ECOLOGY OF MONTEZUMA QUAIL IN SOUTHEAST ARIZONA

A Dissertation

by

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ABSTRACT

Montezuma quail (*Cyrtonix montezumae*) life history is the least understood of all North American quail due to historical difficulties in capturing and monitoring marked individuals of this species. Most aspects of its population dynamics, range and habitat use have remained as knowledge gaps until now. My study overcame these difficulties and I was able to trap and monitor 88 individuals from 2008–2010 at 3 study sites in southeast Arizona. Techniques for trapping and monitoring included the use of trained pointing dogs, hoop nets, funnel traps, and forward-looking infrared (FLIR) cameras.

I estimated survival probabilities as well as range size for radio-marked individuals. The estimated survival, using the Kaplan-Meier staggered entry method, combined amongst 3 study sties, was 21.9% from fall 2008–2009. Survival for quail at the Appleton-Whittell Research Ranch in 2010 was 4.8%. For range estimation, I used the minimum convex polygon (MCP) and fixed kernel estimators. The largest MCP range estimate for an individual (206.65 ha) was far greater than previous estimates reported for this species in the literature. The mean seasonal range size, using the fixed kernel 95% utilization distribution, also was 60% higher at Stevens Canyon, 63% higher at Hog Canyon, and 47% higher at the Appleton-Whittell Research Ranch than the largest use area (50 ha) reported in the literature. A wildfire in 2009 provided an opportunity to examine post-fire succession and habitat use. I observed roosting in fire-affected areas within 1 week post-fire and successful nesting in fire-affected areas within

3 months post-fire. Low survival and reduced 95% fixed kernel ranges for quail at the Appleton-Whittell Research Ranch in 2010 was attributed to strong El Niño conditions in the Pacific that brought a severe winter storm to the region.

The combined results from this research help to address knowledge gaps about Montezuma quail survival demographics, range, habitat use, and provide references to baseline data to assist managing potential impacts associated with stochastic events such as wildfire and periods of inclement weather associated with above average winter precipitation.

DEDICATION

For my family—including my dogs Chico and Choco—who persevered with me through wild thickets and a thin economy.

For my dog Blanca, who dedicated her last moments of life, despite cancer and old age, to helping me find birds in the rugged fields.

For the preservation and conservation of the Montezuma quail.

ACKNOWLEDGEMENTS

At Texas A&M University, my advisors provided moral and financial support throughout the course of my doctoral studies. Dr. Roel Lopez has been my mentor throughout my Masters and Doctoral studies and has been the most profound Latino role model I've ever had in academia. Dr. Nova Silvy has been a great source of encouragement and I have been very fortunate to have learned from his wisdom in the wildlife sciences. Dr. Manuel Piña has taught me much about leadership, motivation, and grant proposal writing through the benefit of the Hispanic Leadership Program in Agriculture and Natural Resources. Dr. Don Davis helped me complete my dissertation to the very end. Gillian Bowser, former faculty and long-time mentor in the National Park Service, introduced me to TAMU and the graduate programs and I owe much to her in helping me and other minority students succeed in the sciences. Louis Harveson of Sul Ross State University provided initial guidance with the project.

Several students, interns, and field assistants made collecting data for this research successful. Brady Surber of Sul Ross State University volunteered at the very beginning of the project. Cynthia Soria and Alison Kocek spent many long hours trapping quail with me in the wilderness of southeast Arizona. Audubon interns Rachel Burand, Gavin Cude, Sarah Lapidus, Richard Chasey and Lindsey Reifl assisted with radiotelemetry. Lily Ng, a student intern from the National Hispanic Environmental Council summer science institutes, also helped with trapping and taking care of my dogs.

Several professional dog handlers and their dogs helped out on this project. I thank Angel Montoya of U.S. Fish and Wildlife Service (USFWS) and Steve Hopkins

(Arizona Quail Alliance) for field assistance with their well-trained dogs. Angel Montoya, in particular, spent many long hours in the field getting me started on the project and teaching me how to "hunt" with dogs. Steve Hopkin's familiarity with the Coronado National Forest lands was particularly helpful in locating birds. Dr. Sanford D. Schemnitz provided much counsel for training dogs when I began my research and also introduced me to my research assistant "Blanca". My last year of collecting data in the field also would not have been possible if Ray Trejo, of New Mexico, had not donated and let me adopt my research assistant "Chico".

The research assistant dogs in my study deserve Masters of Science degrees and their fair share of credit for the time and effort they put into this research. Without the contribution provided by dogs it would have been nearly impossible to locate and trap birds. Amongst the cast and crew are Steve Hopkin's Brittany Spaniels "Dolly" and "Deejay", Kirby Bristow's German Short-haired Pointer "Tiny", and Angel Montoya's German Short-haired Pointers "Chispa" and "Rippa". Louis Harveson and Sul Ross State University lend a hand by allowing "Choco", another German Short-haired Pointer, to assist in my research. I also adopted 2 English Pointers, "Blanca" and "Chico", to assist in my project. Choco and Blanca braved the fire-scorched conditions for post-fire succession quail surveys even when the ground was still hot and the Mojave green rattlesnakes were out and about. Blanca and Chico did not mind searching for birds despite high wind chill and freezing conditions in the field in 2010.

Generous support was provided by a Sloan Foundation Fellowship, Ariel-Appleton Fellowship, National Audubon Society Apacheria Fellowship, Dr. Tad Pfister

(Arizona Quail Alliance), and other generous folks that visited my presentations at the Appleton-Whittell Research Ranch. The "Chavarria Charitable Fund" (Mom, Dad, Sis, Bro) provided moral support and helped me get through tough economic times. Peter Toot of southeast Arizona provided initial funding in support of this research. Gene Kindred of Canyon View Kennels trained my field assistant "Choco". Hank Hartnek of Tri-tronics provided a dog training collar for use in this research. Staff at the Appleton-Whittell Research Ranch, including Leo Gonzalez and Pat Kugler, provided logistical support and reported quail sightings. Jim Upchurch and A. W. Campbell of the Coronado National Forest provided GIS coverage and wildland fire reports regarding the Canelo fire. Kirby Bristow and Jim Heffelfinger (AZG&F) Department provided counsel. Edwin Juarez (AZG&F) volunteered countless hours in the field trapping birds during the night. Alison Kocek, Jan Miller, and staff at Liberty Wildlife Rehabilitation (Prescott, Arizona, USA) provided support in rehabilitating 2 injured quail in my study—one which went to a captive breeding program and another which was successfully released back to the wild in spring 2010. Dr. Christine Hass, Dr. Linda Kennedy, and Dr. Mark Stromberg at the Appleton-Whittell Research Ranch of the National Audubon Society deserve special mention. Without their permission to conduct studies at the Ranch, their moral support, support for lodging and fellowships, this study would not have been very successful. I thank them for believing in me and my research so that we can make necessary advances in science for conserving this precious species—the Montezuma quail.

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CHAPTER I[*]

ECOLOGY OF THE MONTEZUMA QUAIL: INTRODUCTION, BACKGROUND AND NEED FOR RESEARCH

Cryptic plumage and extreme adaptive stillness are just 2 characteristics of Montezuma Quail (*Cyrtonyx montezumae spp.*) which makes it the least understood species of quail throughout North America. A neotropical bird in origin, the geographic distribution of this species is more widespread throughout Mexico than in the southern United States (U.S.). Some subspecies, such as *Cyrtonyx montezumae sallei,* range as far south as Oaxaca, Mexico (Sullivan 1994). The northernmost subspecies, *Cyrtonyx montezumae mearnsi*, is sparsely populated in west-central Texas, more abundant in central New Mexico, and most abundant from central Arizona south to northern Coahuila (Sullivan 1994). Other members of the subspecies include *Cyrtonyx montezumae merriami* which occurs in Veracruz, in the vicinity of Mount Orizaba, *Cyrtonyx montezumae montezumae* which occurs in Michoacan, Oaxaca, Distrito Federal, Hidalgo, Puebla, northern and eastern Nuevo Leon, and west-central Tamaulipas, and *Cyrtonyx montezumae rowleyi* which occurs in Guerreo (Sullivan 1994). Past research has provided some insight into the natural history of this species (Wallmo 1954, Leopold and McCabe 1957, Bishop and Hungerford 1965), but most

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[*] Part of the data reported in this chapter is reprinted with permission from "Use of portable infrared cameras to facilitate detection andcapture success of Montezuma quail" by Chavarria P. M., A. R. Kocek, N. J. Silvy, and R. R. Lopez. 2012. Proceedings of the National Quail Symposium 7:333–338.

ecological knowledge on this species is anecdotal and few studies have provided in-depth analysis of their movements and population dynamics (Stromberg 1990).

Conservation of many quail species, including Montezuma quail, throughout the U.S. is facing increasing challenges with the broader impacts including loss of suitable habitat, habitat fragmentation, and pressure from increased popularity in hunting (Brennan 1991, Rollins 2002). Arizona manages for the conservation and recreational hunting of the largest density of Montezuma (Mearn's) quail (*Cyrtonyx montezumae mearnsi*) in the U.S.—abundant throughout many federal and state-managed public lands in southeast Arizona. Because of their greater abundance in Arizona, Montezuma quail there have historically served as transplants for reintroducing populations thought to be extirpated in Texas (Brennan 2007). However, the lack of successful mark-recapture and telemetry studies in the past, coupled by less effective survey methods, have led to knowledge gaps in their life history and poorly understood estimates of their populations throughout their known range. The Montezuma quail is described as a rank 2 "Responsibility", rank 1 "Community /Focal", rank 2 "Vulnerability", and rank 3 "Unknown Status" species of management concern by Arizona Game and Fish Department's Comprehensive Wildlife Conservation Strategy for 2005–2015. A better understanding of their abundances, population dynamics, and habitat use is crucial for planning conservation and reintroduction strategies in areas where they are subject to intensified recreational hunting, habitat fragmentation, overgrazing, and other stochastic factors that have led to extirpations throughout much of their historical range in the southern U.S..

My research focused aspects of Montezuma quail life history such as its population dynamics and habitat use. My objectives were to (1) develop more effective methods for capturing and monitoring Montezuma quail, (2) estimate abundances and densities of populations, (3) estimate survival rate and causes of mortality from radio-marked individuals, (4) estimate “home range” size or habitat utilization ranges from radio-marked individuals, (5) examine components of habitat use from radio-marked individuals, (6) evaluate behavior, survival, and post-fire succession following a human-caused incidental wildfire in 2009, (7) analyze the impact of severe winter weather on their survival following a period of record-setting precipitation in 2010, and (8) provide recommendations for improving future studies for the management and conservation of this species. The dissertation addresses these objectives in 5 chapters. Chapter 2 focuses on survival demographics and cause of mortality. Chapter 3 focuses on movements and estimates of seasonal ranges. Chapter 4 focuses on landscape characteristics of habitat use from locations gathered through radio telemetry. Chapter 5 provided concluding thoughts and management recommendations. A more thorough description of the study area follows in the next section, but some of this information is repeated among chapters (i.e., species and study area description) because the dissertation is divided into chapters that have been prepared as independent, standalone manuscripts with a distinct research focus.

STUDY AREAS

Surveys of Montezuma quail were conducted throughout Arizona Game and Fish Department’s (AZGFD) Management Unit 35 in southeastern Arizona (Fig. 1.1) within areas administrated by the Coronado National Forest in Santa Cruz County. Most research was concentrated near Stevens Canyon and Smith Canyon in Patagonia, Apache Tank and Williamson Tank in the San Rafael Valley, Apache Spring, Hog Canyon, and Gardner Canyon near Sonoita, and the Appleton-Whittell Research Ranch (AWRR) near Elgin. Trapping and long-term monitoring of radio-marked individuals occurred primarily in Stevens Canyon, Hog Canyon, and AWRR.

AZGFD's Comprehensive Wildlife Conservation Strategy (AZGFD 2006) notes the major vegetation types occupied by Montezuma quail in southeastern Arizona consist of: Plains and Great Basin Grasslands, Subalpine Grasslands, Madrean Evergreen Woodland, and rarely Montane Conifer Forest. Hog Canyon (~31° 40' N, 110° 42' W) was dominated by Madrean Evergreen Woodland and Montane Meadow for vegetation and Caralampi gravelly sandy loam (22.2%) soils (NRCS 2012). Steven's Canyon (~31° 35' N, 110° 45' W) also was dominated (52.8%) by Caralampi gravelly sandy loam soils [Natural Resource Conservation Service (NRCS) 2012] and had similar vegetative characteristics to Hog Canyon, but with a reduced overstory canopy layer; Madrean Evergreen Woodland was sparser and intermixed with Desert Scrub midstory species (i.e., *Acacia* sp.; mesquite, *Prosopis* sp.). The AWRR (~31° 35' N, 110° 30' W) consists 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 (Coronado NF). 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 Coronado NF. Seasonal hunting of Montezuma quail was permitted at Stevens Canyon (Fig. 1.2) and Hog Canyon (Fig. 1.3) and was regulated by Arizona Game and Fish. The AWRR (Fig. 1.4), owned and managed by the Audubon Society, was a designated “Sanctuary” and did not permit grazing or hunting on their property. Climate data from the nearest long-term weather station (#1231 Canelo 1 NW; 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 (WRCC) 2012].

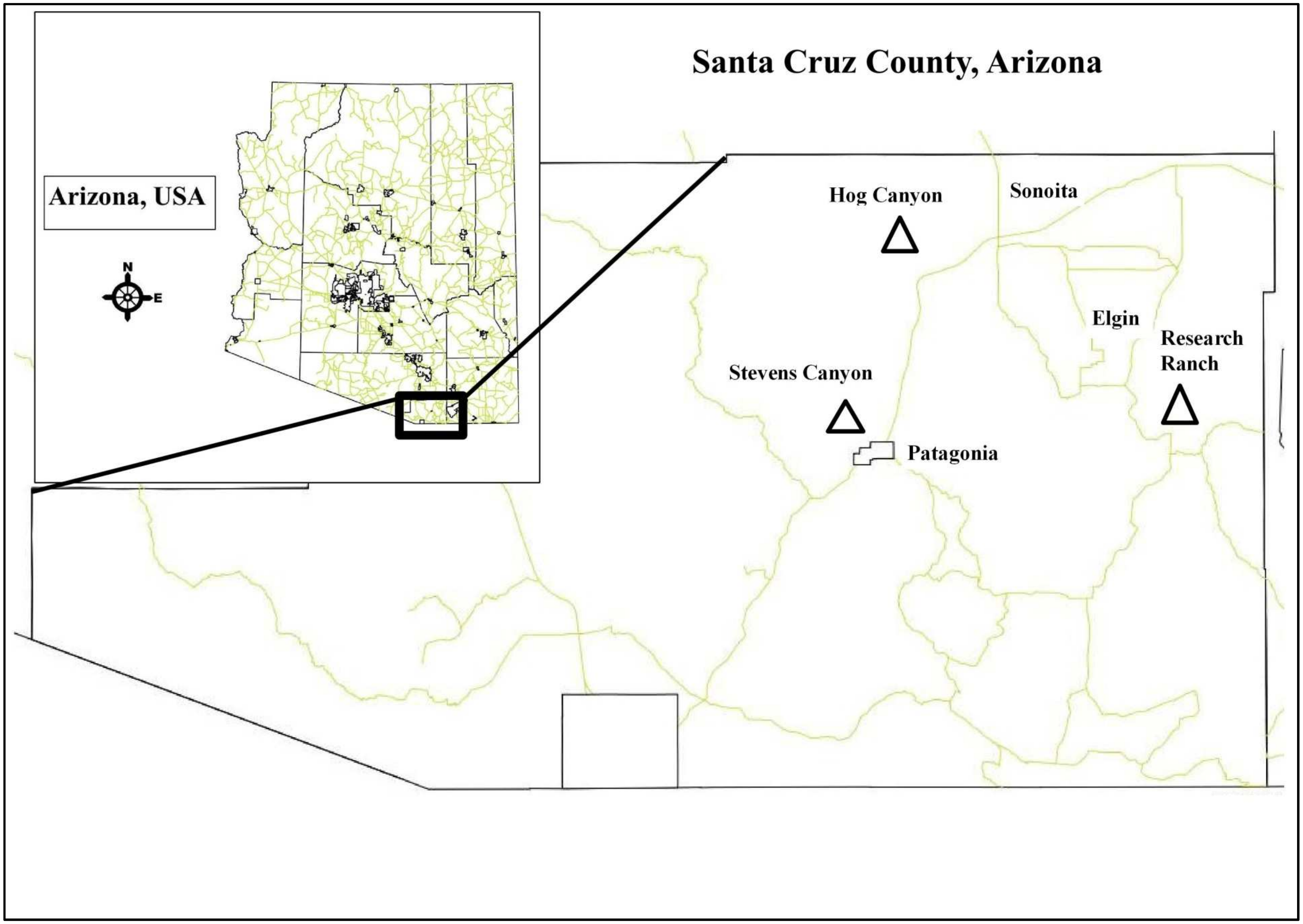

Figure 1.1. Map of Montezuma quail study sites in Santa Cruz County, Arizona, 2007–2010

