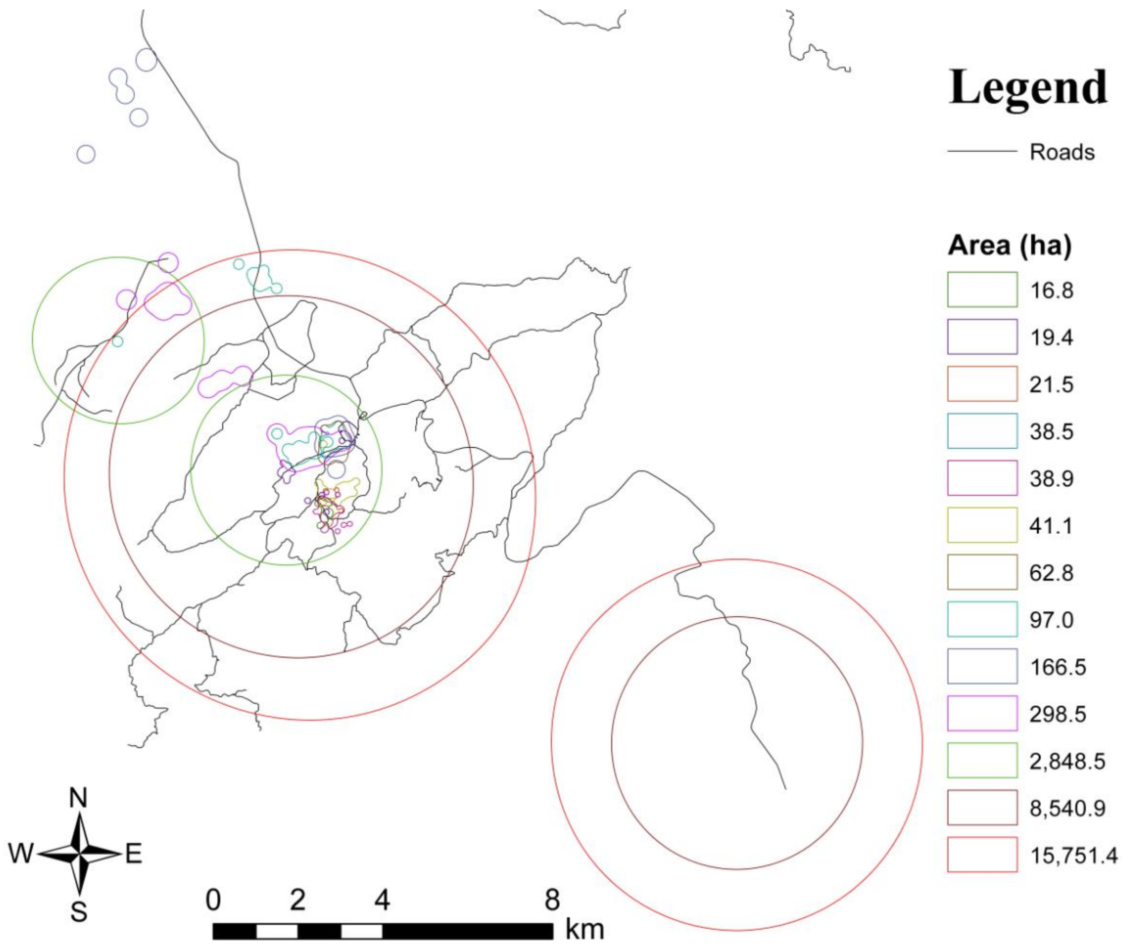

Figure 1.15. Home ranges (95% fixed kernels) for 13 radio-marked Montezuma quail in the Davis Mountains of Texas, 2009 – 2010.

Table 1.1. Home range size and maximum distance across home ranges for radio-marked Montezuma quail in the Davis Mountains of Texas from 2009-2010.

Sex	Bird Band Number	Number of Locations	95% Fixed Kernel (ha)	95% MCP[a] (ha)	Distance[b] (km)
Males	13	29	41.1	32.7	1.42
	21	45	21.5	24.7	0.82
	22	30	16.8	11.5	0.62
	50	36	298.5	651.1	6.08
	52	27	19.4	38.0	1.73
	54	28	166.5	1,486.6	10.70
	62	50	8,540.9	732.7	12.74
	63	49	2,848.5	360.1	5.84
Females	23	82	38.9	31.7	0.95
	47	30	38.5	19.8	0.76
	48	41	62.8	29.4	0.86
	61	37	97.0	406.3	5.49
	65	27	15,751.4	813.7	12.74
$\bar{X}$ (SD)			2,149.4 (4,736.8)	356.8 (454.4)	4.67 (4.70)

[a]Minimum Convex Polygon

[b]Greatest distance across home range

estimates. Others have described range sizes for Montezuma quail (Brown 1978, Leopold and McCabe 1957). Leopold and McCabe (1957) suggested 4–10 ha for general range based off of observations of coveys. My data reflects home range sizes much larger than previous reports. Although Montezuma rarely fly they had the ability to cover long distances a foot. Over short periods of time they often used centralized areas (Stromberg 1990, my study). However, Montezuma quail have the ability to move great distances (>10 km) in a short amount of time. Stromberg (1990) reported that Montezuma quail have multiple small use areas within their range. This study concurred with Stromberg's findings, only movements between small use areas were considerably greater distances.

Contradictory to the findings of Stromberg (1990), quail moved distances >61 m in a day. In my study, larger movements (>1 km) were recorded in summer months (May – July). These longer movements were made following coveys break-up and prior or during the pairing season. The longest movement was observed for a pair in which both M62 and F65 were radio-marked. From 29 June – 20 July the radioed pair moved 11.3 km and eventually nested at their new site. Reasons for the large movement are unknown. Much of the habitats the pair traversed was considered optimal habitat and supported Montezuma quail. A similar instance occurred with M63 after he lost his mate (F66) on June 3. M63 was captured again with a new mate (F68) June 10, and then proceeded to make a 4.86 km move (June 17 – June 25).

Another example of abnormal movements that I documented was with a male Montezuma quail (M50). M50 was located with an unmarked female throughout the pairing season. The movements began to become concentrated as if preparing for a nesting attempt. Following the smaller movements, an erratic movement caused his disappearance from 5 May – 4 June. M50 lost his pair bonded female and began to move more freely. He was captured the date of being relocated without a mate. The distance between the last location before being lost and the recapture was 3.15 km. After the apparent disappearance of the mate, he began moving great distances (>1 km) between locations (Appendix A). In doing so I considered him to be a satellite male looking for a mate.

Leopold and McCabe (1957) suggested Montezuma quail showed feeding site fidelity. Although my study did not analyze site fidelity it should be mentioned that radio-marked coveys were observed in the same general area over short durations (e.g., 1 – 4 weeks) suggesting it applies to Montezuma quail in Texas as well. Brown (1978) observed that coveys normally have home ranges <6 ha. Before pairing season, coveys generally did not make large movements but they did cover much larger ranges than the 6 ha suggested by Brown (1978).

Short range altitudinal migrations due to weather have been noted in higher elevations in Arizona and New Mexico, but were thought never to exceed a few km (Zornes and Bishop 2009, Leopold and McCabe 1957). No such migrations were observed in this study. I did observe quail throughout varying elevations regardless of the time of year. Montezuma quail were observed at the highest elevations along mountain rims as well as along drainages in the summer and winter months. The highest elevation in the Davis Mountains occurs atop Mount Livermore where hikers often have Montezuma quail sightings throughout the year (C. Pipes, unpublished data).

Home range size of Montezuma quail in the Davis Mountains could be considered similar to its neighboring species, scaled quail. It has been reported that scaled quail in western Texas have winter home ranges 71-210 ha and summer home ranges of 291 – 882 ha (Wallmo 1956, Brown 1989). Although winter data is limited, it suggests the possibility that while coveys are still together Montezuma quail had more restricted home ranges like those described in previous research (Brown 1978, Stromberg 1990), but in spring and summer they begin to make larger movements therefore increasing home range. Similar movements have been reported for scaled quail going to and from their winter range in foothill habitats (Brown 1989); usually these movements did not exceed 4 km (Schemnitz 1994).

Management Implications

Montezuma quail have been a great challenge to researchers in the past limiting what is known about movements amongst a population. Using trained dogs during the day and at night proved to be successful in capturing birds. Modern backpack style transmitters allow for prolonged monitoring and limited the radio-handicapping experienced in the past (Hernandez et al. 2004). Although my sample size is just 13, knowing Montezuma quail have the ability to make long movements and have larger than expected home ranges impact the management strategies and overall understanding of the species. Managing lands on larger scales could be valuable in expanding Montezuma quail populations. Also, knowing the ability for the ground dwelling bird to make long movements gives potential for increasing the areas occupied by Montezuma quail potentially leading back to the historical distribution that has been affected by overgrazing.

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CHAPTER 2:

HABITAT SELECTION BY MONTEZUMA QUAIL IN THE DAVIS MOUNTAINS OF TEXAS

In the United States, Montezuma quail (*Cyrtonyx montezumae*) are found in southeastern Arizona, southern New Mexico, and western Texas within mountainous habitats or rolling foothills (Stromberg 2000). Montezuma quail are unique among other quail species in that they excavate the tubers and rhizomes in the root system of various plants composing much of their diet (Stromberg 2000). Sightings are rare due to the cryptic nature of Montezuma quail and their presence is often identified by signs or vocalizations such as diggings, roost sites, and calls during the breeding season (Hernandez 2006). With limited hard data, most literature about Montezuma quail habitat has been based on sightings or sign (Bristow and Ockenfels 2002, 2004; Brown 1978; Leopold and McCabe 1957). Most studies on Montezuma quail have been anecdotal because of the challenges researchers were faced with in capturing and keeping them alive (Harveson et al. 2007, Hernandez et al. 2009, Hernandez et al. 2006).

Montezuma quail are considered to be an indicator species for pine–oak woodlands throughout the southwest (Harveson et al. 2007). Using flush sites to determine habitats used, vegetation height and dense grass cover was determined to be an important component (Bristow and Ockenfels 2004). Cattle grazing practices have been shown to directly affect Montezuma quail (Brown 1982). Dense bunch grasses have been found to provide nesting structure during the production phase of a Montezuma quail's life cycle (Stromberg 2000). Cover provided from prominent grass understories were essential for protection from predators (Brown 1989).

Stromberg (1990) performed a telemetry study on Montezuma quail in the Huachuca Mountains of southeastern Arizona in which some habitat use was evaluated. However, number of locations used and number of individuals were low limiting the interpretation of those findings. Other researchers have faced hardships when trapping and monitoring because of the radio-handicapping created by traditional neck-loop transmitters (Garza et al. 2007, Hernandez et al. 2006). With improvised trapping techniques and modified backpack style transmitters success in capturing larger quantities of birds and monitoring over longer periods of time were made possible.

By discovering what habitats are preferred landowners could better manage for Montezuma quail. My objective was to determine habitat use by Montezuma quail, specifically habitat selection using the S-statistic (S') to determine preference of habitat type using a radio telemetry study. Radio telemetry allowed for minimal disturbance of the same individuals continually followed throughout their daily routines. This provided an in depth look into which habitat types were preferred out of the habitats available within the study area. In return, landowners or managers could potentially use information on habitat preferences to more efficiently manage properties for production of Montezuma quail in the Davis Mountains of Texas.