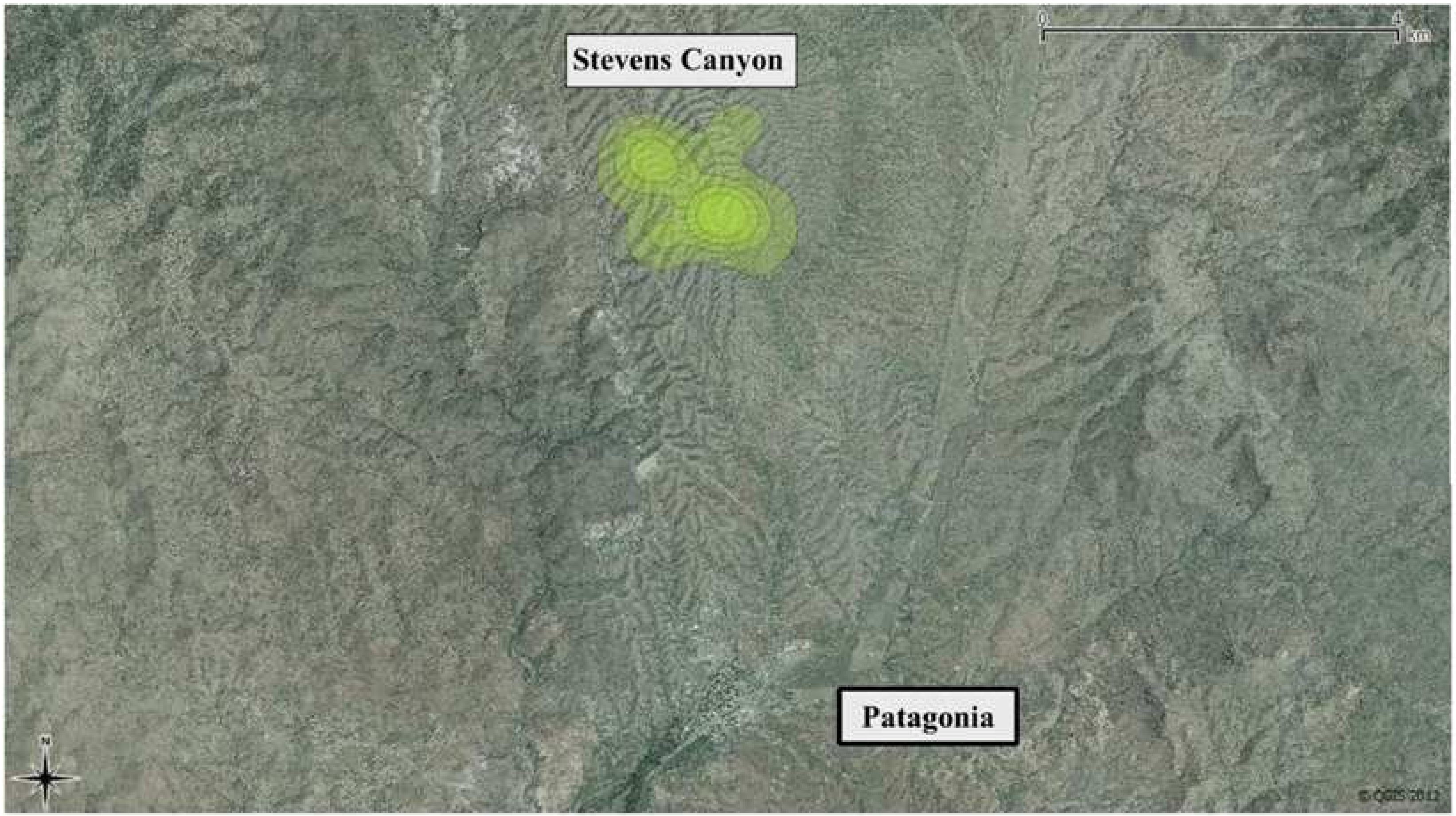

Figure 1.2. Map of Stevens Canyon study site in Santa Cruz County, Arizona. Displayed is the observed Montezuma quail population range.

Figure 1.3. Map of Hog Canyon study site in Santa Cruz County, Arizona. Displayed is the observed Montezuma quail population range.

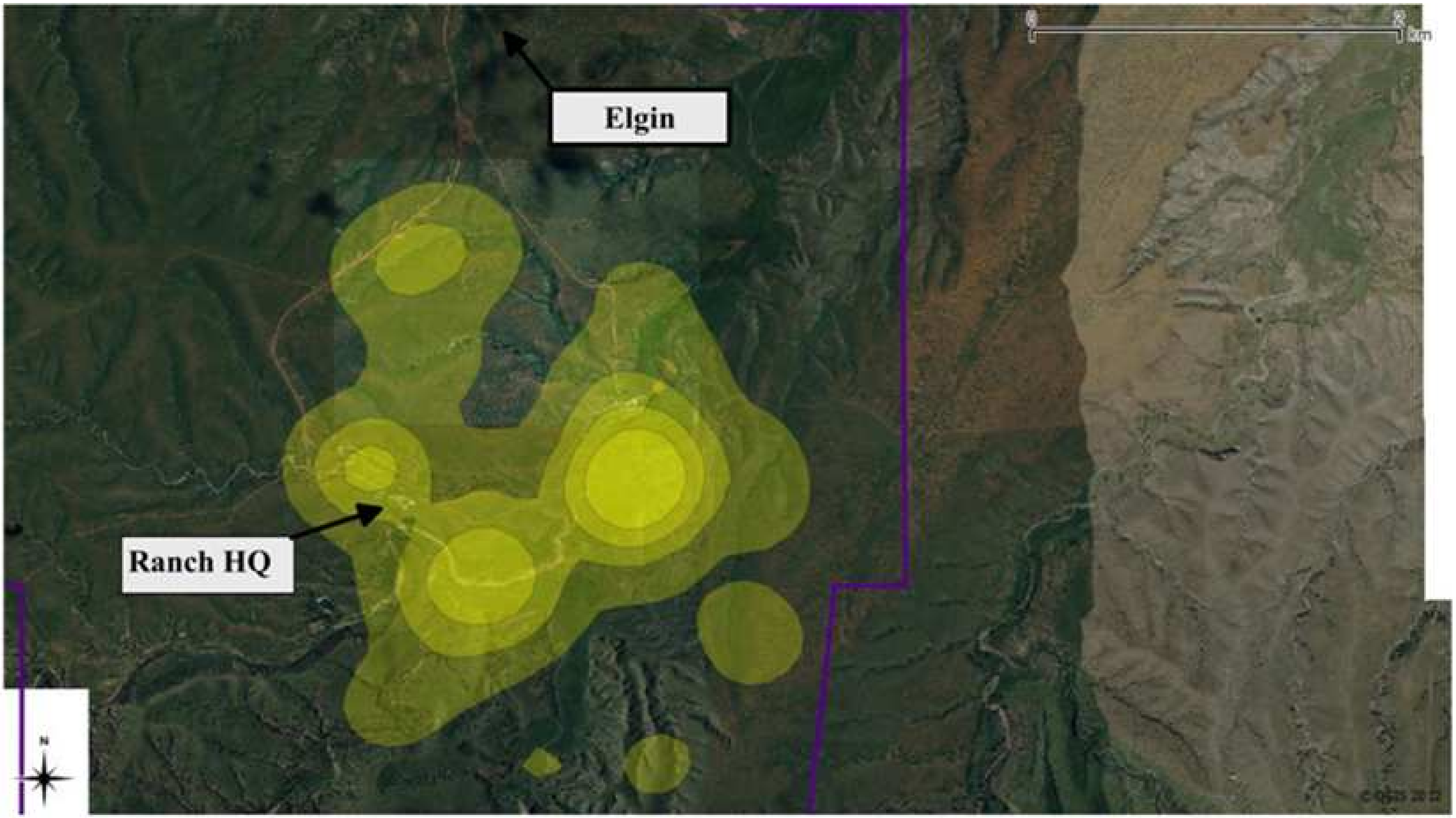

Figure 1.4. Map of AWRR study site in Santa Cruz County, Arizona. Displayed is the observed Montezuma quail population range.

CHAPTER II[*]

SURVIVAL DEMOGRAPHICS OF MONTEZUMA QUAIL IN SOUTHEAST ARIZONA

SYNOPSIS

Many facets of Montezuma quail (*Cyrtonix montezumae mearnsi*) population dynamics, such as survival and causes of mortality, are unknown due to a limited or lack of mark-recapture studies on wild populations of this species. Much of what is known about this species comes from casual observations in the field or from dog-assisted flush-count surveys. Further insight into rate and causes of mortality for this species is necessary to ensure proper conservation measures. I evaluated survival and causes of mortality of Montezuma quail in southeast Arizona from winter 2007 to spring 2010. Survival was determined from quail captured, radio-tagged, and monitored amongst 3 separate study sites. In 2 of these sites hunting was permitted and 1 site consisted of a control where hunting was not permitted. Estimating accurate rate of mortality in hunted sites was complicated by large quantities of censored data; some of which was attributed to lack of reported mortalities from hunting. Mortality in the control site may have been compounded by a combination of stochastic events (i.e., wildfire, freezing) occurring during the course of the study. Mortality rate for all sites were higher than any estimates reported or hypothesized in known scientific literature. The estimated rate of survival, combined amongst the 3 sites, was 21.9% from fall 2008–fall 2009. Survival for the

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[*] Part of the data reported in this chapter is reprinted with permission from "Impact of inclement weather on overwinter mortality of Montezuma quail in southeast Arizona" by Chavarria, P. M., A. Montoya, N. J. Silvy, and R. R. Lopez. 2012. Proceedings of the National Quail Symposium 7:346–351.

control site (Appleton-Whittell Research Ranch) from winter 2009–spring 2010 was 4.8% and was most likely attributed to atypically higher levels of winter precipitation that season.

INTRODUCTION

Although past research has provided much insight into the natural history of the Montezuma quail (Wallmo 1954, Leopold and McCabe 1957, Bishop and Hungerford 1965), few studies have provided in-depth analysis of their population dynamics from radio telemetry analysis (Stromberg 1990). The few studies that have attempted monitoring of wild Montezuma quail populations through radio telemetry have had complications associated with trapping a sufficient sample size, transmitter failure, negative impact of transmitters on radio-marked quail, or combinations of these effects (Stromberg 1990, Hernandez et al. 2009). Lack of successful mark-recapture and telemetry studies have led to knowledge gaps in their life history and poorly understood estimates of their populations throughout their known range. A better understanding of the abundance, densities, and survival rate and causes of mortality in wild populations of the Montezuma quail is important for their conservation and is especially crucial in areas where they face selective pressures from anthropogenic sources such recreational hunting and grazing, and are at additional risk from fire-effected habitats (i.e., prescribed burns, wildfires).

My goal was to evaluate survival of Montezuma quail on 3 separate study sites in southeast Arizona and to determine the causes of mortality. My objectives were then to test if differences occurred within and amongst study sites, treatments (hunting vs. non-hunting), sex, and age classes. Where possible, I examined differences in mortality rate amongst seasons as well as across all the aforementioned strata. High rate of mortality are thought to occur within younger age classes of this species immediately following the hatch season (fall–winter). This is mostly attributed to naïve behavior and unlearned survival instincts by the younger age classes. High rate of mortality amongst adult age classes of this species are thought to occur during the breeding season, from May–August, due to risky behaviors associated with reproduction (i.e., courting displays and calls) or increased movements. My objective was to evaluate survival and test for differences among study sites, sex, and age if data permitted.

STUDY AREAS

Surveys of Montezuma quail were conducted throughout Arizona Game and Fish Department's (AZGFD) Management Unit 35 in southeastern Arizona within areas administrated by the Coronado National Forest in Santa Cruz County (Fig. 1.1). Most research was concentrated near Stevens Canyon and Smith Canyon in Patagonia, Apache Tank and Williamson Tank in the San Rafael Valley, Apache Spring, Hog Canyon, and Gardner Canyon near Sonoita, and Appleton-Whittell Research Ranch (AWRR) near Elgin. Trapping and long-term monitoring of radio-marked individuals occurred primarily in Stevens Canyon (Fig. 1.2), Hog Canyon (Fig. 1.3), and AWRR (Fig. 1.4).

METHODS

Capture and Handling

An assessment of trapping potential at each location was based on estimates of covey size from flush counts. More trapping effort was initially invested in larger coveys because they provided an increased probability of capturing individuals. Man-hours and dog-hours invested in trapping effort varied amongst study sites, but generally did not exceed 2–3 trap sessions per week, with trap sessions spaced apart by no less than 2 days, totaling no more than 15 man-and-dog hours a week (Chavarria et al. 2012*a*). More trap hours were generally invested at the control site because potential conflicts with hunters at the experimental sites reduced opportunities for trapping during the hunting season from mid-November to early February.

A combination of techniques was used to capture Montezuma quail: wire-cage funnel traps, day trapping with hoop-nets and dogs, and night trapping with hoop nets and dogs. The primary means of trapping quail was initially to track birds with assistance of trained dogs, which will hold point, until the quail are cautiously approached by and captured by researchers with large hoop-nets (Brown 1976, Chavarria et al. 2012*a*) or throw-nets. The use of a lightweight and transportable FLIR (Forward Looking Infra-Red) camera (FLIR Systems, North Billerica, Massachusetts) was used at times to narrow down the location of quail (Chavarria et al. 2012*a*) by tracking their heat signature at a location where a dog had gone “on point”. Variation in hoop-net size and throw-net design were used to better fit conditions of vegetation density obstruction (e.g., smaller nets for thickets of vegetation) or to adapt to escape behavior of birds (i.e., throw-nets for weary birds).

Upon capture, birds were placed into individual cloth sacks and then transported in a small and mobile field holding pen at the trap location until they were fitted with a backpack radio-transmitter (about 5–8 g, < 5% of body mass; Wildlife Materials, Murphysboro, Illinois, USA), and evaluated for morphological characteristics. I recorded gender, age, weight, wing length, tail length, head and bill length, culmen length, bill width, bill depth, and tarsus length for each individual. Age of birds was determined from 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). The body condition and presence of parasites or disease also was noted. All captured birds were given numbered aluminum leg bands (Appendix I). In the case of multiple captures or birds caught in night-trapping sessions, birds 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. This was done to reduce possible mortality from hypothermia from releasing birds at night once a covey had been displaced. Once at least 1 or 2 members of a covey were radio-tagged, other members of the same covey could be trapped via Judas telemetry (Taylor and Katahira 1988). Birds 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. If a bird was non-releaseable due to serious injury 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 were radio-tagged once again and released back into the wild. If not, the wildlife rehabilitation center became responsible for the care and oversight of non-releasable birds.

Radiotelemetry

Birds fitted with radio transmitters were tracked on a weekly basis. Monitoring through triangulation of signal was conducted about 3–5 times a week at random times stratified by morning or afternoon. Walk-ins and flush counts were conducted periodically on each radio-tagged bird at least once every 3 weeks during the non-breeding season. This was done to determine the health status of a bird, determine the covey size with which a tagged bird was interacting, as well as to note habitat use, roost selection, nest-site selection, and other behavioral components (i.e., feeding, reproduction). Transmitters included built-in “mortality signals” to indicate a long period of inactivity or no movement of a marked bird, meaning that a bird was potential deceased or the transmitter was nearing battery failure. The frequency of walk-ins and flush counts was reduced during the breeding season to reduce potential impact to reproduction. Night-time walk-ins were conducted at least once every 2 weeks during the breeding season to determine clutch size and hatch size if nests had been established. Extra precautions were taken for night-time walk-ins not to flush birds, especially during the breeding season so as to avoid disruption to breeding behavior and nesting. Mortality signals were investigated and carcasses recovered if possible. Carcasses that remained mostly intact were collected and preserved in a freezer. Some of these remains were submitted to Dr. Mark Stromberg at the collections facility at the University of California Berkeley. Locations of visually relocated birds were georeferenced using Universal Transverse Mercator (UTM) coordinates, in the NAD83 datum, with a Garmin Legend GPS unit in ArcView. Aspects of their habitat use such as home range, vegetation selection, and topography also were recorded.