Study Area

My study was conducted in the central portion of Jeff Davis County, Texas 40 km northwest of Fort Davis along HWY 118, the 8,760 ha study area is composed of mountainous terrain in the northeastern Chihuahuan Desert (Figure 1.1). My study site consisted of a highly diverse desert ecosystem with elevations ranging from 1,600 – 2,200 m. Soils were drained, hilly to steep, loamy, shallow to deep and non-calcareous (Soil Conservation Service 1977). Monsoonal rains were prominent from June on into September generating 28 – 57 cm annually. The area was composed of 12 ecological sites (Figure2.1). Grazing practices ranged from not being grazed at all to being highly utilized in some areas. Dominant grazing practices were conservative to not grazed. Although hunting of large ungulates was common throughout, Montezuma quail populations had no hunting pressure with little human interface. Predator control was moderately implemented on some ranches and not at all on others. The Nature Conservancy property, Davis Mountain Preserve, was in the central portion of the study area with many of the properties adjoining it under conservation easements. Prescribed fire had been used throughout most of the area to mimic historical fire regimes.

Methods

Two capture techniques were conducted that are similar and are both modified from previous research on game birds. The first technique consists of using trained pointing dogs to locate the birds in the evening hours before the quail went to roost. I would hunt the dogs as typical bird hunters do in Arizona and New Mexico, only the use of hoop nets and throw nets allowed for birds to be captured alive. When a dog locked down on point the research crew would slowly and carefully maneuver around the dog, locate the quail, and place a net over the birds when possible (Brown 1976). If successful, birds were placed in a carrying bag and taken back to be radio-marked using a backpack style transmitter (4-6 g), aged, sexed, leg banded, and had morphological measurements taken. If unsuccessful, the location of the flush site was recorded on a

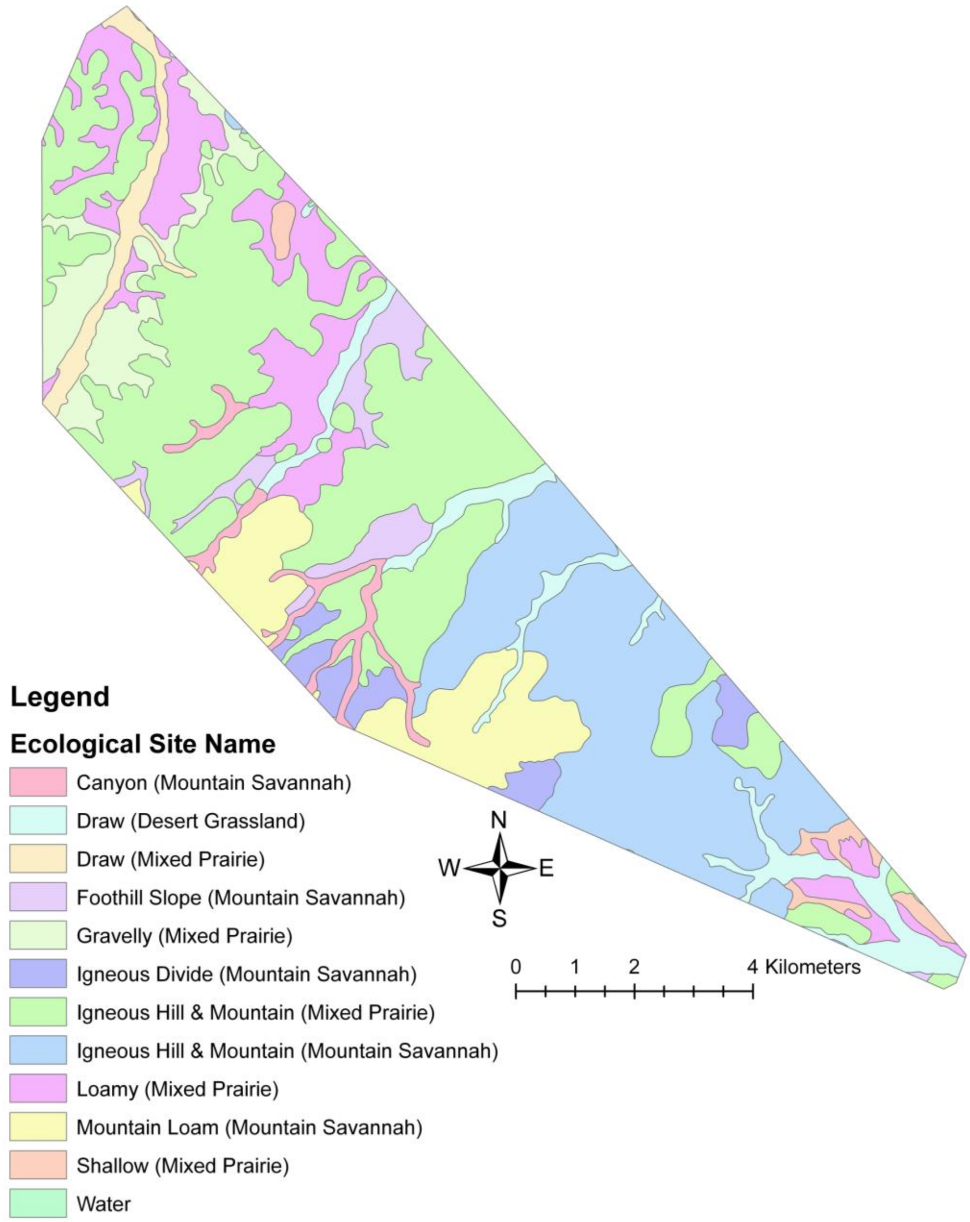

Figure 2.1. Twelve ecological sites distributed across the 8,760-ha study area used for monitoring Montezuma quail in the Davis Mountains of Texas.

global positioning system (GPS) with the intent of coming back at night. After waiting 30 minutes after sunset using dogs equipped with a tracking collar (Garmin Astro 220 and DC-30, Olathe, Kansas) as well as a lighted collar were taken back to the original flush site to pursue the roosting covey. A research crew with head lamps, throw nets, and hoop nets would then hunt the dog in the surrounding area until the dog went on point or became fatigued. If the dog went on point, the crew rushed to the site and looked in front of the stationary dog until a roosting covey was located. Crew members were then strategically placed around the located roost with hoop nets, and the throw net was cast upon the covey. Captured birds were placed in bags and taken to a lighted facility to be processed and radio-marked.