Statistical Analysis

***Survival*.–.**I used the Kaplan-Meier staggered entry estimator (Pollock et al. 1989) to calculate survival rate (*S*) and distributions by treatment (hunting vs. non-hunting), sex, and age-class for tagged birds. Annual survival rate were estimated from the beginning of one fall season (starting 21 September) to the start of fall season the following year. Seasonal survival rate were determined for birds captured post-fall. I considered analysis on 4 seasons based on the commonly accepted 3-month periods: 21 September–20 December for fall, 21 December–20 March for winter, 21 March–20 June for spring, and 21 June–20 September for summer. Birds that survived from one fall season to the next were censored and readmitted that following season. The total number of days which a bird was observed during the course of the study also was noted. Survival rate and standard errors were calculated using software program Ecological Methodology (Krebs 2002). Where data allowed, I used the log-rank Chi-squared test (Krebs 2002) to determine differences among annual or seasonal survival distributions by treatment (hunted vs. non-hunted), sex, and age-class. I tested differences in survival from the Chi-squared statistic at $P = 0.05$.

***Mortality*.–.**Censored observations or losses from mortality were categorized into groups based on any available evidence at the recovery site: predation (avian, mammalian), hunted, unknown, and other (trap injury, trap stress, dropped transmitter). If cause of death was not directly known, I noted the most probable or “suspected” cause of death. Summary statistics were compiled based on study site and probable cause of censor or death.

RESULTS

Capture Success and Survival

Trapping was first conducted at Stevens Canyon from January–May 2008, with 10 individuals captured during this time: 4 adult males, 1 juvenile male, 3 adult females, and 2 juvenile females (Appendix 1). Survival estimates for birds captured during that period were not calculated because of transmitter problems and censored data. An additional 4 birds (1 adult male, 3 adult females) were captured in fall 2008 and were monitored successfully on a more consistent basis. The mean number of days (± SD) tracked for these birds were 24.86 ± 18.91 and ranged from 5–60 days (Table 2.1). Three other birds also were captured during this time, but not tagged (2 died from dog inflicted injury and 1 died from stress during capture). The number of relocations for these birds also was limited, however, leading to censoring early in winter 2008–2009. The causes of censoring were: confirmed hunting mortality ($n = 1$), and suspected hunting mortalities ($n = 3$). One radio transmitter was retrieved from a hunter with a

Table 2.1. Finite survival probability estimates (*S* ± *SE*) calculated using Kaplan-Meier staggered entry design (Pollock et al. 1989) for radio-tagged Montezuma quail in southeast Arizona for fall 2008–2009 and winter 2009–spring 2010. Included in the table is sample size (*n*) for individuals trapped, mean ± *SD* and range for number of days tracked for each category.

Study site		*n*	Mean ± SD	Range	*S*	*SE*	Lower CI	Upper CI
Stevens								
	All Sexes	4	24.86 ± 18.91	5–60	0.750	0.217	0.326	1.00
Hog								
	All Sexes	13	61.77 ± 47.19	7–145	0.400	0.203	0.002	0.798
Ranch								
	All Sexes	31	62.13 ± 56.19	2–211	0.236	0.128	0.00	0.486
	Subadult Males	13	41.86 ± 39.39	2–112	0.238	0.191	0.00	0.612
	Subadult Females	9	71.4 ± 68.08	7–211	0.169	0.151	0.00	0.465
	Adult Males	4	60.0 ± 61.23	13–150	0.667	0.272	0.133	1.00
	Adult Females	5	112.0 ± 52.24	70–185	1.00	0.00	1.00	1.00
	Males (All)	17	83.0 ± 64.81	2–150	0.223	0.177	0.00	0.571
	Females (All)	14	45.89 ± 43.68	7–211	0.360	0.171	0.025	0.695
	All Sexes[a]	24	12.52 ± 8.47	2–44	0.048	0.037	0.00	0.120
All Sites								
	All Sexes	50	42.53 ± 46.54	2–211	0.219	0.090	0.043	0.397

[a] Winter 2009–spring 2010. All other estimates represent fall 2008–2009.

letter describing the location, time, and date the bird had been shot. The finite survival probability estimated within this time interval was *S*= 0.750 ± 0.217 (Table 2.1).

At Hog Canyon trapping was first conducted in fall 2008 and captures ranged from 6 December 2008 to 31 May 2009 (Appendix I), with 13 individuals captured during this time. Demographics of captures are as follows: 2 adult males, 1 adult female, 7 juvenile males, and 3 juvenile females. The mean number of days (± SD) radio-tagged individuals were tracked was 61.77 ± 47.19 and ranged from 7–145 days. There were 4 confirmed mortalities: confirmed raptor (*n* = 2), owl suspected (*n* = 1), and unknown (*n* = 1). There were 9 censures: suspected mortality (unknown, *n* = 1), suspected hunting mortalities (*n* = 3), and suspected transmitter failures (*n* = 5). Of the suspected hunting mortalities, 2 were later confirmed as hunting mortalities from reports submitted through AZGF wing barrel counts. The finite survival probability estimated within this time interval was *S*= 0.400 ± 0.203 (Table 2.1). No survival probabilities within the different sex and age classes were calculated because of low sample size. Three other birds were captured during this time, but were not tagged (2 died from dog inflicted injury and 1 escaped capture before processing).

Trapping was first conducted at the AWRR in February 2009 and capture records ranged from 12 February 2009 to 11 March 2010 (Appendix I), with 54 individuals captured during this time interval. Demographics of captures are as follows: 7 adult males, 11 adult females, 21 juvenile males, and 15 juvenile females. One other bird was captured during this time, but was not tagged because it died from dog inflicted injury. The mean number of days observed for tagged individuals in the 2009 season was 62.13

± 56.19 days and ranged from 2–211 days (Table 2.1). A subadult male was observed the least number of days and a subadult female was observed the most number of days (Table 2.1). There were 29 confirmed mortalities (Appendix I): confirmed raptor [*n* = 7; 1 Northern harrier (*Circus cyaneus*), 1 owl, 1 Harris hawk (*Parabuteo unicinctus*), suspected raptor (*n* = 8), confirmed mammal (*n* = 1), suspected mammal (*n* = 7), frozen on roost (*n* = 3), mortality suspected (*n* = 1), trap injury (*n* = 1), and unknown cause (*n* =1)]. There were 25 censures: suspected mortalities (*n* =6; unknown), suspected mortalities from raptor (*n* = 5), fallen transmitters (*n* = 3), transmitter failures (*n* = 9), injury-rehabilitation (*n* = 1), and untagged (*n* = 1). The finite survival probability (Table 2.1) for fall 2008–fall 2009 was *S*= 0.236 ± 0.128 for all sexes and age classes combined. Finite survival probabilities for separate sex and age classes are as follows (Table 2.1): all males only, *S*= 0.223 ± 0.177; all females only *S*= 0.360 ± 0.171; adult males *S*= 0.667 ± 0.272; adult females *S*= 1.00 ± 0.00; juvenile males *S*= 0.238 ± 0.191; juvenile females *S*= 0.169 ± 0.151. The finite survival probability for winter 2009–spring 2010 was *S*= 0.048 ± 0.037. Finite survival probabilities for separate sex and age classes were not calculated for winter 2009–spring 2010. The mean number of days (± SD) tracked for birds at the AWRR in 2010 were 12.52 ± 8.47 days and ranged from 2–44 days.

The finite rate of mortality (Table 2.1) for all sites combined for fall 2008–fall 2009 was *S*= 0.219 ± 0.090. The average of number of days birds from all sites were tracked throughout the course of the study was 42.53 ± 46.54 days, with a minimum of 2 and maximum of 211 days (Table 2.1). Females from all study sites, throughout the course of the entire study, were tracked an average of 49.57 ± 53.79 days, with a minimum of 2 and maximum of 211 days (Table 2.1). Males from all study sites, throughout the course of the entire study, were tracked an average of 36.47 ± 38.89 days, with a minimum of 2 and maximum of 150 days.

Hypothesis Testing

A large sample size and low censure ratio at the AWRR for the 2009 season allowed for Log rank Chi-square comparisons (Pollock et al. 1989) of weekly survival probabilities amongst different age-sex classes of radio-tagged Montezuma quail at that site. Analysis of survival probabilities were conducted for these groups where relocation histories overlapped within and between the different age-sex classes. I found no significant differences when comparing weekly survival probabilities between all males and all females ($\chi^2 = 0.01$, $P = 0.920$), between adult males and adult females ($\chi^2 = 0.33$, $P = 0.566$), between all juveniles and all adults ($\chi^2 = 0.1.41$, $P = 0.235$), between juvenile males and juvenile females ($\chi^2 = 0.030$, $P = 0.863$), or between adult males and juvenile males ($\chi^2 = 0.00$, $P = 0.1.00$). The test comparing weekly survival probabilities between adult females and juvenile females also showed no significant difference ($\chi^2 = 0.2.77$, $P = 0.096$), but showed a trend supporting higher survival probability for adult females.

DISCUSSION

Sources of mortality and the survival demographics of Montezuma quail were examined in-depth for the first time, through the use of radio-telemetry, in my study from 2008–2010. Though scientific literature provides an abundance of information of probable sources of mortality in Montezuma quail from field observations (Leopold and McCabe 1957, Brown 1979, Bishop 1964), none of those sources provide actual rate of mortality and estimates of survival at the population or covey level. Stromberg (1990) provided the first estimates of survival and documented sources of mortality, but from a limited sample size (*n* = 15). His study noted the mean number of days his tagged birds were alive was 28.4 (*SE* = 8.9), with the longest time a tagged bird was observed, before falling to predation, being 140 days. Results from my study, with a sample size of 77 radio-tagged birds, spanned the course of 3 years across 3 different study sites in southeast Arizona. Problems faced with radio-transmitter methods in previous studies (Stromberg 1990, Hernandez et al. 2009) were overcome in my research and I was able to track birds an average of 42.53 ± 46.54 days, with the maximum number of days an individual bird was tracked being 211 days. My transmitter attachment method, and slight modifications made to the design (still using the standard back-pack transmitter design with loop-hole attachment to the wing) was evaluated for their movements and survival. Radio-tagged quail were flight-tested when released to assure that the attachment did not affect their ability to fly, and thus did not reduce their chances of survival. My methods had no observable negative impact on their ability to fly and I believe did not significantly reduce their survival probabilities. Birds that were injured from trapping and which could not fly were treated for their injuries at a wildlife rehabilitation center and later released (*n* = 1) back to the wild or, if not releasable (*n* = 1), remained in captivity at the center. Many birds were recaptured on more than 1 occasion so as to trap other members of their coveys in subsequent trapping sessions, or to replace transmitters with drained or fading batteries. Re-trapping of birds seemed to have no significant impact on their survival. Potential impacts to Montezuma quail survival from trapping, such as exposing them to additional predation, or increasing their risk of exposure to the elements from flushing them off roosts, was reduced by not trapping or flushing birds when increased predator activity or extreme departures from normal in climate were observed.

From telemetry data, I evaluated actual estimates of survival probability for the 3 study sites, but could not evaluate estimates of survival for each study site each year. No survival probabilities within the different sex and age classes were calculated for Steven's Canyon because of low sample size. For the season from fall 2008–fall 2009, survival probability was very high for Steven's Canyon (S = 0.750), moderate for Hog Canyon (S = 0.400), and low for the AWRR (S = 0.236). For all sites combined, from fall 2008–fall 2009, survival probability was low (S = 0.219). For the season from winter 2009–spring 2010, survival probability was extremely low at the AWRR (S = 0.048). Estimates of survival in my study, derived from the Kaplan-Meier staggered entry design (Pollock et al. 1989), were most accurate for results obtained at the AWRR study site. A large amount of censored data resulted in smaller sample sizes at Stevens Canyon and Hog Canyon and prevented estimates of survival for those sites. The major problem at Stevens Canyon, the first pilot study area in early 2008, was identifying why transmitter signals were being lost from birds monitored from January–May 2008. Loss of transmitter signals or birds moving out of range were considered likely causes. Faulty transmitters were largely responsible, leading to censored data and inability to estimate survival probabilities. Long-distance movements of radio-marked birds, outside of the immediate range, were first thought to be the problem in relocating birds, but this was not the case. Most birds would be visually relocated with pointing dogs, within close vicinity of where they were captured, and often had transmitters attached that were not producing a signal.

Issues with faulty transmitters were resolved the following seasons and this allowed me to conduct a more thorough analysis of survival at the AWRR by both gender and age class. The Log-rank Chi-square comparison of survival probabilities at the AWRR noted no significant differences between all variations comparing age and gender classes. Sample size within the Steven Canyon and Hog Canyon sites was low so hypothesis testing to note differences amongst age and sex classes also was not conducted for those sites. Another problem in analysis was dealing with censored data from possible hunting mortality. This complicated or prevented proper analysis of survival probabilities for both Stevens Canyon and Hog Canyon. I could not control for unreported cases of tagged birds that were legally taken under permit from those 2 sites. Results for Stevens Canyon and Hog Canyon were biased to right-censoring due to excessive amount of transmitter failure and unreported mortalities from hunting. Birds which were potentially dead could not be statistically treated as mortalities, thus artificially inflating estimates of survival probability. The impact of right-censoring on inflating survival estimates is best observed for Steven's Canyon where the survival estimate was extremely high and also included a large standard error (S = 0.750, SE= 0.217) and wide lower–upper confidence interval (0.326–1.00). Such high survival probability is not very realistic for quail species for the time frame in which the study was conducted. The survival estimate for Hog Canyon was more realistic (*S* = 0.400, SE = 0.203), but was likely inflated from birds that went unaccounted and were censored from December–January during the hunting season. Because of those problems, hypothesis testing to compare weekly rate of mortality between experimental and control treatments was not conducted. The mean survival probability when combining all 3 study sites was low to moderate (*S* = 0.219, SE = 0.090) and had a reasonable lower–upper confidence interval (Table 2.1). That combined mean survival probability seems like a reliable estimate for the southeast Arizona region as a whole and is comparable to rate of mortality observed for other North American quail species.

Most mortality of Montezuma quail is likely not attributed to hunting; natural factors relating to changes in habitat quality and climate probably create the biggest impact on their survival (Leopold and McCabe 1957, Yeager 1966, Heffelfinger and Olding 2000). This may be partly responsible for low survival probabilities listed for tagged birds at the AWRR from 2009–2010 following 2 stochastic events—a large and severe wildfire in May 2009 (Chavarria et al. 2012*c*) and a severe winter storm from winter 2009–2010 (Chavarria et al. 2012*b*). This is especially true for the winter storm since, in addition to radio-telemetry, severe drops in population abundances were documented across the 3 study sites in 2010 from dog-assisted flush-count surveys (Chavarria et al. 2012*b*). Natural predation, from avian predators such as red-tailed hawk (*Buteo jamaicensis*), Cooper's hawk (*Accipiter cooperii*), and great-horned owl (*Bubo virginianus*), likely account for the second greatest proportion of mortalities—

especially of hatchlings and naïve juveniles—from early fall to late winter. Predation by meso-mammals such as coyote (*Canis latrans*) and bobcat (*Lynx rufus*) also accounted for other sources of mortality. Stromberg (1990) listed the causes associated with last observations of his birds due to transmitter failure (*n* = 7), raptor predation (*n* = 5), and some canid predation (*n* = 3) likely attributed to coyote (*Canis latrans*). My research noted higher incidence of confirmed and suspected predation by avian raptors for all 3 study sites. Predation by coyotes and bobcats was suspected to be high at the AWRR following the loss of cover following a severe wildfire that occurred in May 2009 and during the course of severe winter weather from 2009–2010.

Estimates of hunting mortality for this quail also are likely much higher than that reported in the literature. Leopold and McCabe (1957) claimed that “hunting has no bearing whatsoever on populations”, which is contrary to opinions by other biologists that have studied this species. Lopez and Lopez (1911) claimed that Montezuma quail’s behavior of holding still after being flushed was a risky behavior that put it at additional risk of hunting mortality. Vorhies (1928) speculated that then current and historical hunting of the gamebird in Arizona likely explained its scarcity throughout the state. Most literature on the impact of hunting mortality of Montezuma quail forms its basis on evidence drawn from hunter surveys, counts of wings voluntarily submitted by hunters, check-station surveys, or estimates of abundances conducted from flush-counts (Heffelfinger and Olding 2000, Bristow and Ockenfels 2000, Yeager 1966). Sources of information drawn from hunter surveys, wing-counts, and check-stations are limited in many ways and thus reduce the accuracy of estimating wild populations. Those data should be compared with more accurate means of estimating population abundances and densities such as that provided by a combined use of flush-count surveys with monitoring via radio telemetry.