A different style of capture was conducted on coveys with ≥1 transmitted to generate numbers. I used a night netting technique with the aid of radio telemetry described by Labisky (1959, 1968) and Hernandez et al. (2006). In doing so, researchers homed-in on a radio-marked bird at night and located the roosting covey with head lamps. Using the same technique described earlier a net was placed over the covey. Captured birds were taken back to the facilities to be worked up. Recaptured birds had weights and transmitters replaced as needed. All captured birds were held overnight and released the following morning at the capture site.

Radio telemetry was conducted using a receiver (Advanced Telemetry Systems R4000, Isanti, MN), yagi antenna, handheld device (Palm T/X or Palm Tungsten E2) equipped with Locate III software (Tatamagouche, NS, Canada), and a GPS. The error associated with the GPS was acceptable as long as it was <7 m. Locate III software allowed locations to be checked in the field to ensure the area of error ellipse was

<30,000 m^2. Such precision was needed to correctly identify the habitat type the transmitted Montezuma quail was located within (<100 m). Each radio-marked individual had 2-5 locations collected weekly at various times throughout the day. These locations were then brought into Locate III on a computer for usable locations in ArcGIS. Each individual had a corresponding shapefile consisting of all locations including capture locations and visual locations.

Shapefiles of soils were taken from the United States Department of Agriculture Natural Resource Conservation Service (NRCS) soil data mart. Ecological site names along with range classification were used to generate habitat types. Soil layers were joined with habitat classification tables for the habitat selection analysis. Selection ratios (*S'*) were calculated as $S' = ([U+0.001]/[A+0.001])$ where *U* is the observed use and *A* is the availability of the habitat variable (Lopez et al. 2004, Manly et al. 2000). Habitat selection ratios were analyzed on 3 spatial scales (Johnson 1980). The first-order selection considers all locations with physical characteristics compared to the presence of all physical characteristics within the study area (i.e., point to study area). The second-order selection analysis compares physical characteristics within each individual's MCPs to the physical characteristics within the study area (i.e., range to study area). The third-order selection reflects the individual's use of physical characteristics based on locations to what characteristics compose their home range (i.e., point to range).

Availability was determined for the study area by including all radio locations for radio-marked birds with >25 locations in a 100% minimum convex polygon (MCP) using Home Range Tools (HRT) in ArcGIS. For second order analysis, I used individual 100% MCP performed on their locations for their range to be used for availability. Soil shapefiles were clipped using the 100% MCPs and areas were determined for each habitat classification. All locations were clipped from soil shapefiles to determine the use of birds for first and third order selection ratios. Determining use for second order selection consisted of using HRT to perform 50% fixed kernels as core use areas. Soil shapefiles were clipped using core use areas and values for habitat composition were employed for use in the selection ratio.

Results

Over the course of the study a total of 72 Montezuma quail was captured, 68 of which radio-marked, resulting in a total 966 radio locations. Thirteen of the 68 transmitted quail had (>25) sufficient relocations for analysis totaling to 638 locations used in evaluating habitat selection in this study. Two birds (M21 and F23) were monitored in both years of data collection. All other birds were monitored during only one of the field seasons.

For first-order analysis, Montezuma quail preferred canyon mountain savannah, foothill slope mountain savannah, and igneous divide mountain savannah (Figure 2.2). Montezuma quail appeared to use igneous hill and mountain mixed prairie in proportion to availability while avoiding other habitat types.

For second-order analysis, Montezuma quail preferred canyon mountain savannah and foothill slope mountain savannah (Table 2.1). Igneous hill and mountain mixed prairie and mountain loam mountain savannah were both preferred by 3 radio-marked Montezuma quail. Individuals preferring igneous hill and mountain mixed prairie and mountain loam mountain savannah had the majority of locations collected in the pairing and breeding season (March – July). Montezuma quail appeared to avoid draw desert