Historical estimates of population abundances and densities of Montezuma quail in southeast Arizona lack accuracy because there is insufficient data to account for rate of emigration and immigration between adjacent habitats or landscapes (i.e., canyons, mountain ranges). Hypothesized rate of recruitment and mortality derived from past studies, therefore, need to be reevaluated. Without accurate estimates of range size and movements within a local area one is at risk of overestimating the number of coveys in an area, and thus overestimate the local population, by double-sampling the same birds that move between adjacent hillsides, ravines, and patches of useable habitat. Stromberg (1990) cautioned that, because of Montezuma quail's high site fidelity and small use areas, "frequent and intense hunting pressure, particularly with trained bird dogs, can lead to virtual elimination of quail where hunter density is high, and thus should be considered as a conservation issue by land managers". Information from this research, especially that regarding estimates of Montezuma quail ranges, need to be incorporated into future studies in order to more accurately evaluate actual rate of mortality throughout southeast Arizona—with particular emphasis in areas where they are exposed to more frequent and intense anthropogenic pressures such as grazing and hunting.

CHAPTER III[*]

SEASONAL RANGE AND MOVEMENTS OF MONTEZUMA QUAIL IN SOUTHEAST ARIZONA

SYNOPSIS

Historical assumptions about Montezuma quail movements and 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. Apart from 1 study using radio-telemetry, which was limited by sample size, much remained unknown about this quail's range and habitat use. Such information is crucial for estimating population sizes, densities, and rate of emigration and immigration throughout the landscape. My study examined range size and movements of 65 Montezuma quail in southeast Arizona from 2008–2010. I used radiotelemetry to follow radio-tagged birds in 3 study sites that varied in vegetation composition and topography. I used the fixed kernel estimation method to derive 95% and 50% utilization distributions (UD) and the minimum convex polygon (MCP) method to describe range size. I evaluated these range sizes for different age and gender classes and compared these between and within study sites. Descriptive statistics were also derived to note mean maximum distance moved by individuals, maximum linear distance moved by an individual, average distance moved between observations, and distance between first and last observation.

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[*] Part of the data reported in this chapter is reprinted with permission from "Post-fire succession and Montezuma quail in a semidesert grassland of southeast Arizona" by Chavarria, P. M., N. J. Silvy, R. R. Lopez, C. Hass, and L. Kennedy. 2012. Proceedings of the National Quail Symposium 7:339–345.

I found that mean seasonal range size (95% UD) was about 60% higher at Stevens Canyon, 63% higher at Hog Canyon, and 47% higher at the Appleton-Whittell Research Ranch (AWRR) than the largest use area (50 ha) described in the literature for this species. The largest MCP range estimate for an individual (206.65 ha) also was far greater than that reported in the literature. Within 1 season, the largest mean maximum distance moved between 2 locations was 1,128.39 ± 619.5 m and the largest maximum linear distance between 2 locations for an individual was 2,375.5 m. Differences in range size between gender and age classes were observed between 2 study sites, but similarities within age classes were observed between the 2 sites. Females had larger mean UD areas than males, even when comparing within age classes. Within gender, both hatch-year males and females had larger mean UD areas than after-hatch-year males and females at Hog Canyon. The opposite trend was observed at the AWRR, for the 2009 season, when comparing range size between males and females—AHY males had slightly larger mean UD areas than AHY females and, similarly, HY males had much larger UD areas FK95 UD areas than HY females.

INTRODUCTION

Understanding the range and movements of wildlife populations is integral to their conservation. Ecological knowledge about the spatial-temporal dynamics associated with a species' life history, habitat 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 range of Montezuma quail (*Cyrtonix 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 in the literature, only Stromberg (1990) was successful in estimating, to some extent, the 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 range throughout the landscape. A need exists, therefore, to address this knowledge gap to resolve management and conservation objectives for this species' distribution across the southeast Arizona region. My goal in this study was to improve upon previous attempts at monitoring this species through radio-telemetry and to evaluate movements and seasonal ranges of Montezuma quail. My 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

I selected 3 study sites in southeast Arizona (Fig. 1.1), separated several kilometers apart from one another, to evaluate ranges and movements of spatially independent subpopulations across the landscape. Diversity of habitat variables, particularly major vegetation types and topography, and how these could potentially impact range and movements, were accounted for in study site selection. Of these sites, 2 were located in public lands managed by the Coronado National Forest. Steven's Canyon, located along State Route 82 in Patagonia, Santa Cruz County (Fig. 1.2) and Hog Canyon, also along State Route 82, located closer to Sonoita, Santa Cruz County (Fig. 1.3), were both within Coronado NF boundaries. Hunting of Montezuma quail is permissible at both Steven's Canyon and Hog Canyon under legal AZGF permit, so those served as experimental treatments for evaluating potential impacts of hunting on their range and their movements. The thirds site was at the Appleton-Whittell Research Ranch in Elgin, Santa Cruz County (Fig. 1.4). The Appleton-Whittell Research Ranch (AWRR) is private land managed with an emphasis on research on native grassland communities in southeast Arizona. It is jointly managed by the National Audubon Society and Bureau of Land Management (BLM). The Research Ranch is a considered a "Sanctuary" and, as such, does not permit legalized hunting, thereby serving as a control site for evaluating range and movements independent of impacts associated to hunting, grazing, and other sources of anthropogenic pressures realized in public lands across southeast Arizona.

Capture and Handling

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*). 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. 2012a). Wire-cage funnel traps, baited with scratch seed, also were used with limited success. Other adaptations of audio (i.e., recorded call-backs) and visual lures (i.e., taxidermied 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 (Appendix I) and a loop-hole, wing-mounted, 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. I recorded gender, age, weight, as well as morphological characteristics such as wing length, tail length, head and bill length, culmen length, bill width, bill depth, and tarsus length for each individual. I 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 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. If a bird was non-releaseable due to serious injury 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 were radio-tagged once again and released back into the wild. If not, the wildlife rehabilitation center became responsible for the care and oversight of non-releasable birds.

Radiotelemetry

I 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 range and movement 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 was monitored; the relocation-to-day ratio that season was about 1:1. 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 to estimate the locations of birds when they could not be visually relocated. Flush relocation and visual re-sighting was conducted 1–2 times per month prior to the breeding and nesting season. 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, I 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, I 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 2 bearings available (LOAS 2000).

Range Analysis

Montezuma quail 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). For the MCP method, I used 100% of the points to estimate the area (ha) used. Using the fixed kernel range method, I 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 range area (Powell 2000) and it is generally supported as the best method currently available (Seaman and Powell 1996; Powell 2000; Kernohan et al. 2001). Seasonal 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 (Fig. 3.1–3.4) were plotted in ArcView 3.2a and QGIS.

Statistics for 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. Where sample size would allow, we would test for differences in range and core areas by using an (ANOVA), followed by Tukey’s HSD for multiple comparisons to separate means when F-values are significant ($P < 0.05$, Ott 1993).

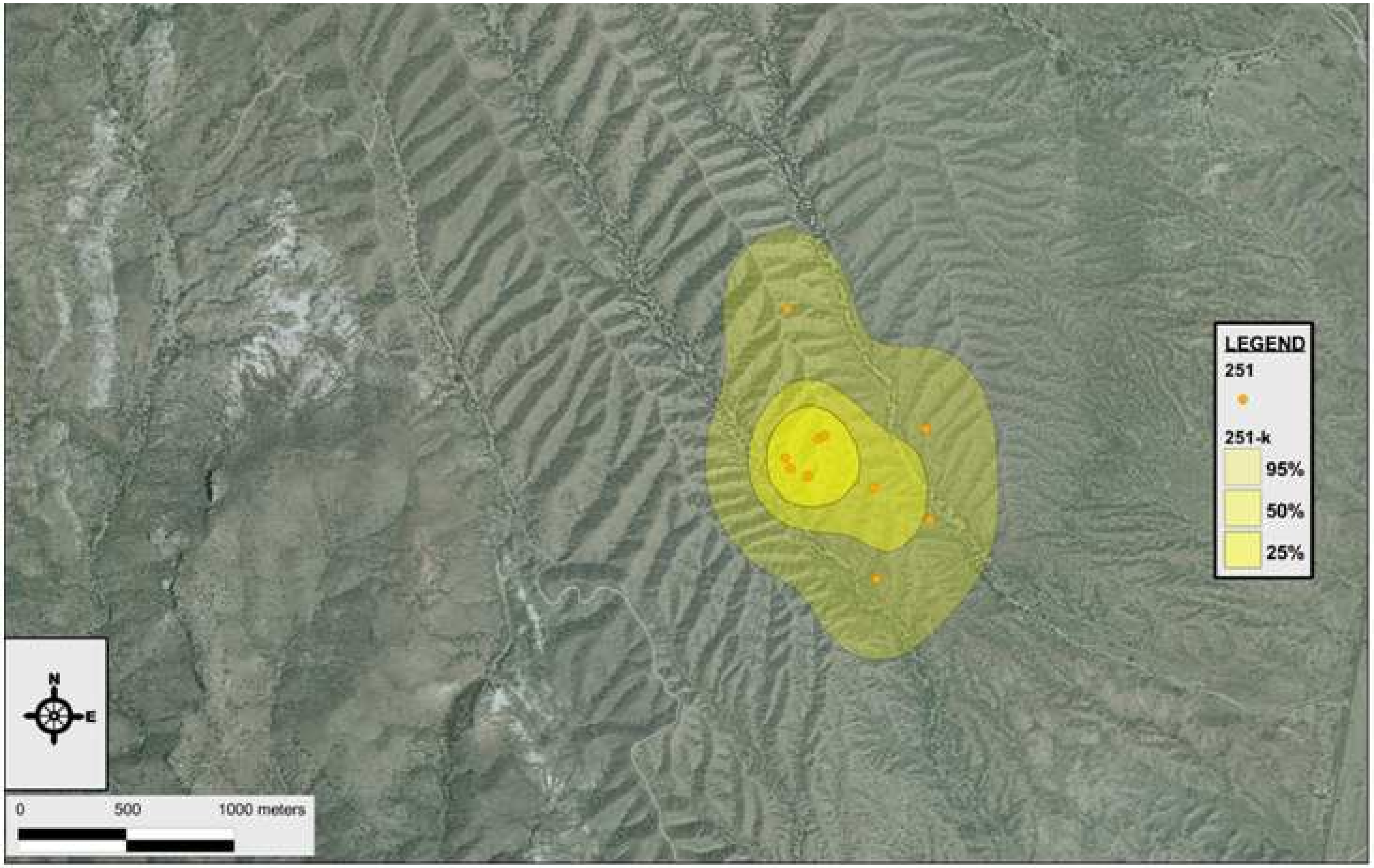

Figure 3.1. Montezuma quail range for AHY male #251 showing 25%, 50%, and 95% utilization distributions at Stevens Canyon 2008–2009.

Figure 3.2. Montezuma quail range for HY female #211 showing 25%, 50%, and 95% utilization distributions at Hog Canyon 2009.

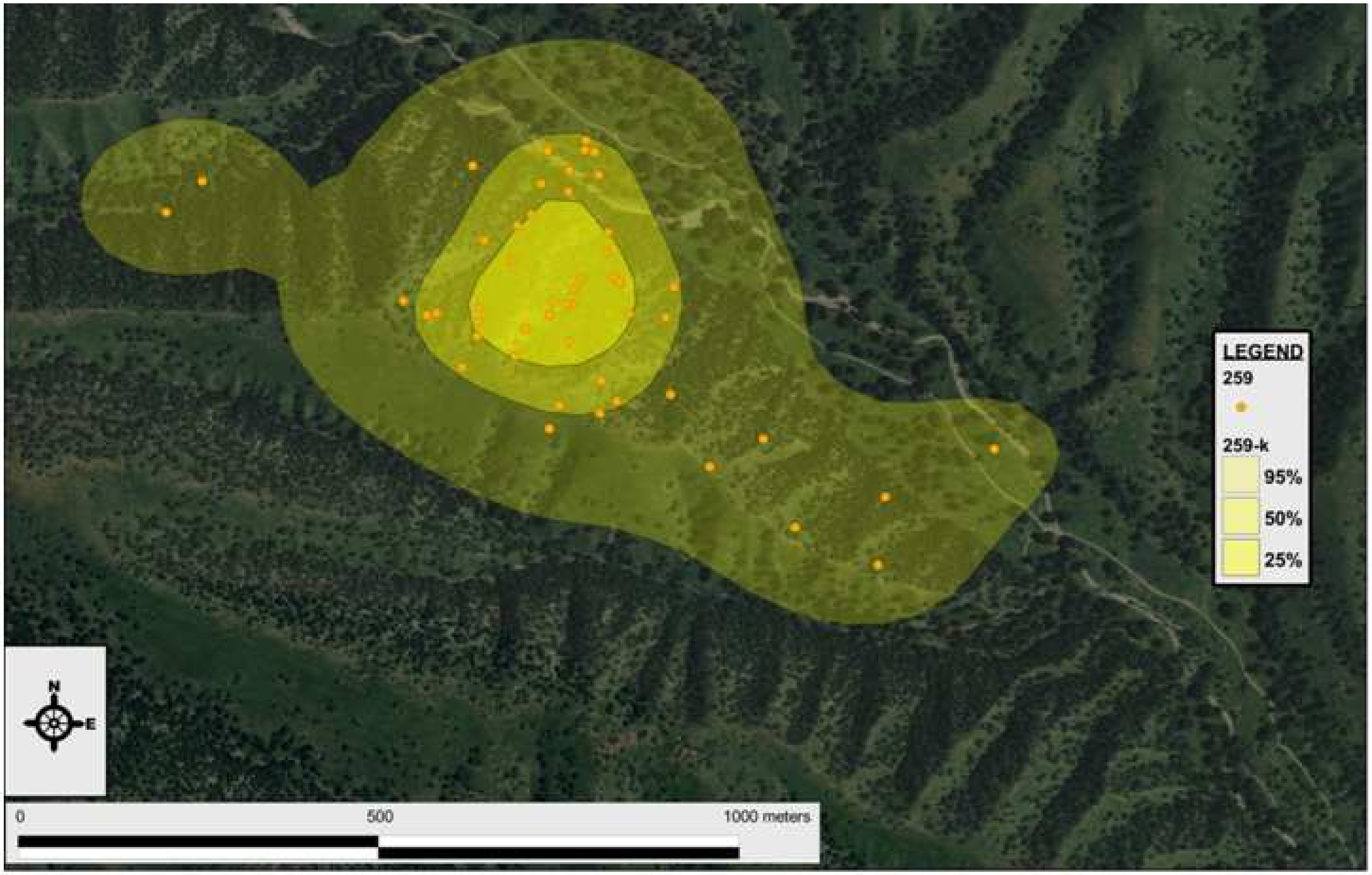

Figure 3.3. Montezuma quail range for HY male #259 showing 25%, 50%, and 95% utilization distributions at Hog Canyon 2009.

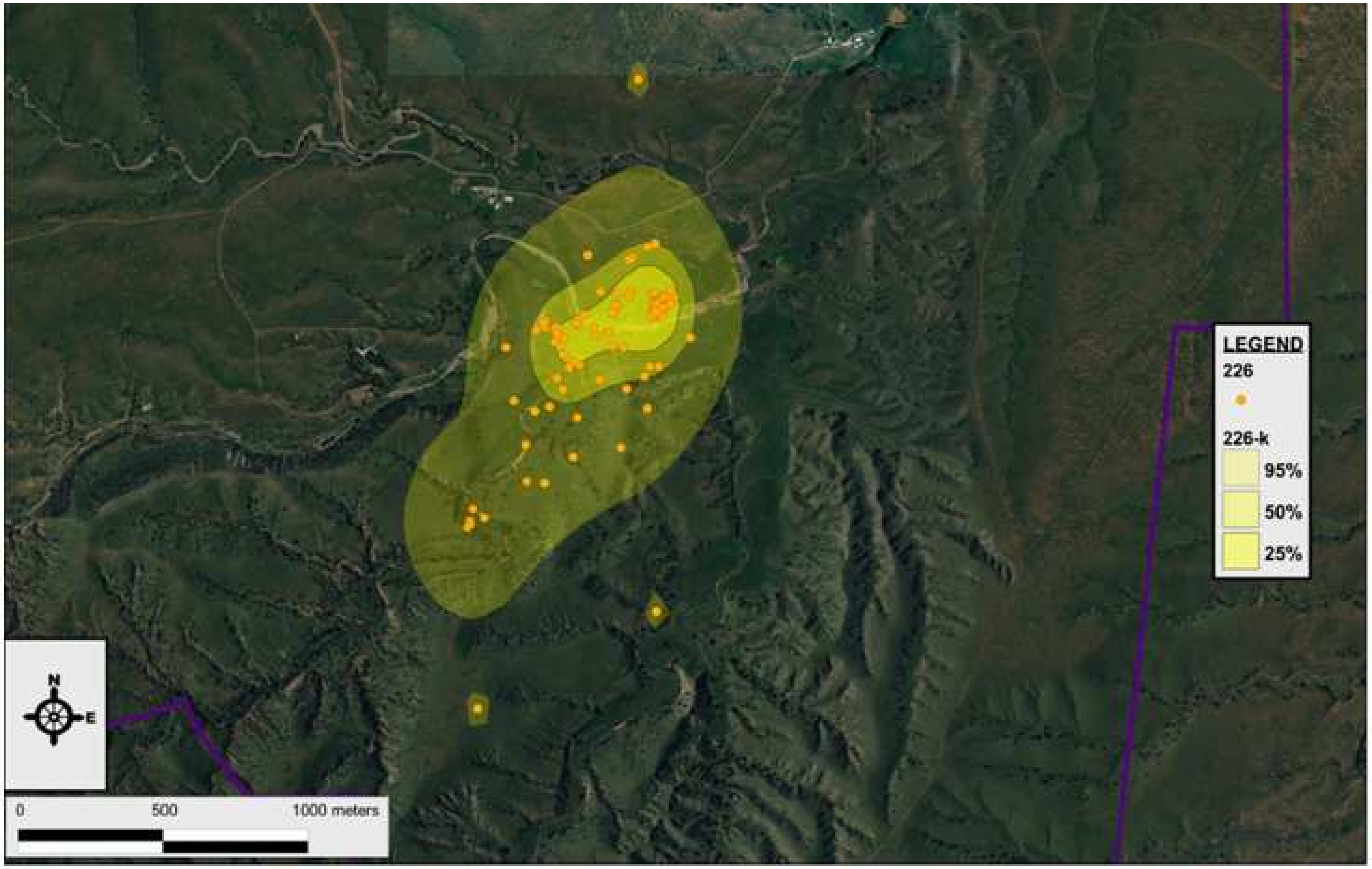

Figure 3.4. Montezuma quail range for HY female #226 showing 25%, 50%, and 95% utilization distributions at the Appleton-Whittell Research Ranch 2009.

RESULTS

Montezuma Quail Seasonal Ranges

***Stevens Canyon*.–.**Seasonal ranges and utilization distributions were evaluated for Stevens Canyon only for the 2008 field season (Table 3.1 and 3.2). I tracked 10 individuals for a mean 31.1 ± 19.0 days, and mean 5.4 ± 2.3 for number of locations (Table 3.1). Seasonal ranges using the MCP method produced small mean range size (8.7 ± 15.5 ha) for all quail at this site with the average MCP range size being higher for males than females (Table 3.2). The mean FK50 UD and mean FK95 UD for all quail at this site were about 2.3 times and about 9.6 times greater, respectively, than the mean MCP for all quail at this site (Table 3.2). The largest estimated range for an individual using the MCP method was 49.3 ha and 268.1 ha using the FK95 UD method. Seasonal ranges also were evaluated for different gender and age classes at Stevens Canyon (Table 3.2). Using the MCP method, both AHY and HY females had substantially smaller mean range sizes than males (Table 3.2). When using the fixed kernel method, however, this was the opposite. The FK50 and FK95 UDs (Table 3.2) were large for females than males. A comparison in mean range size could not be made between AHY and HY males because no HY males were captured and marked. When comparing AHY and HY females, however, mean range sizes were very similar and did not exceed a difference of 13 ha (FK95, Table 3.2).

***Hog Canyon*.–.**Seasonal ranges and utilization distributions were evaluated for Hog Canyon only for the 2009 field season (Table 3.1 and 3.2). I tracked 12 individuals for a mean of 65.3 ± 47.5 days and a mean 25.6 ± 25.8 for number of locations (Table 3.1). Seasonal ranges using the MCP method produced moderate range size (32.3 ± 44.4 ha) for all quail at this site

Table 3.1. Demographics of radio-marked Montezuma quail used to calculate annual and seasonal ranges and movements 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	Days range
Stevens (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 (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
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
Ranch (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

Table 3.2. Seasonal ranges [95% fixed kernel distribution (FK95), ha; 50% fixed kernel distribution (FK50), ha; 100% minimum convex polygon (MCP), ha] 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 (2008)	Male	AHY	4	13.0 ± 24.2	0.5–49.3	14.3 ± 21.7	2.0–46.7	55.8 ± 85.4	7.9–183.5
		HY	0	-	-	-	-	-	-
	Female	AHY	5	5.9 ± 8.2	1.2–20.4	24.1 ± 25.9	3.1–62.3	104.0 ± 110.2	12.7–268.1
		HY	1	5.2	5.2	19.1	19.1	91.7	91.7
	Total	All	10	8.7 ± 15.5	0.5–49.3	19.7 ± 21.9	2.0–65.3	83.5 ± 91.7	7.9–268.1
Hog (2009)	Male	AHY	1	2.5	2.5	5.0	5.0	17.7	17.7
		HY	7	24.4 ± 34.1	1.1–97.7	14.1 ± 9.8	3.9–30.9	76.0 ± 66.5	14.7–196.9
	Female	AHY	1	24.4	24.4	6.5	6.5	37.0	37.0
		HY	3	63.2 ± 72.4	1.5–142.9	23.2 ± 2.4	21.5–26.0	119.4 ± 30.3	85.0–142.2
	Total	All	12	32.3 ± 44.4	1.1–142.9	15.0 ± 9.4	3.9–30.8	78.8 ± 59.4	14.7–196.9
Ranch (2009)	Male	AHY	4	57.3 ± 99.6	3.5–206.7	18.4 ± 22.7	4.4–51.9	94.6 ± 129.3	17.6–287.0
		HY	8	41.9 ± 37.6	9.5–98.3	30.1 ± 28.7	7.5–85.7	126.4 ± 118.8	32.4–349.5
	Female	AHY	4	42.3 ± 14.2	25.5–55.8	16.7 ± 10.9	5.0–30.3	86.1 ± 44.8	32.4–129.7
		HY	8	52.6 ± 56.1	0.9–150.2	26.2 ± 23.1	1.4–62.4	104.3 ± 87.8	6.6–228.9
	Total	All	24	48.6 ± 52.4	0.9–206.7	24.6 ± 22.9	1.4–85.7	107.0 ± 96.5	6.6–349.5
Ranch (2010)	Male	AHY	3	6.6 ± 4.0	3.8–11.2	8.5 ± 4.2	3.6–11.5	33.2 ± 15.5	15.3–43.4
		HY	7	5.1 ± 6.3	1.4–119.0	4.5 ± 2.8	0.9–9.5	19.7 ± 11.7	3.9–34.4
	Female	AHY	5	6.3 ± 2.9	2.4–10.5	4.4 ± 3.2	1.4–9.2	19.6 ± 11.5	6.9–35.5
		HY	4	5.6 ± 2.3	3.3–8.2	4.3 ± 2.2	1.8–7.0	20.1 ± 10.4	7.6–30.4
	Total	All	19	5.8 ± 4.2	1.4–19.0	5.1 ± 3.1	0.9–11.5	21.9 ± 12.1	3.9–43.4

with the average MCP range size being higher in females than males (Table 3.2). The FK50 and FK95 means were about 0.5 times lower and 2.0 times higher, respectively, than the mean MCP for all quail at this site (Table 3.2). The largest estimated range for an individual using the MCP method was 142.9 ha and 196.9 ha using the FK95 UD method. Seasonal ranges were evaluated for different gender and age classes (Table 3.2), though sample size was limited to 1 individual for both AHY males and AHY females. Using both the MCP, FK50, and FK95 methods, females of all age classes had substantially larger mean range sizes when compared to male counterparts of same age class (Table 3.2). The AHY female, however, had a similar MCP range size when compared to the mean for HY males. Mean range size for the HY age classes was substantially larger than mean range size for AHY age classes when comparing within gender (Table 3.2); this was true independent of which method was used to estimate range size.

Research Ranch: 2009.–.Seasonal ranges and utilization distributions were evaluated separately for the AWRR for the 2009 season (Table 3.1 and 3.2). I tracked a total of 24 individuals for a mean of 74.2 ± 57.7 days and a mean 31.2 ± 24.6 for number of locations (Table 3.1). Seasonal ranges using the MCP method produced moderate range size (48.6 ± 52.4 ha) for all quail at this site with the average MCP range size being very similar, but slightly higher in AHY males (Table 3.2). The FK50 means were lower for all age and gender classes when compared to MCP. The HY age classes for males and females also were larger, by about 10 ha, when compared to AHY age classes within their genders (Table 3.2). FK95 means were very high: almost twice as large within the AHY age classes and almost 3 times as large within HY age classes when compared to MCP. The largest estimated range for an individual using the MCP method was 206.65 ha and 349.5 ha using the FK95 UD method. Seasonal ranges were evaluated for different gender and age classes (Table 3.2) and sample size was balanced between AHY and HY classes within gender. Mean range size for HY age classes were much higher than AHY age classes in both the FK50 and FK95 estimates when compared within gender and between genders (Table 3.2). Range size between AHY males and females, however, were very similar in the FK50 and FK95 estimates. HY males had both the largest FK95 mean range size and largest recorded range size for an individual this season (Table 3.2).

Research Ranch: 2010.–.Seasonal ranges and utilization distributions were evaluated separately for the AWRR for the 2010 season (Table 3.1 and 3.2). A total of 19 individuals was tracked for a mean 13.4 ± 8.4 days and a mean 12.4 ± 7.3 for number of locations (Table 3.1). Seasonal ranges using the MCP method produced very small range size (5.8 ± 4.2 ha) for all quail at this site, with little difference between the different age and gender classes (Table 3.2). The FK50 means were very similar to those derived using the MCP method for all age and gender classes (Table 3.2). However, the FK95 mean range estimates were 3–5 time greater when compared to MCP mean range size (Table 3.2). The largest estimated range for an individual using the MCP method was 19.0 ha and 43.4 ha using the FK95 UD method. Seasonal ranges were evaluated for different gender and age classes (Table 3.2) and sample size was similar between all gender and age classes although there were twice as many HY males than AHY males. The AHY males had the largest mean range size (33.2 ± 15.5 ha) in comparison to all other age and gender classes (Table 3.2). AHY males also had the largest recorded range size for an individual during this season (Table 3.2).

Statistics on Montezuma Quail Movements

***Stevens Canyon*.–.**Movement statistics were calculated for a total of 10 individuals at Stevens Canyon for the 2008 season (Table 3.3 and 3.4). The mean maximum distance moved by all quail at this site was 678.4 ± 485.5 m. The maximum linear distance between 2 locations within the range of an individual at this site was 1339.58 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 3.4). The mean maximum distance moved was highest for females than males, and the HY female had the largest mean (Table 3.4). Both the AHY females and AHY males had similar maximum linear distance moved, but this was lower for the only HY female observed (Table 3.4). The average distance moved between observations, given the wide variation in standard deviations, was similar between AHY females and AHY males (Table 3.4). No HY males were monitored so those statistics are unavailable for that age-gender class.

***Hog Canyon*.–.**Movement statistics were calculated for a total of 12 individuals at Hog Canyon for the 2009 season (Table 3.3 and 3.5). The mean maximum distance moved by quail at this site was 1,068.9 ± 741.2 m. The maximum linear distance

Table 3.3. Seasonal movement statistics showing distances (meters) moved 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, range), maximum distance moved, maximum linear distance, average distance moved between observations (mean), and distance between first and last observation (mean).

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

Table 3.4. Seasonal movement statistics, by age class and gender, showing distances (meters) moved 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, range), maximum distance moved, maximum linear distance, average distance moved between observations (mean), and distance between first and last observation (mean).

	Stevens Canyon			
Age Class	AHY Female	HY Female	AHY Male	HY Male
N Individuals	5	1	4	0
N Locations (mean, range)	5.4 (3–7)	6 (6)	5.3 (3–10)	-
Maximum distance moved (mean)	771.3 ± 519.1	867.6	515.1 ± 534.8	-
Maximum linear distance (individual)	1339.6	867.6	1316.4	-
Average distance moved between observations (mean)	328.7 ± 196.8	305.2	269.8 ± 230.4	-
Distance between first and last observation (mean)	388.8 ± 357.8	640.6	323.6 ± 260.7	-

Table 3.5. Seasonal movement statistics, by age class and gender, showing distances (meters) moved 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, range), maximum distance moved, maximum linear distance, average distance moved between observations (mean), and distance between first and last observation (mean).

	Hog Canyon			
Age Class	AHY Female	HY Female	AHY Male	HY Male
N Individuals	1	3	1	7
N Locations (mean, range)	53 (53)	27.3 (3–64)	5 (5)	23.86 (3–69)
Maximum distance moved (mean)	754.3	1,531.4 ± 908.1	312.9	1,023.6 ± 714.9
Maximum linear distance (individual)	754.3	2375.5	312.9	2043.9
Average distance moved between observations (mean)	163.8	377.9 ± 69.9	140.0	272.5 ± 92.8
Distance between first and last observation (mean)	268.7	362.4 ± 22.0	259.8	409.2 ± 297.3

between 2 locations within the 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 statistics also were evaluated by gender and age class for the 2009 season (Table 3.5). The mean maximum distance moved was much higher for HY males and females than AHY males and females and highest in HY females (Table 3.5). Maximum linear distance moved also was considerably higher 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 3.5). The average distance moved between observations also was highest for HY males and females than AHY males and females (Table 3.2).

Research Ranch: 2009.–.Movement statistics were calculated separately for the 2009 and 2010 seasons at the AWRR. Movements for 24 individuals were evaluated for the 2009 season (Table 3.3 and 3.6). 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 2locations within the range of an individual at this site was 2,250.35 m. The grand mean for average distance moved between successive observations for all birds at this site was 239.2 ± 246.8 m. Lastly, the mean distance moved between first and last observation was 676.8 ± 533.7. Movement statistics also were evaluated by gender and age class for the 2009 season (Table 3.6). The mean maximum distance moved was higher for females than males when comparing within age classes (Table 3.6). Within gender, these means were higher in AHY females than HY females and higher in HY males than

Table 3.6. Seasonal movement statistics, by age class and gender, showing distances (meters) moved 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, range), maximum distance moved, maximum linear distance, average distance moved between observations (mean), and distance between first and last observation (mean).

	Research Ranch			
Age Class	AHY Female	HY Female	AHY Male	HY Male
N Individuals	4	8	4	8
N Locations (mean, range)	36.3 (14–57)	34.1 (4–92)	22.8 (8–57)	29.9 (6–63)
Maximum distance moved (mean)	1,336.7 ± 216.7	1,175.6 ± 841.7	942.1 ± 840.9	1,070.2 ± 422.2
Maximum linear distance (individual)	1582.8	2250.4	2188.3	1546.3
Average distance moved between observations (mean)	198.7 ± 22.1	214.6 ± 107.1	174.3 ± 48.6	316.5 ± 420.2
Distance between first and last observation (mean)	535.8 ± 398.8	803.3 ± 702.0	510.3 ± 549.1	704.2 ± 446.7

AHY males (Table 3.6). Maximum linear distance moved by an individual was highest in HY females (2250.4 m), followed by AHY males. The average distance moved between observations also was highest in HY females and second highest in HY males (Table 3.6).

Research Ranch: 2010.–.Movement statistics for 19 individuals were evaluated for the 2010 season (Table 3.3 and 3.7). In 2010, the mean maximum distance moved by all quail at this site was 445.0 ± 179.3 m. The maximum linear distance between 2 locations within the range of an individual at this site was 894.8 m. The grand mean for 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 3.7). The mean maximum distance moved was fairly similar amongst all age and gender classes, but highest for HY females (Table 3.7). Maximum linear distance moved by an individual was highest for HY males (894.8 m) and second highest for HY females (Table 3.7). The average distance moved between observations was very similar for AHY females, HY females, and HY males, but much larger for AHY males (Table 3.7).