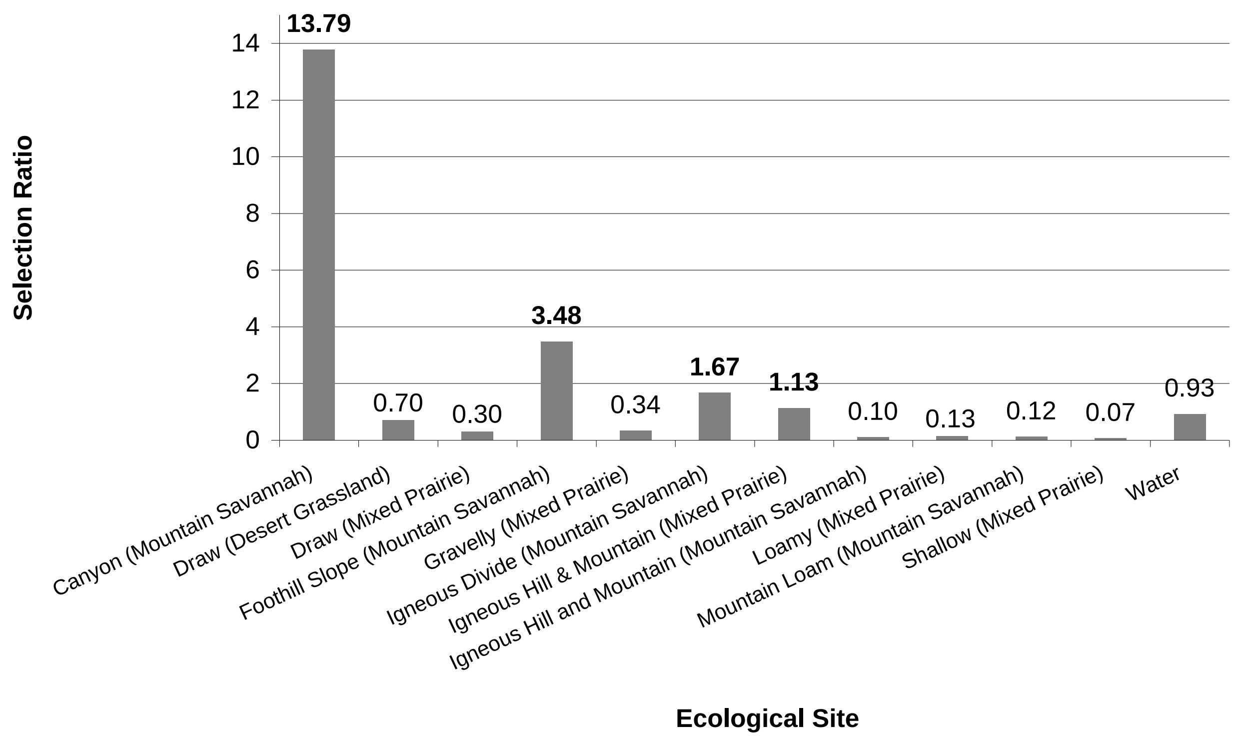

Figure 2.2. First-order habitat selection using the S-statistic, *S'*= ([Use+0.001]/[Availability+0.001]), for radio-marked Montezuma quail in the Davis Mountains of Texas from 2009 – 2010.

Table 2.1. Second-order habitat selection using the S-statistic, *S'*= ([Use+0.001]/[Availability+0.001]), for radio-marked Montezuma quail in the Davis Mountains of Texas from 2009 – 2010.

Habitat Type	M13	M21	M22	F23	F47	F48	M50	M52	M54	F61	M62	M63	F65
Igneous Hill and Mountain (Mountain Savannah)	-	-	-	-	-	-	-	-	-	-	0.03	-	0.22
Canyon (Mountain Savannah)	**1.52**	**2.07**	**2.24**	**3.01**	0.09	0.45	**2.01**	**2.81**	0.43	0.12	**4.61**	**1.75**	**3.49**
Draw (Desert Grassland)	0.04	-	-	-	-	0.01	0.04	0.03	0.05	0.03	0.10	-	0.17
Draw (Mixed Prairie)	-	-	-	-	-	-	-	-	0.01	**7.70**	-	0.94	-
Foothill Slope (Mountain Savannah)	0.04	-	-	-	**1.01**	**1.22**	**6.10**	0.10	**37.94**	0.06	**63.60**	**1.27**	**36.45**
Gravelly (Mixed Prairie)	-	-	-	-	-	-	0.30	-	0.02	-	-	0.79	-
Igneous Divide (Mountain Savannah)	-	-	-	0.10	-	-	-	0.23	-	-	-	-	0.56
Igneous Hill & Mountain (Mixed Prairie)	0.93	0.71	0.46	0.57	-	0.32	0.69	0.24	0.00	**1.04**	**2.37**	0.67	**2.07**
Loamy (Mixed Prairie)	-	-	-	-	-	-	0.01	-	0.00	0.00	0.41	-	0.51
Mountain Loam (Mountain Savannah)	-	-	-	-	-	-	0.02	-	-	0.02	**1.71**	**1.51**	**1.95**
Shallow (Mixed Prairie)	-	-	-	-	-	-	-	-	-	-	0.03	-	0.03

grassland, gravelly mixed prairie, igneous divide mountain savannah, loamy mixed prairie, and shallow mixed prairie.

For third-order analysis, Montezuma quail preferred canyon mountain savannah and 4 preferred foothill slope mountain savannah (Table 2.2). Igneous hill and mountain mixed prairie was preferred by 3 individuals with no more than 1 individual preferring any other habitat type when analyzed on a point to range scale.

Discussion

Previous studies have described habitats used by Montezuma quail (Bristow and Ockenfels 2004, Brown 1978, Brown 1989, Leopold and McCabe 1957, Stromberg 1990, Walmo 1954). The use of diggings for food, flush sites, and roosts has allowed researchers to determine areas known to be used and compared such areas to random locations for evaluating the habitat use areas (Stromberg 1990, Garza 2007). In Arizona, Montezuma quail used areas where there was higher diversity of grasses, forbs, and tree species (Bristow and Ockenfels 2000, 2002, 2004). Height of grass has also been distinguished to be an important component in areas used (Bristow and Ockenfels 2000, 2002, 2004). Canopy cover has been determined to be at optimal levels from 20 – 50% (Brown 1982, Bristow and Ockenfels 2000). With crop analyses and assessment of vegetation in areas where diggings are present, diet composition has been identified and primarily consisted of bulbs and tubers of sedges (*Cyperus* spp.) and woodsorrels (*Oxalis* spp.) (Bishop and Hungerford 1965, Brown 1978). Throughout the winter months with insects and acorns being staple food items in the summer months (Albers and Gehlbach 1990, Bishop and Hungerford 1965).

Table 2.2. Third-order habitat selection using the S-statistic, *S'* = ([Use+0.001]/[Availability+0.001]), for radio-marked Montezuma quail in the Davis Mountains of Texas from 2009 – 2010.

	M13	M21	M22	F23	F47	F48	M50	M52	M54	F61	M62	M63	F65
Igneous Hill and Mountain (Mountain Savannah)	-	-	-	-	-	-	-	-	-	-	0.00	-	0.00
Canyon (Mountain Savannah)	**1.61**	**1.75**	**2.19**	**2.78**	**3.09**	**1.52**	0.02	**2.42**	0.43	0.03	**32.45**	**8.45**	**27.14**
Draw (Desert Grassland)	0.04	-	-	-	-	0.56	0.04	0.03	0.05	0.03	0.43	-	0.64
Draw (Mixed Prairie)	-	-	-	-	-	-	-	-	0.99	-	-	**3.41**	-
Foothill Slope (Mountain Savannah)	**1.33**	-			0.98	0.99	**5.79**	0.56	**28.46**	**7.05**	0.34	0.92	0.32
Gravelly (Mixed Prairie)	-	-	-	-	-	-	0.86	-	0.02	1.63	-	0.99	-
Igneous Divide (Mountain Savannah)	-	-	-	0.10	-	-	-	0.23	-	-	-	-	0.56
Igneous Hill & Mountain (Mixed Prairie)	0.86	0.79	0.48	0.62	-	**8.09**	0.65	0.35	0.14	**1.01**	0.93	0.28	**1.53**
Loamy (Mixed Prairie)	-	-	-	-	-	-	0.55	-	0.33	0.00	0.23	-	0.48
Mountain Loam (Mountain Savannah)	-	-	-	-	-	-	0.52	-	-	0.58	0.01	0.01	0.01
Shallow (Mixed Prairie)	-	-	-	-	-	-	-	-	-	-	0.03	-	0.03

In my study, Montezuma quail occupied much of the study area throughout the year and therefore habitat requirements were assumed to have been met. Across the 3 spatial scales, trends of habitat selection emerged. Canyon mountain savannah and foothill slope mountain savannah were the most preferred habitats in this study. Such habitat types are often associated with drainage areas or creeks. These lowlands have been known to keep fertile soils and higher moisture content. These habitats also provided adequate vertical structure with a higher diversity of forbs, grasses, trees, and shrubs.

Igneous hill and mountain mixed prairie was the most preferred habitat overall in the first order of selection along with 3 or more quail in the second and third order selection analyses. During the pairing and nesting season movements were made into the mixed prairie habitat type. Two nests were documented in the mixed prairie habitat consisting of less canopy cover by trees and a higher abundance of bunch grasses. Bristow and Ockenfels (2004) found similar results of selection for dense grass cover during the pairing season.

Management Implications

Previous studies have provided information on desired habitat components and grazing strategies to benefit Montezuma quail (Brown 1982, Bristow and Ockenfels 2004, Leopold and McCabe 1957). The ability to monitor individuals with radio telemetry allowed for determining what habitat types were selected for throughout various times of the day. Land managers can focus efforts for improving habitat conditions on preferred habitat types to make management practices more effective and cost efficient. Identifying preferred areas could lead to providing insight on key areas of interest for locating Montezuma quail for hunting purposes or ecotourism.

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CHAPTER 3:

POPULATION CHARACTERISTICS AND BASIC ECOLOGY OF MONTEZUMA QUAIL IN THE DAVIS MOUNTAINS OF TEXAS

Montezuma quail (*Cyrtonyx montezumae*) only occur within 3 states in the southwestern portion of the United States. The northern portion of their historical range includes southeastern Arizona through the Edwards Plateau of Texas (Stromberg 2000). Much of the distribution of Montezuma quail includes Mexico ranging from the United States – Mexico border to the central portion of the country (Stromberg 2000). While historical range has been established, other aspects of population characteristics and life history remain unknown. At one point it was thought that Montezuma quail were nowhere common and possibly extinct in the United States with the exception of pen reared birds owned by breeders (Pearson 1936). Although populations are localized, Arizona and New Mexico have allowed annual hunting seasons. Such seasons have provided information on adult and juvenile composition of the populations as well as sex ratios (Zornes and Bishop 2009). Arizona has also used trained pointing dogs to census areas where quail exist to monitor covey size and give rough density estimates (Ockenfels et al. 2009). Texas does not have a hunting season or survey method for Montezuma quail limiting knowledge of population composition and density of quail from year to year. I conducted a radio telemetry study to elucidate the life history characteristics of Montezuma quail in the Davis Mountains of Texas. My objectives were to identify population characteristics, assess breeding ecology, and determine survival rates of Montezuma quail in Texas.

Study Area

The study was conducted in the central portion of the Davis Mountains of Texas (Figure 3.1). Based on the Davis Mountain Preserve owned by The Nature Conservancy, the study also is spread out through many of the neighboring ranches along HWY 118, 45 km northwest of Fort Davis, Texas in Jeff Davis County. With elevations ranging from 1,600 to 2,200 m the study site was 8,760 ha in size. Precipitation varied annually from 28.2 to 56.9 cm. Its habitat types were composed primarily of mountain savannahs and mixed prairies, and it was considered 1 of 3 sky island communities in the Trans-Pecos of Texas (DeBano and Ffolliot 2005). With mature stands of ponderosa pine (*Pinus ponderosa*) in the higher elevations followed by oak (*Quercus* spp.), pinyon pine (Pinus *cembroides*), and juniper (*Juniperus* spp.) in the lower elevations, there is a high diversity of both herbaceous and woody plant species.

Land management practices vary greatly across the landscape. Much of the property was not grazed but prescribed burning was used on natural fire intervals to provide disturbance in setting back succession (C. Pipes, pers. comm.). Other areas were active cattle operations with mainly conservative grazing practices implemented. A small portion was highly utilized by cattle which limited herbaceous cover. Predator control was practiced at varying intensities from no removal to very active control by trapping and shooting.