Table 3.7. Seasonal movement statistics, by age class and gender, showing distances (meters) moved 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, range), maximum distance moved, maximum linear distance, average distance moved between observations (mean), and distance between first and last observation (mean).

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

DISCUSSION

Montezuma quail movements and ranges were examined for a total of 65 birds in southeast Arizona from 2008–2010. My research improved upon samples sizes examined for this species through radiotelemetry in the past as well as the length of time radio-tagged individuals were monitored in the wild. Though I encountered problems with radio-transmitter failure initially at the start of the 3-year study, a little innovation in transmitter attachment and refurbishing methods allowed opportunities for successful monitoring the following years. Radio-tagged birds would very rarely drop transmitters from attachment failure and the use of transmitters and the attachment method did not seem to impact survival—a problem encountered by other researchers in previous studies. Evidence for this is supported by the high value for mean number of days that radio-tagged individuals were followed at each study site (Table 3.1) as well as the high number of radio-tagged individuals that survived 2008–2009 in my study. For Hog Canyon and the AWRR in particular, I was able to track some individuals for as long as 145 and 211 days, respectively. These results surpass those of the only other previously successful telemetry study on this species—that of Stromberg (1990)—wherein the mean number of days captured birds were known to be alive was 28.4 (*SE* = 8.9) and the longest time a radio-tagged bird was monitored was about 140 days.

Most assumptions in the literature about the sedentary nature of this species, and thus low range sizes associated with it, were supported from our analysis. However, I documented wider variation in the range sizes and movements of Montezuma quail from 2008–2010 between the various study sites and age-class treatments. Stromberg's

(1990) study provides the best data for comparison. His study 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 that, from June to October, pairs "remained sedentary in small areas, often smaller than 2 ha" (Stromberg 1990). Coveys in his study were consistently relocated in the same small areas and usually within the same 50 m^2 area (Stromberg 1990). The mean distance between relocations, on sequential days, observed by Stromberg (1990) was 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). Daily movement patterns, often noting hourly movements of coveys, were examined more intensively by Stromberg (1990): a small covey he tracked in Post Canyon during November had small distance movements of 18.6 m per 30-min intervals. A separate covey he tracked in December moved a mean distance of 63.8 m (*SE* = 46.4) every hour (Stromberg 1990).

Unlike Stromberg (1990), I did not track radio-tagged birds by hourly or 30-minute intervals because I felt such intensive tracking could be intrusive and affect the behavior of birds being monitored in the field. 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 range areas for radio-tagged individuals. These observations compelled me to monitor birds less frequently and from further distances in the field. Time invested in night-trapping reduced the number of days spent relocating birds at sites where trapping was conducted the previous night. Time invested in monitoring birds also was divided between multiple study sites a given week such that no 2 sites could be monitored for the same time strata for a given day. This explains the low relocation-to-day ratio in my data from 2008–2009. In general, tracking less often allowed for reduced accidental flushing of coveys on a weekly basis. Though this method reduced the number of relocation events per bird per day of a given week, this less intensive monitoring also probably accounts for higher survival rate of radio-tagged birds in my study. Less intrusion in the field also reduces the potential of contagion in aversive behaviors between marked and unmarked coveys. Radio-tagged birds that continually feel harassed or threatened in an area may learn to avoid that area (e.g., predator evasion) and other untagged coveys with which they associate also may follow suit. Our method, therefore, allowed me to improve the accuracy of estimating range areas with less worry that my monitoring activities artificially impacted estimates of their utilization distributions.

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 range size (FK95 UD) was about 60% higher at Stevens Canyon, 63% higher at Hog Canyon, and 47% higher at the AWRR than estimates of the largest use area (50 ha) derived by Stromberg (1990). The only exception was for the AWRR in 2010 whereby range size (FK95 UD) was about 44% lower than the largest use area Stromberg (1990) observed. Estimates of FK50 UD core areas show some similarity to the small use areas described by Stromberg

(1990) for winter ranges. Relative comparisons can be made between estimates of ranges for winter, late summer, and early fall derived by Stromberg (1990) to those derived in our study by examining both MCP and FK50 (or FK25) UDs. Estimated mean FK50 core areas in my study were about 31% higher at Stevens Canyon, 40% higher at Hog Canyon, and about the same at the AWRR, in comparison to the small use areas described by Stromberg (1990) for those seasons. The average MCP areas in 2010 parallel the small-use areas described by Stromberg (1990) for winter ranges and the mean MCP for all age and gender classes are similar to the maximum use-area (50 ha) described by Stromberg (1990). My research provides evidence for how use areas are reduced when extreme changes in seasonal climate occur (Chavarria et al. 2012*b*). or when pairs have formed and breeding and nesting is taking place. Data for the 2010 season at the AWRR serves as an example of how extreme shifts in climate may temporarily contract this species' range. Severe winter weather that year (Chavarria et al. 2012*b*) reduced the largest FK95 UD (43.4 ha) and FK50 UD (11.5 ha) observed for any individual (AHY male #247) and the average FK95 UD and FK50 UD for all birds at that site were both about 79% lower than the previous winter season—which did not deviate from climatic normals. Other stochastic factors, such as wildfire, or anthropogenic pressures, such as increased grazing pressure, may impact the range size of these birds. A wildfire that occurred in May 2009 at the AWRR had the potential to both limit movement and range size of individuals, due to a corresponding decrease in available cover, or increase movements and range size of individuals that took advantage of changes in habitat made available in various stages of post-fire succession (Chavarria et al. 2012*c*).

Large-scale migrations were not observed in my study and the maximum linear distance between locations observed for an individual (HY female #211) was at Hog Canyon and did not reach beyond 2.4 km outside the winter range. At the AWRR, a female (#240) made a large (~1.4 km) transition outside the center of her winter range to a new core area for nesting and 2 HY females (#215 and #226) had the maximum linear distance between locations, but this did not exceed 2.3 km. In 2010, the maximum linear distance between locations (849.8 m) belonged to an HY male (#705). Maximum distance moved and average distance moved between observations was fairly similar between a hunted (Hog Canyon) and non-hunted (AWRR) site in the post-hunting season. Multiple individuals (*n* = 5) at the AWRR had FK95 UDs above 200 ha, with the largest area reaching 349.5 ha. At Hog Canyon, only a few individuals had FK95 UDs above 100 ha, with the largest area reaching 196.9 ha. Differences in vegetation type and topography may impact movements and range sizes in ways that differ from common assumptions noted in the literature. A comparison of FK95 UD areas for individuals captured at Hog Canyon and the AWRR at relatively the same time, and tracked for a similar number of days (i.e., #212 and #212 at Hog Canyon, #215 and #216 at AWRR), supports this hypothesis. Reduced FK95 UD areas at Hog Canyon might be explained by the increased availability of canopy cover (e.g., *Quercus* spp.), more rugged topography, or a combination of those 2 factors. By contrast, larger FK95 UD areas at the AWRR might be a function of reduced canopy cover, overall less rugged topography, or a combination of those 2 factors. Comparison between genders and different age classes, and the interaction of these, also revealed some important differences that occur in both range size and movements. These differences need to be examined further in future studies with larger sample sizes of radio-marked birds in hunted and non-hunted sites that also account for diverse landscape features.

In summary, 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 2 study sites, but similarities within age classes were observed between the 2 sites. My data corroborates historical assumptions about relatively small range sizes for this species, but my estimates are much larger than those presented in the literature. Reduced sample sizes did not allow me to test statistical differences for our observations. Further research is recommended to lend further support to conclusions drawn from this study and is warranted for developing better management and conservation strategies for this species in southeast Arizona

CHAPTER IV

LANDSCAPE CHARACTERISTICS OF MONTEZUMA QUAIL HABITAT USE IN SOUTHEAST ARIZONA

SYNOPSIS

Montezuma quail (*Cyrtonix montezumae mearnsi*) habitat use at second and third-order scales has remained largely unexamined historically due to a limited or lack of mark-recapture and telemetry studies from which one can draw such conclusions. Existing habitat use models derived in Geographic Information Systems (GIS) thus lack the accuracy needed for conservation of this species where management actions for its habitat are concerned. Further review also is needed of assumptions of Montezuma quail habitat use drawn from daytime flush site or nighttime roost site observations in previous studies. Such studies have been limited to only a few vegetation associations where this species is typically expected to occur. To resolve these knowledge gaps and examine previous assumptions cited in the literature, I evaluated landscape characteristics of Montezuma quail habitat use in southeast Arizona using georeferenced point data from 3 study sites combined from flush-surveys and radiotelemetry. Specifically, I evaluated habitat use for elevation, aspect, ruggedness (a combination of slope and topography), and major Gap Analysis Program (GAP) vegetation associations. I first explored the data by conducting a contingency analysis, using a Chi-square test, to determine if there was a significant difference, for 8 categories of aspect, between those points selected by Montezuma quail compared to random locations. I then combined all

landscape variables into a model and used logistic regression to examine which components Montezuma quail were selecting for when comparing actual locations to random locations.

I found that Montezuma quail will use other vegetation types more so than Madream oak woodlands and Encinal Mixed Oak, where they are typically expected to occur. Populations at the Appleton-Whittell Research Ranch (AWRR) predominantly used Semidesert-Mixed Grass, mostly represented by Sacaton (*Sporobolus wrightii*) bottomlands, even when the Encinal Mixed Oak vegetation type was available within their immediate range. Where sacaton bottomland was absent from a populations range, most quail conformed to observations noted in the literature and selected for Encinal Mixed Oak rather than more open grasslands. I also found that elevation, ruggedness, and the interaction of these are significant components for Hog Canyon, whereby quail selected for high elevation and more rugged topography. At AWRR, elevation was a significant component for the time-independent and all time-dependent tests, but ruggedness was only significant for time interval 2 (1100–1459 hours) and interval 3 (1500–1859 hours).

INTRODUCTION

Conservation of North American quail species requires that ecological knowledge gaps be minimized in order to more effectively manage them at local, regional, or larger scales. For Montezuma quail (*Cyrtonix montezumae mearnsi*), distribution and habitat use at local and landscape scales have been poorly understood because of past difficulties with mark-recapture studies (Hernandez et al. 2009). Much of what is known about their range and habitat use is inferred from observations noted in informal surveys or those determined from dog-assisted flush counts (Fuertes 1903, Wallmo 1954, Leopold and McCabe 1957). Most sources of literature note a strong association of Montezuma quail in Arizona to Madrean evergreen woodlands of oaks and pines (Brown 1989). However, this species has been observed in other diverse habitats with rough topography, ranging in elevations from 1,219.2–2,895.6 m, wherever there is sufficient grass cover (Bishop 1964). Distribution maps generated with GIS using habitat suitability models are sometimes used for conservation purposes of some quail species (Bristow et al. 2005). Such models have been developed for Montezuma quail (University of Arizona 1999) albeit with limited and less accurate data about landscape features that may comprise suitable habitat for this species. Without the use of radiotelemetry to track marked populations, ecologists have only been able to make generalized assumptions about this species' range and the spatial-temporal dynamics of how it interacts with its habitat in terms of elevation, vegetation associations, and other prominent landscape features.

Stromberg (1990) made headway into this knowledge gap with a study conducted in southeast Arizona. He was the first to successfully follow this species through radiotelemetry and his research painted a clearer picture of how this species used habitat at finer scales; thus, providing refined insights into their spatio-temporal movements and habitat selection. Along with being able to determine daily and seasonal range size, radio-tracking individual movements of marked individuals allowed Stromberg (1990) to assess fine-scale use of vegetation type, percent cover, aspect, and slope for daytime activities as well as choice in roosting habitat. Despite these advances, however, a small sample size and restriction to 1 localized study site (Stromberg 1990) reduced the explanatory power and limited the application of these findings for this species at broader landscape and regional scales. Thus, a more intensive review of their movements and habitat choice and requirements is needed to build more accurate habitat suitability models and better understand the possible extent of their range in the landscape and regional scale.

Efforts to further examine spatial components of Montezuma quail habitat use now are facilitated from monitoring data from my recent research. With the acquisition of a moderately large sample size of radio-tagged birds and flush-counts surveys from 2008–2010, that were collected from a diverse range of habitats throughout southeast Arizona, a more refined analysis of Montezuma quail selection for landscape features were conducted. My goals in this study were to evaluate how Montezuma quail selected for landscape features such as major vegetation associations, elevation, topographical ruggedness, and aspect throughout southeast Arizona.

METHODS

Study Site Selection

Three study sites were selected for evaluating landscape characteristics of habitat use by Montezuma quail in southeast Arizona. The main factors influencing choice of study areas in this evaluation were diversity in topographical features (e.g., elevation, ruggedness), diversity in dominant vegetation composition, distance between study areas for independence of sampling, and presence or absence of hunting pressure. These areas were the same ones used to evaluate home range demographics of marked individuals through the use of radio telemetry. All areas, with the exception of the Appleton-Whittell Research Ranch in Elgin, Santa Cruz County were located in public lands managed by the Coronado National Forest (Fig. 1.1). Steven's Canyon, located along State Route 82 in Patagonia, Santa Cruz County (Fig. 1.2) and Hog Canyon, also along State Route 82 in Sonoita, Santa Cruz County (Fig. 1.3), were both within Coronado NF boundaries. Hunting of Montezuma quail was permitted in both Steven's Canyon and Hog Canyon under legal AZGF permit. The Appleton-Whittell Research Ranch (AWRR), jointly managed by the National Audubon Society and Bureau of Land Management (BLM), was private land managed with an emphasis on research on native grassland communities in southeast Arizona (Fig. 1.4). The Research Ranch was considered a "Sanctuary" and, as such, did not permit legalized hunting to the public.

Habitat Use Data

Location data for Montezuma quail habitat use was obtained from a combination of georeferenced points collected from flush-surveys and radiotelemetry. Trained pointing dogs were typically used to locate Montezuma quail in daytime flush-count surveys (Brown 1976). Flush-counts with dogs were conducted periodically, about 2–4 times a month, during 0500–1700 hours, to record changes in covey size and gender demographics throughout the various study sites. However, night surveys also were conducted periodically from about 1900–0300 hours for the purpose of trapping quail and to note choice of roosting habitat. Of 88 Montezuma quail that were captured from 2008–2010, 80 were fitted with aluminum leg bands and backpack radio transmitters (about 5–8 g, less than 5% of bodyweight; Wildlife Materials, Murphysboro, Illinos, USA) using newly enhanced methods adapted from those used by Stromberg (1990) and Hernandez et al. (2009). Captured quail were evaluated for morphological characteristics (i.e., sex, age, body condition, wing length) and released before daybreak the following morning. Radio-tagged birds were monitored about 2–5 times a week through random hours stratified by day (0700–1900 hours), when quail were most active, or night (1901–0659 hours), when quail were primarily on their roosts. All quail locations were georeferenced using Universal Transverse Mercator (UTM) coordinates in NAD83 datum.

Vegetation Assessment

Dominant vegetation composition within a study area was first evaluated at a broad scale using GIS layers from the southwest regional GAP analysis of vegetation (Halvorson et al. 2001) specifically for the Sonoita region, southeast Arizona. Arizona Game and Fish Department's Comprehensive Wildlife Conservation Strategy (AZGF 2006) also was used to describe the major vegetation types occupied by Montezuma quail in the southeast Arizona region; these consisted of Plains and Great Basin Grasslands, Subalpine Grasslands, Madrean Evergreen Woodland, and in rare instances Montane Conifer Forest. Hog Canyon, closer to the Santa Rita Mountain range, is dominated mostly by Madrean Evergreen Woodland and Montane Meadow along a moderately rugged and steep topographical contour. Located further south along the Santa Rita Mountain range, Steven's Canyon has similar vegetative and topographic characteristics to Hog Canyon, but is less steep and rugged. A reduced overstory canopy layer was observed in Stevens Canyon whereby the Madrean Evergreen Woodland was sparser and intermixed with Desert Scrub midstory species (i.e., Acacia, Mesquite). By contrast, the Appleton-Whittell Research Ranch, nestled at the foothills of the Huachuca Mountain range, consisted mostly of Plains and Great Basin Grasslands dominated by sacaton bottomlands along the Turkey Creek watershed. Madrean Evergreen Woodlands were sparsely dispersed amongst most of the long sloping hills at the Ranch, but could be found in greater abundance and densities along the southern and eastern borders that neighbor the Coronado NF.