Methods

Two primary methods of capture were employed to successfully apprehend Montezuma quail without harm. The first method used trained pointing dogs to locate the covey or pair in the evening (Brown 1976). If possible a throw net was used in attempt to capture birds on the initial flush by casting over the hunkered down birds. If unsuccessful, the flushing location was marked on a global positioning system (GPS) to be revisited after sunset. With the use of a GPS (Astro 220 GPS and DC-30 tracking collar, Olathe, Kansas) along with a lighted collar, the same bird dogs were released in the area the covey had been located that evening for relocation of the birds at night. If the dog locked down on point, a capture crew with hoop and throw nets would identify the exact location by getting a visual on the roosted birds using head lamps and place a net over them. Captured birds would then be placed in a small tote sack for later handling. The other commonly used capture technique involved using radio telemetry equipment instead of relying on a dog's nose to relocate a quail or covey on the roost for new captures and recaptures (Labisky 1959, 1968). Although a similar approach was taken by the capture crew, the receiver with an antenna would allow for pin pointing the roosting birds allowing for a better fix on the covey in a timelier manner.

Once successfully captured, Montezuma quail were then taken back to a lighted facility for aging, sexing, radio-collaring, and measurements of morphological features. Birds were then kept overnight to be released the following morning at the roost site where they were captured. Prior to release the 5.8 g ATS (Isanti, MN) radio transmitters were activated to start the duty cycle.

Locations were collected using a receiver (ATS R4000, Isanti, MN), yagi antenna, compass, GPS, and handheld device (Palm T/X or Palm Tungsten E2) equipped with Locate III (Tatamagouche, NS, Canada). Each location consisted of ≥3 points with azimuths. An error ellipse of <100 m (<30,000 m^2) established a threshold for accurate and usable locations.

During the nesting season recognizable landmarks were used regularly with azimuths to identify nest initiations. Once determined to be nesting, a homing technique was used to mark the nest for locating it after the nest was abandoned.

Radio transmitters were equipped with a mortality sensor that would be activated by 4 hours of no movement. Mortality forms were used to document the first date of a mortality signal along with the condition of the recovered transmitter and location. Known fate models were produced using program MARK (Fort Collins, CO, USA) for calculating survival estimates (White and Burnham 1999).

Results

Montezuma quail were captured within the study area from January 2009 – September 2010 resulting in 72 captured and banded birds (36 M, 35 F, 1 Unknown; 30 Juveniles, 42 Adults). Of the captured birds 68 were radio marked before release. Montezuma quail coveys began breaking up into pairs at the end of February through the beginning of March in 2009, but covey break-up was much later in 2010 with the first pairs not being formed until late March. A covey of 3 males remained together until late April. I documented 4 nesting attempts initiated from mid-June through August. Three of the 4 nests were deemed successful containing 12 hatched eggs located within 2 of the 3 successful nests; the third successful nest was not found. The first brood observed during the study was on 07 July 2009 containing ≥7 chicks (2 – 3 weeks old) traveling with an unmarked pair.

Identified mortalities throughout my study were predominately predated by raptors (n=10) with ground dwelling predators being a secondary cause (n=6). In most cases, cause of death or transmitter removal was classified as unknown. Transmitter failure was also a common problem in the spring and summer of 2009. Using the known fate model through program MARK the survival estimate for transmitted Montezuma quail was 12.8% annually with 95 % Confidence Intervals ranging from 5.5% to 23.8%.

Discussion

Basic knowledge of population characteristics have been established for Montezuma quail in other states due to hunting seasons and wing barrels (Stromberg 2000). Collecting wings from birds harvested has provided information on age and sex ratios. Stromberg (1990) reported similar age and sex ratios from his study involving trapped birds. Both means of collection in Arizona and throughout New Mexico have described sex ratios to be skewed, having a bias toward males (up to 63:37) (Brown and Guitierrez 1980, Leopold and McCabe 1957, Stromberg 2000, Stromberg 1990). In fact, Brown and Guitierrez (1980) describe Montezuma quail as having the highest male bias of all bird species in North America, but my data did not suggest such extreme numbers. In my study, sex ratios were equal with only 1 more male than female being captured over the course of two years. Detectability of males in previous observational studies is likely higher than females due to the plumage differences. A hunter bias for male Montezuma quail could have influenced sex ratios due to the close range of shots taken and distinguishable coloration of males easily identifiable during a covey rise.

Juvenile Montezuma quail have composed steady percentages of harvested birds in Arizona from 1984 to 2005 (Mean = 72.7%, range 48 – 83%) which has suggested brood survival does not fluctuate as greatly as other quail species (Brown 1978, Heffelfinger and Olding 2000, Zornes and Bishop 2009). It has been speculated that production of Montezuma quail is influenced by population carryover and summer rainfall (Brown 1979, Brown 1989). The juvenile-adult ratio in this study was lower than expected at 43:57. Such a low percentage of juveniles is likely due to the time of year many birds were captured. Once Montezuma quail were paired up and in full breeding plumage (March – August), they were considered sexually mature and therefore counted as adults. Actual fall ratios would have revealed higher percentages of juveniles making age ratios more similar numbers suggested in literature.

Noted for having extended pairing seasons, Montezuma quail have been found to break up out of coveys in late February through March (Harveson et al. 2007, Stromberg 2000, Wallmo 1954). Covey disassembly occurred as expected in 2009 with no transmitted coveys remaining intact. However for reasons unknown, coveys delayed separation in the spring of 2010. The first observed parting or pair bonding did not occur until late March. The process was more drawn out than the prior year with a bachelor covey of 3 not breaking up until late April. The 3 males remained in a close area (often <100 m) from one another for over a month. During the early portion of determining pair bonds it was not uncommon to find >1 male accompanying a lone female on the roost. Stromberg (2000) describes spacing between pairs throughout most years to be 100 – 200 m apart. My observations suggest that within 2 – 3 months of pairing season it was not uncommon to find ≥2 pairs within 30 m of each other. As nesting season neared, less pressure was placed on finding new birds to radio mark and fewer recapture attempts were made to minimize effects of nesting making observations of spacing more limited. The largest movements made by any radio-marked Montezuma quail were done so in the form of pairs from May – July. During this time 3 pairs made large movements (>2 km) before a nesting attempt was made.

Biological timing of the nesting season of Montezuma quail coincides with monsoonal rains from July – August. Stromberg (2000) reported both sexes did not begin enlargement of reproductive structures until mid to late June. Nesting ecology of Montezuma quail is based on few documented nests and observations made of lone males or pairs during late summer. Combined literature has information on <20 nests (Stromberg 2000). My study, with the use of radio telemetry, closely monitored males and females during the production phase of their life cycle. Radio-marked Montezuma quail did not begin nest initiation in this study until the month of June in concurrence with Zornes and Bishop (2009). Movements before nesting were very isolated with the pair remaining close to the nest and staying in close contact with each other. Females were the only confirmed sex to incubate the eggs. Males were often within close proximity of the female, rarely exceeding 100 m of the nesting site. The male would then rejoin the female within a day of coming off of the nest with the brood. No cooperative nesting was documented in my study. However, with the small number of nesting attempts observed and the behavior exhibited by males during the nesting process, multi-clutch nesting strategies as seen in other quail species is still a possibility.

I recorded a nesting success rate of 75%. One of which was a successful renesting attempt performed within a month of prior nest being predated. Another female was thought to initiate a nest due to her behavior of restricting movements after a long move (>2 km) over a series of mountains. The male of the pair bond remained in the general vicinity of the female as observed in other cases in my study; however due to limited land access, no information was gathered of the suspected nesting attempt. Two of the 3 verified successful nests were located both having 12 hatched egg shells in the bowl. This was consistent with the average of 11.1 eggs/clutch (range: 2 – 15) reported by Leopold and McCabe (1957). The earliest visual observation of a brood occurred on 07 July 2009 when a covey containing at least one mature male and female along with ≥7 chicks was flushed. The brood was 2 – 3 weeks of age suggesting the female began nesting in late May. Wallmo (1954) reported that it is typical to find first broods in mid-July. First sightings of broods have been noticed as early as mid-June and as late as August (Stromberg 2000).

Documented nests were located in different habitats similar to nests reported by Stromberg (2000). Two of the 4 nests were in open grassland habitat with widely scattered oaks (*Quercus* spp.) and junipers (*Juniperus* spp.). The third nest was located within a small meadow under a snag on the edge of a juniper covered flat just before a drop off into Madera Canyon. The fourth nest was located in the bottom of a canyon near 2 large oak trees 4 m from a road. All nests located were in either a clump of bunch grass or in dense clumps of bunch grass (*Bouteloua* spp.). Montezuma quail have used covered chambers with finely woven grass and leaves for nest lining in Arizona (Wallmo 1954). The only visible portion of any nest found in my study was a small tunnel used for entering or exiting the enclosed nest. The nest lining was composed of primarily woven grass and the nest found in more open grassland used the roots similar to nests reported by Stromberg (2000). Dummy nests were found within close proximity to 2 of the actual nests in my study. In one case, a dummy nest was located on top the same clump grass which contained the enclosed nest underneath interwoven in the root system.

While little is known about nesting by Montezuma quail, even less is known on survivorship on the species. Very few birds have been banded with low recovery rates

(Stromberg 2000). No other study has been able to document the survival rates due to the difficulty capturing and keeping them alive (Hernandez et al. 2006, Stromberg 1990). Survival estimates for Montezuma within this study are similar to those found for both northern bobwhite (*Colinus virginianus*) and scaled quail (*Callipepla squamata*) in other telemetry studies. Rollins and Carroll (2001) reported annual survival rates varied from 5 to 26% across studies reviewed which closely corresponds to the confidence intervals projected in my study (5 - 24%). Stromberg (2000) reported Montezuma quail living up to 7 years in captivity. Avian predators, such as the Cooper's hawk (*Accipiter cooperii*), were the dominant cause of mortality as has been reported in Arizona (Stromberg 1990). Following the release of a captured bird, a Cooper's hawk was actually spotted with a quail in its talons. Being spooked by the observers the quail was dropped and identified as the same bird that had just been released.

Management Implications

Most knowledge on the general ecology of Montezuma quail is anecdotal and outdated with little known about birds occupying the northeastern portion of their range. A multi-clutch reproductive strategy is possible as seen in captivity, but was not observed in this study. Development of population indices based on age ratios has already been in place throughout much of their range due to the ability of sampling hunter harvested birds. With a continuance of monitoring, similar indices could become developed throughout their range in Texas as well. The population sampled in the Davis Mountains portrayed similar attributes to those in Arizona and Mexico populations.

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Appendix A. Distances traveled between successive locations for radio-marked Montezuma quail (M55) from 6 February 2010 – 12 July 2010 in the Davis Mountains of Texas.

Date (2010)	Movement (km)	Days Between
02/06-02/13	0.93	7
02/13-02/23	0.63	10
02/23-02/27	0.19	4
02/27-02/27	0.11	0
02/27-03/02	0.30	3
03/02-03/06	0.34	4
03/06-03/17	0.13	11
03/17-03/21	0.09	4
03/21-03/24	0.16	3
03/24-03/27	0.19	3
03/27-03/29	0.38	2
03/29-03/31	0.40	2
03/31-04/02	0.15	2
04/02-04/06	0.39	4
04/06-04/08	0.24	2
04/08-04/10	0.16	2
04/10-04/16	0.20	6
04/16-04/18	0.44	2
04/18-04/21	0.69	3
04/21-04/24	0.45	3
04/24-04/28	0.68	4
04/28-04/30	0.25	2
04/30-05/04	0.20	4
05/04-05/05	0.38	1
05/05-06/04	3.15	30
06/04-06/11	0.38	7
06/11-06/23	2.26	12
06/23-06/25	0.91	2
06/25-06/26	1.31	1
06/26-06/27	0.43	1
06/27-06/29	0.78	2
06/29-07/01	1.13	2
07/01-07/02	0.28	1
07/02-07/08	0.42	6
07/08-07/12	2.62	4

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