High resolution orthoimagery was used to determine general vegetation composition of overstory canopy cover or open grasslands. For Stevens Canyon, a set of U.S. Geological Survey (USGS 2007) digital orthophoto quarter-quadrangles (DOQQs) (raster orthoimages set at 1-m resolution from 2005) were used in GIS analysis. For Hog Canyon and the AWRR, a set of U.S. Geological Survey (USGS 2010) DOQQs, set at 0.3-m pixel resolution from 2008, were used in GIS analysis. All DOQQs used conformed to the Universal Transverse Mercator (UTM) projected coordinate system with a NAD83 datum, spheroid GRS80. Finer-scale evaluation of vegetation composition was done from on-the-ground surveys at locations associated with Montezuma quail presence-absence data (e.g., flush-count dog surveys and telemetry data of marked birds).

Topography Assessment

Topographical analysis of features such as elevation, aspect, and ruggedness were derived using digital elevation models (DEMs) from the 2009 National Elevation Dataset (NED), the primary elevation data product produced and distributed by the USGS (2009). The DEMs for all 3 study sites were set at 1 arc-second resolution (approximately 30 m). The original DEMs provided by the NED conformed to the Universal Transverse Mercator (UTM) projected coordinate system, but with a North American Vertical Datum of 1988 (NAVD 88). To align and be compatible with the NAD83 datum used for all other GIS layers, the DEMs were re-projected using the "Warp" function in software package Quantum GIS (QGIS) 1.7.0 (QGIS 2011).

Elevation data (meters) associated with quail points (i.e., sign, sightings, and telemetry data) was directly extracted from the NEDs original DEM using the "point sampling tool" plug-in in QGIS (2011). For features such as aspect and ruggedness, individual raster layers were created for each using the "DEM (Terrain models)" function in QGIS (2011). The "Aspect" and "TRI (Terrain Ruggedness Index" functions were used to create, respectively, the aspect and ruggedness raster layers for each individual study site. The aspect raster layer associates to each pixel, from the original DEM, a value ranging from 0–360 based on the cardinal direction a hillside is facing. The TRI determines "ruggedness" as the mean difference between a central pixel and its surrounding cells (Riley et al. 1999, Wilson et al. 2007). The ruggedness index serves as a means of indexing terrain heterogeneity (Riley et al. 1999), with lower values corresponding to terrain that is flatter, or more level, while higher values correspond to terrain features that are increasingly associated with sharp changes in elevation such as high peaks or large cliffs. As done for elevation, the point sampling tool plug-in was consequently used to extract aspect and ruggedness features associated with each quail point.

Statistical Analysis

Montezuma quail selection for landscape features such as dominant vegetation type, elevation, aspect, and ruggedness was evaluated by comparing actual quail locations to a set of randomly generated points. First, a minimum convex polygon (MCP), encompassing 100% of all actual quail locations, was generated for each study site using the plug-in “home range analysis” in QGIS (2011). To account for random locations that quail could potentially use just outside their observed MCP range, based on potential movement and range data collected from my research, an additional 500-m buffer was extended to the MCP range for Hog Canyon and the AWRR, and a 200-m buffer was extended to Stevens Canyon. A wider buffer was used for Hog Canyon and AWRR because of longer ranges and movements observed at those sites in comparison to Steven’s Canyon. Randomly generated points were generated from locations using the 100% MCP range including the additional buffer. The number of randomly generated points was about equal to the number of actual points for each study site.

Aspect was categorized into 8 nominal values based on a logical range of azimuths. These designations were as follows: $337.5 < N \leq 22.5$; $22.5 < NE \leq 67.6$; $67.5 < E \leq 112.5$; $112.5 < SE \leq 157.5$; $157.5 < S \leq 202.5$; $202.5 < SW \leq 247.5$; $247.5 < W \leq 292.5$; $292.5 < NW \leq 337.5$. Additionally, where sample size was sufficient, landscape feature selection by quail was evaluated according to the time of day an observation was made. This was done primarily to control for uneven sampling effort between time intervals. Time of day, recorded using military 24-hour cycle, was partitioned into categories: Time 1 (0700 ≤ 1059 hours); Time 2 (1100 ≤1459 hours); Time 3 (1500 ≤ 1859 hours); Time 4 (1900.≤.0659 hours). These time intervals were designated to evaluate selection by Montezuma quail for landscape features based on factors, such as available sunlight and temperature, which would have regular impact on their activities and movements during those time intervals. Chi-squared contingency tests, set with a critical test value of $P \leq 0.05$, were conducted using statistical software JMP 9.0 (SAS 2007) to explore differences in selection for aspect between actual and random points. Where sufficient sample sizes for each time interval was available, the Chi-squared contingency test was stratified by time interval.

Nominal logistic regression models comparing actual points to random points were evaluated using statistical software JMP 9.0 (SAS 2007) for the elevation, aspect, and ruggedness landscape features at each study site. Where sample size was sufficient, logistic regression models incorporated all landscape features, including interactions (e.g., elevation * rugged, rugged * aspect) and also stratification by time interval. The critical test value of $P \leq 0.05$ was evaluated for all tests. Wald χ^2 scores are reported with their corresponding parameter estimates from JMP 9.0 output (SAS 2007). Although Wald χ^2 scores “provide an adequate significance indicator for screening effects” (SAS 2007), likelihood-ratio χ^2 scores are recommended as a more trustworthy method for evaluating models (SAS 2007, Fox 1997). For this reason, parameter significance was evaluated primarily from χ^2 scores derived from the effect likelihood ratio tests in JMP 9.0 (SAS 2007). Lastly, where adequate sample size permitted, corresponding odds ratios for the nominal category “aspect” also were derived using JMP 9.0 (SAS 2007).

RESULTS

Vegetation Selection

***Stevens Canyon*.–.**The dominant GAP vegetation type at Stevens Canyon within the buffered MCP region consisted of Semidesert Mixed Grass—Mixed Scrub (90.93%), followed by Encinal Mixed Oak (8.02%), and then Semidesert Mixed Grass—Mesquite (1.05%). Habitat use by quail was very high in the Semidesert Mixed Grass—Mixed Scrub (98.38%, $n = 61$) compared to only 1 observation in the Encinal Mixed Oak (1.62%). On-the-ground surveys of quail habitat use did not note such a 1-sided preference for open-grass cover. Quail were often observed feeding and roosting in open-grass fields, but much of the daytime activity, particularly around the hottest parts of the day, were spent within 5-m distance of overstory canopy cover. Hillsides abundant with mesquite (*Prosopis* spp.) were rarely used by quail except in rare instances when they would flee there for protective cover.

Hog Canyon.–.The dominant GAP vegetation type at Hog Canyon within the buffered MCP region consisted of Encinal Mixed Oak (72.6%), followed by Semidesert Mixed Grass—Mesquite (15.28%) and Semidesert Mixed Grass—Yucca-Agave (12.1%). Semidesert Mixed Grass—Mixed Scrub also was nearby, within a 1 km of the buffer in the region, and some Encinal Mixed Oak—Mexican Mixed Pine was present within 2 km to the north of the buffer. Quail selected for Encinal Mixed Oak overwhelmingly (99.5%, *n* = 372), with only a few points located in Semidesert Mixed Grass—Mesquite (0.5%, *n* = 2). On-the-ground surveys of quail habitat use confirmed the overwhelming preference for dense canopy cover provided by oaks within the study area. Quail were observed feeding in open-grass fields at the bottoms of hillsides and along arroyos and dried creek beds, but about as often as they were seen within conducting the same activities within 5 m of canopy cover provided primarily by oaks. Roosting locations were rarely observed in open-grass fields and were almost always within 5–10-m distance of large canopy cover.

Research Ranch.–.The dominant GAP vegetation type at the Research Ranch within the buffered MCP region consisted mostly of Semidesert Mixed Grass—Mixed Scrub (76.6%), followed by Semidesert Mixed Grass—Mesquite (17.88%) and Semidesert Mixed Grass—Yucca-Agave (5.6%). Quail selected for Semidesert Mixed Grass—Mesquite (68.1%, *n* = 821) far more than Semidesert Mixed Grass—Mixed Scrub (31.8%, *n* = 384) or Semidesert Mixed Grass—Agave (0.1%, *n* = 1). On-the-ground surveys of quail habitat use confirmed the overwhelming preference for Semidesert Mixed Grass—Mesquite. Most of that habitat type within the AWRR was found within lower-elevation riparian and arroyos dominated by sacaton bottomlands. Observations of different quail coveys noted sharp differences in selection of habitat types depending on where their coveys resided within the AWRR. Most coveys primarily utilized sacaton bottomlands if they were within 100–200 m of their roosting locations, opting for the greater abundance of high grass cover to the sparse overstory canopy cover provided by oaks or sycamores at the AWRR. A few coveys (*n* =3) instead chose to use gentle-sloping hillsides with moderate overstory canopy, which directly bordered arroyos and open-grass fields, despite sacaton bottomlands being well within 100–200 m of their typical roost locations. One covey selected for the open-grass fields in early spring, seeking cover primarily within the rugged topography and midstory shrubs lining the dendritic drainages between gentle-sloping hills.

Contingency Analysis of Aspect

***Stevens Canyon*.–.**Sample size at Stevens Canyon was limited to 62 observations, most of which were constrained to daytime observations (*n* = 16). Most records were missing accurate records for time (*n* = 46), so the Chi-squared test was not evaluated stratified by time interval. The Chi-squared contingency analysis found a significant difference between actual versus random locations by aspect (Pearson χ^2 = 14.371, *P* = 0.045).

***Hog Canyon*.–.**Sample size at Hog Canyon was moderate (*n* = 374), of which most constituted daytime observations (*n* = 228). Many observations were missing accurate records for time (*n* = 115), and few observations were accurately listed for nighttime intervals (*n* = 31) so the Chi-squared test was not evaluated stratified by time interval. The Chi-squared contingency analysis found a significant difference between actual versus random locations by aspect (Pearson χ^2 = 123.058, *P* < 0.001).

***Research Ranch*.–.**Sample size at the AWRR was large (*n* = 1,206) and constituted nearly even sample sizes amongst the 4 designated time intervals (time interval 1, *n* = 210; time interval 2, *n* = 312; time interval 3, *n* = 313; time interval 4, *n* =

210). Observations that had missing or inaccurate time records (n = 161) were omitted from analysis. The Chi-squared contingency analysis found a significant difference between actual versus random locations by aspect for all time intervals (time interval 1, Pearson χ^2 = 54.677, P < 0.001; time interval 2, Pearson χ^2 = 44.295, P < 0.001; time interval 3, Pearson χ^2 = 37.431, P < 0.001; time interval 4, Pearson χ^2 = 36.589, P < 0.001).

Nominal Logistic Regression Analysis

***Stevens Canyon*.–.**Sample size at Stevens Canyon was small so a full model stratified by time and including all landscape features could not be evaluated. Instead, a model with only elevation, ruggedness, and the interaction between elevation ruggedness was evaluated. Results for the model indicated no difference in selection between actual and random landscape features in the model (χ^2 = 2.67, P = 0.44).

***Hog Canyon*.–.**A full model integrating elevation, aspect, and ruggedness was evaluated for Hog Canyon. Stratification by time interval was not evaluated because of limited sample sizes for each interval. Models testing all possible interactions between the landscape features sometimes produced unstable results in JMP 9.0 (SAS 2007). This was likely due to there being more parameters in the model than could be estimated by the data or “sparse” data where there were few or no repeats of each setting of the covariates (SAS 2007). The number of variables or interactions between variables was then reduced to allow model testing. The regression model that was selected evaluated elevation, aspect, ruggedness and the interaction between elevation and ruggedness. The full model showed that some landscape features differed significantly between actual and random points ($\chi^2 = 170.76$, $P < 0.001$, AICc = 889.928), thus rejecting the null hypothesis the full model for points actually selected by quail is no better at explaining the selection than a random distribution for all observations.

The effect likelihood-ratio test suggests all the main parameters were significant (Table 4.1): elevation ($\chi^2 = 7.80$, $P = 0.005$), aspect ($\chi^2 = 112.24$, $P < 0.001$), ruggedness ($\chi^2 = 13.97$, $P < 0.001$), and elevation * ruggedness ($\chi^2 = 3.87$, $P = 0.049$). Wald's χ^2 values were used to further explore significant values for "aspect" (Table 4.2), these were: aspect E ($\chi^2 = 4.16$, $P = 0.041$), aspect N ($\chi^2 = 16.45$, $P < 0.001$), aspect NE ($\chi^2 = 21.51$, $P < 0.001$), aspect NW ($\chi^2 = 19.56$, $P < 0.001$), aspect SW ($\chi^2 = 19.47$, $P < 0.001$), and ruggedness ($\chi^2 = 13.61$, $P < 0.001$).

Research Ranch.–.A full model, independent of time intervals, integrating elevation, aspect, and ruggedness was evaluated for the AWRR. There also was sufficient sample size for each time interval to evaluate the model stratified by time interval. Models testing all possible interactions between the landscape features sometimes produced unstable results in JMP 9.0 (SAS 2007). The interaction between elevation and aspect was not evaluated in the time-stratified model. This was likely due to there being more parameters in the model than could be estimated by the data or "sparse" data where there were few or no repeats of each setting of the covariates (SAS 2007).

Table 4.1 Effect Likelihood ratio tests and corresponding Chi-square (χ^2) statistics for logistic regression parameters tested for Hog Canyon. Number of parameters (N), L-R Chi-square statistics (χ^2), and corresponding *P*-values also are listed in the table. Source categories include elevation, aspect, ruggedness (rugged) and the interaction of these categories.

Source	*N*	*df*	χ^2	*P*
elevation	1	1	7.800	0.005*
aspect	7	7	112.237	<0.001*
rugged	1	1	13.971	<0.001*
elevation*rugged	1	1	3.866	0.049*

Table 4.2 Parameter estimates, Wald's Chi-square values (χ^2), and corresponding *P*-values for logistic regression test for Hog Canyon. Source categories include elevation, aspect, ruggedness (rugged), and the interactions of those categories.

Term	Estimate	*SE*	χ^2	*P*
Intercept	-12.616	4.10	9.45	0.002*
elevation	0.007	0.003	7.63	0.006*
aspect[E]	0.514	0.252	4.16	0.041*
aspect[N]	1.00	0.247	16.45	<.001*
aspect[NE]	0.967	0.208	21.51	<.001*
aspect[NW]	1.906	0.431	19.56	<.001*
aspect[S]	0.109	0.226	0.23	0.631
aspect[SE]	0.239	0.268	0.80	0.372
aspect[SW]	-1.922	0.435	19.47	<.001*
rugged	0.110	0.030	13.61	<0.001*
(elevation)*(rugged)	0.002	0.001	3.78	0.052

Both the time-independent and time-stratified models provided results that rejected the null hypothesis of no difference in selection between actual and random locations. The time independent model was significant ($\chi^2 = 801.55$, $P < 0.001$), but had a very large AICc value (AICc = 2164.98) in comparison to the time-stratified models: time interval 1 ($\chi^2 = 163.03$, $P < 0.001$, AICc = 458.29); time interval 2 ($\chi^2 = 239.50$, $P < 0.001$, AICc = 664.06); time interval 3 ($\chi^2 = 264.45$, $P < 0.001$, AICc = 640.50); time interval 4 ($\chi^2 = 178.31$, $P < 0.001$, AICc = 443.02). The time-stratified models were selected as better fits for the data based on lower AICc values. However, there were some noteworthy and significant trends observed in the time-independent model that were not observed in the time-stratified models. Unlike some of the time-stratified models, ruggedness was not a significant parameter in the time-independent model, but several 2-way and 3-way interactions (Table 4.3) were: rugged * elevation ($\chi^2 = 14.58$, $P < 0.001$); elevation * aspect ($\chi^2 = 19.01$, $P = 0.008$); rugged * elevation * aspect ($\chi^2 = 53.78$, $P < 0.001$).

Table 4.3 Effect Likelihood ratio tests and corresponding Chi-square (χ^2) statistics for logistic regression, time-independent parameters tested for the Appleton-Whittell Research Ranch. Number of parameters (N), L-R Chi-square statistics (χ^2), and corresponding *P*-values also are listed in the table. Source categories include ruggedness (rugged), elevation, aspect (aspect-cat), and the interactions of those categories.

Source	*N*	*df*	χ^2	*P*
rugged	1	1	0.126	0.723
elevation	1	1	254.131	<0.001*
aspect-cat	7	7	154.306	<0.001*
rugged*elevation	1	1	14.586	<0.001*
rugged*elevation*aspect-cat	7	7	53.783	<0.001*
elevation*aspect-cat	7	7	19.015	<0.001*
rugged*aspect-cat	7	7	8.150	0.320

Effect likelihood ratio tests for time interval 1 (Table 4.4) note that elevation ($\chi^2 = 83.84$, $P < 0.001$), aspect ($\chi^2 = 55.80$, $P < 0.001$), and rugged * aspect ($\chi^2 = 19.76$, $P = 0.006$) were significant explanatory variables in the model. Exploratory analysis of Wald's χ^2 values (Table 4.5) note that aspect-E ($\chi^2 = 8.31$, $P = 0.004$), aspect-N ($\chi^2 = 8.20$, $P = 0.004$), aspect-NW ($\chi^2 = 25.48$, $P < 0.001$), rugged * aspect-E ($\chi^2 = 5.78$, $P = 0.016$), and rugged * aspect-SW ($\chi^2 = 4.85$, $P = 0.028$) were specifically significant components within the model.

Effect likelihood ratio tests for time interval 2 (Table 4.6) note that ruggedness ($\chi^2 = 6.07$, $P = 0.014$), elevation ($\chi^2 = 157.10$, $P < 0.001$), aspect ($\chi^2 = 26.96$, $P < 0.001$), and rugged * elevation ($\chi^2 = 6.64$, $P = 0.010$) were significant explanatory variables in the model. Exploratory analysis of Wald's χ^2 values (Table 4.7) note that aspect-E ($\chi^2 = 7.33$, $P = 0.007$), aspect-N ($\chi^2 = 13.73$, $P < 0.001$), rugged * elevation ($\chi^2 = 7.01$, $P = 0.008$), and rugged * aspect-SE ($\chi^2 = 8.51$, $P = 0.004$) were specifically significant components within the model.

Effect likelihood ratio tests for time interval 3 (Table 4.8) note that ruggedness ($\chi^2 = 5.91$, $P = 0.015$), elevation ($\chi^2 = 170.01$, $P < 0.001$), and aspect ($\chi^2 = 47.32$, $P < 0.001$) were significant explanatory variables in the model. Exploratory analysis of Wald's χ^2 values (Table 4.9) note that aspect-E ($\chi^2 = 11.98$, $P < 0.001$), aspect-N ($\chi^2 = 6.61$, $P = 0.010$), aspect-NW ($\chi^2 = 14.64$, $P < 0.001$), aspect-SE ($\chi^2 = 5.83$, $P = 0.016$), and rugged * aspect-N ($\chi^2 = 6.62$, $P = 0.010$) were specifically significant components within the model.

Table 4.4 Effect Likelihood ratio tests and corresponding Chi-square (χ^2) statistics for logistic regression, time interval 1, parameters tested for the Appleton-Whittell Research Ranch. Number of parameters (N), L-R Chi-square statistics (χ^2), and corresponding *P*-values also are listed in the table. Source categories include ruggedness (rugged), elevation, aspect (aspect-cat), and the interactions of those categories.

Source	*N*	*df*	χ^2	*P*
rugged	1	1	1.753	0.186
elevation	1	1	83.846	<.001*
aspect-cat	7	7	55.800	<.001*
rugged*elevation	1	1	3.086	0.080
rugged*aspect-cat	7	7	19.763	0.006*

Table 4.5 Parameter estimates, Wald's Chi-square values (χ^2), and corresponding *P*-values for logistic regression, time interval 1, test for the Appleton-Whittell Research Ranch. Term categories include ruggedness (rugged), elevation, aspect (aspect-cat), and the interactions of those categories.

Term	Estimate	*SE*	χ^2	*P*
Intercept	78.017	9.908	62.00	<0.001*
rugged	-0.050	0.042	1.46	0.227
elevation	-0.054	0.007	62.15	<0.001*
aspect-cat[E]	-2.482	0.861	8.31	0.004*
aspect-cat[N]	0.949	0.331	8.20	0.004*
aspect-cat[NE]	0.342	0.397	0.74	0.390
aspect-cat[NW]	1.719	0.340	25.48	<0.001*
aspect-cat[S]	-1.650	1.086	2.31	0.129
aspect-cat[SE]	-0.160	0.362	0.20	0.658
aspect-cat[SW]	0.424	0.535	0.63	0.428
(rugged)*(elevation-)	-0.002	0.001	2.92	0.087
(rugged)*aspect-cat[E]	-0.340	0.142	5.78	0.016*
(rugged)*aspect-cat[N]	-0.039	0.056	0.48	0.488
(rugged)*aspect-cat[NE]	0.118	0.066	3.18	0.074
(rugged)*aspect-cat[NW]	0.042	0.051	0.66	0.417
(rugged)*aspect-cat[S]	-0.098	0.222	0.20	0.658
(rugged)*aspect-cat[SE]	0.096	0.071	1.82	0.177
(rugged)*aspect-cat[SW]	0.204	0.093	4.85	0.028*

Table 4.6 Effect Likelihood ratio tests and corresponding Chi-square (χ^2) statistics for logistic regression, time interval 2, parameters tested for the Appleton-Whittell Research Ranch. Number of parameters (N), L-R Chi-square statistics (χ^2), and corresponding *P*-values also are listed in the table. Source categories include ruggedness (rugged), elevation, aspect (aspect-cat), and the interactions of those categories.

Source	*N*	*df*	χ^2	*P*
rugged	1	1	6.076	0.014*
elevation	1	1	157.101	<0.001*
aspect-cat	7	7	26.966	<0.001*
rugged*elevation	1	1	6.644	0.001*
rugged*aspect-cat	7	7	11.731	0.109

Table 4.7. Parameter estimates, Wald's Chi-square values (χ^2), and corresponding *P*-values for logistic regression, time interval 2, test for the Appleton-Whittell Research Ranch. Term categories include ruggedness (rugged), elevation, aspect (aspect-cat), and the interactions of those categories.

Term	Estimate	*SE*	χ^2	*P*
Intercept	93.362	8.686	115.54	<0.001*
rugged	0.044	0.0180	6.01	0.014*
elevation	-0.064	0.006	115.60	<0.001*
aspect-cat[E]	-0.680	0.251	7.33	0.007*
aspect-cat[N]	0.929	0.251	13.73	<0.001*
aspect-cat[NE]	-0.140	0.276	0.26	0.612
aspect-cat[NW]	0.391	0.256	2.33	0.127
aspect-cat[S]	-0.490	0.313	2.45	0.118
aspect-cat[SE]	0.276	0.304	0.83	0.363
aspect-cat[SW]	-0.163	0.440	0.14	0.711
(rugged)*(elevation)	0.002	0.001	7.01	0.008*
(rugged)*aspect-cat[E]	-0.025	0.041	0.36	0.547
(rugged)*aspect-cat[N]	-0.018	0.036	0.25	0.619
(rugged)*aspect-cat[NE]	-0.062	0.043	2.03	0.155
(rugged)*aspect-cat[NW]	-0.025	0.031	0.66	0.415
(rugged)*aspect-cat[S]	-0.032	0.052	0.38	0.536
(rugged)*aspect-cat[SE]	0.187	0.06	8.51	0.004*
(rugged)*aspect-cat[SW]	-0.051	0.050	1.07	0.301

Table 4.8 Effect Likelihood ratio tests and corresponding Chi-square (χ^2) statistics for logistic regression, time interval 3, parameters tested for the Appleton-Whittell Research Ranch. Number of parameters (N), L-R Chi-square statistics (χ^2), and corresponding *P*-values also are listed in the table. Source categories include ruggedness (rugged), elevation, aspect (aspect-cat), and the interactions of those categories.

Source	*N*	*df*	χ^2	*P*
rugged	1	1	5.908	0.015*
elevation	1	1	170.006	<.001*
aspect-cat	7	7	47.326	<.001*
rugged*elevation	1	1	1.927	0.165
rugged*aspect-cat	7	7	13.261	0.066

Table 4.9. Parameter estimates, Wald's Chi-square values (χ^2), and corresponding *P*-values for logistic regression, time interval 3, test for the Appleton-Whittell Research Ranch. Term categories include ruggedness (rugged), elevation, aspect (aspect-cat), and the interactions of those categories.

Term	Estimate	*SE*	χ^2	*P*
Intercept	91.666	8.272	122.81	<0.001*
rugged	-0.051	0.022	5.33	0.021*
elevation	-0.0627	0.006	121.67	<0.001*
aspect-cat[E]	-1.123	0.325	11.98	<0.001*
aspect-cat[N]	0.697	0.271	6.61	0.010*
aspect-cat[NE]	0.453	0.249	3.30	0.069
aspect-cat[NW]	1.088	0.284	14.64	<0.001*
aspect-cat[S]	-0.443	0.338	1.71	0.190
aspect-cat[SE]	-0.754	0.312	5.83	0.016*
aspect-cat[SW]	-0.127	0.672	0.04	0.850
(rugged)*(elevation)	0.001	<0.001	2.00	0.158
(rugged)*aspect-cat[E]	-0.103	0.065	2.49	0.115
(rugged)*aspect-cat[N]	0.102	0.040	6.62	0.010*
(rugged)*aspect-cat[NE]	0.023	0.041	0.32	0.572
(rugged)*aspect-cat[NW]	0.021	0.042	0.25	0.615
(rugged)*aspect-cat[S]	0.060	0.063	0.90	0.342
(rugged)*aspect-cat[SE]	-0.051	0.064	0.66	0.417
(rugged)*aspect-cat[SW]	-0.113	0.091	1.54	0.215

Effect likelihood ratio tests for time interval 4 (Table 4.10) note that elevation (χ^2 = 99.69, P < 0.001), and aspect (χ^2 = 21.06, P = 0.004) were significant explanatory variables in the model. Exploratory analysis of Wald's χ^2 values (Table 4.11) note that aspect-NW (χ^2 = 7.92, P = 0.005) and rugged and aspect-N (χ^2 = 6.42, P = 0.011) were specifically significant components within the model.

DISCUSSION

Analysis of Montezuma quail location data in southeast Arizona confirmed many notions about their first-order and second-order selection of habitat already described in the scientific literature. Most of those studies, with exception to Stromberg's (1990), however, draw conclusions based on limited presence-absence data, flush-count surveys with dogs, and hunter-harvest surveys, thus reducing the ability to accurately infer selection by this species at finer scales. Such data may poorly reflect or not fully consider habitat that is potentially available to the species at multiple scales (Cooper and Milspaugh 1999). The use of radiotelemetry data in this study allowed me to better extrapolate the potential range of a population and thus the potential of that population to use the habitat within that range based on estimates of home range at a local scale. My study revealed that other landscape characteristics besides vegetation composition of an area are just as important to consider when examining second-order habitat selection by this species. Aspect, elevation, terrain ruggedness, and the interaction of these variables were significant components to consider in how this species selects for landscape features in its behavioral strategies for survival. When combined with vegetation data,

Table 4.10 Effect Likelihood ratio tests and corresponding Chi-square (χ^2) statistics, for logistic regression, time interval 4, parameters tested for the Appleton-Whittell Research Ranch. Source categories include ruggedness (rugged), elevation, aspect (aspect-cat), and the interactions of those categories.

Source	*N*	*df*	χ^2	*P*
rugged	1	1	<0.001	0.990
elevation	1	1	99.691	<.001*
aspect-cat	7	7	21.067	0.004*
rugged*elevation	1	1	0.695	0.404
rugged*aspect-cat	7	7	11.830	0.106

Table 4.11 Parameter estimates, Wald's Chi-square values (χ^2), and corresponding *P*-values for logistic regression, time interval 4, test for the Appleton-Whittell Research Ranch. Term categories include ruggedness (rugged), elevation, aspect (aspect-cat), and the interactions of those categories.

Term	Estimate	*SE*	χ^2	*P*
Intercept	87.594	10.208	73.63	<.001*
rugged	<0.001	0.029	0.00	0.990
elevation	-0.060	0.007	74.21	<.001*
aspect-cat[E]	-0.626	0.365	2.94	0.086
aspect-cat[N]	-0.877	0.474	3.42	0.065
aspect-cat[NE]	-0.459	0.534	0.74	0.390
aspect-cat[NW]	0.883	0.314	7.92	0.005*
aspect-cat[S]	-0.415	0.455	0.83	0.362
aspect-cat[SE]	0.006	0.298	0.00	0.985
aspect-cat[SW]	0.651	0.754	0.74	0.388
(rugged)*(elevation)	<0.001	0.001	0.71	0.400
(rugged)*aspect-cat[E]	0.030	0.059	0.26	0.610
(rugged)*aspect-cat[N]	-0.214	0.084	6.42	0.011*
(rugged)*aspect-cat[NE]	-0.049	0.088	0.31	0.578
(rugged)*aspect-cat[NW]	-0.016	0.038	0.19	0.666
(rugged)*aspect-cat[S]	0.091	0.104	0.78	0.378
(rugged)*aspect-cat[SE]	0.013	0.055	0.06	0.809
(rugged)*aspect-cat[SW]	0.114	0.080	2.04	0.153

these components develop a clearer notion of habitat preferences for this species within similar ecological regions.

Selection for vegetation type showed some key differences between the 3 study sites at both second-order and third-order scales. When examining second-order selection, one must first consider differences in major vegetation types between the 3 study sites using the GAP vegetation layers as a reference. Using the buffered MCP regions derived from telemetry and survey data, as a basis for establishing habitat that was most likely available to the local population, the data shows that the dominant vegetation types within the MCP regions at the 3 sites differed dramatically. Stevens Canyon was predominantly composed of Semidesert Mixed Grass–Mixed Scrub (90.93%), the AWRR was dominated by Semidesert Mixed Grass–Mixed Scrub (76.6%), but the dominant vegetation at Hog Canyon was Encinal Mixed Oak (75.3%). All 3 sites exhibited some variation of Semidesert Mixed Grass, but a greater representation of overstory canopy cover provided by *Quercus* species at Hog Canyon had a major influence in selection for available cover—accounting for 99.5% of all quail locations at that site. At a third-order scale, telemetry data showed that quail selection for roosting, feeding, or escape cover was closely associated within 5–10 m of canopy cover provided by oaks. The results for Hog Canyon support most of what has been published in the literature for this species, but further examination of the data for the region provides evidence to the contrary.

One clear example to the contrary is seen from habitat use at Stevens Caynon. Although Stevens Canyon had some representation of Encinal Mixed Oak (8.0%) within the MCP region evaluated, only 1.6% of the locations were observed within this region. At first glance this might suggest that quail at this study site did not select for oak cover where it was available, but one must consider that the coarse scale of the GAP layer may be partially responsible for under-representing available oak habitat at the study site. Although the abundance and density of oaks and other high canopy trees at Stevens Canyon was less than Hog Canyon, quail would often be observed feeding or roosting within 5–15 m of oak trees within the Semidesert Mixed Grass–Mixed Scrub habitat type. These results reflect similar results found by Stromberg (1990) at the AWRR where most daytime relocations of quail were “within 20m of the nearest oak tree on steep areas”. Similar to Stevens Canyon, the AWRR has a naturally-occurring low abundance and density of oak cover compared to Hog Canyon. Quail selection for available canopy cover at the AWRR, however, differed from the other 2 study sties. Selection for canopy cover within the MCP region at the AWRR differed by covey location within the study site. Some coveys, particularly those whose activity range was mostly associated with sacaton bottomlands, selected to use sycamore or mesquite for canopy cover. Coveys whose activity range was not closely associated with sacaton bottomlands selected oaks more for shade or escape cover. Selection for a particular canopy cover, therefore, was mostly associated to its closer proximity to their common feeding and roosting areas and not the extent of their potential 50% or 95% kernel ranges. These results corroborate some of Stromberg’s (1990) results for choice of canopy cover at this study site, with the exception of those coveys that were not located close enough to oak cover. Such coveys would take advantage of other species of large trees within close proximity, but more often than not, would rather make use of cover provided by the more abundant, tall, and dense sacaton in the bottomlands.

The intensive use of sacaton at the AWRR provides evidence that rejects other common notions about Montezuma quail habitat use in the southeast Arizona region. Most populations of Montezuma quail are thought to predominantly use typical densities and heights of grass commonly associated with Madrean oak woodland and montane meadows. Stromberg (1990), for example, noted the mean vegetation height of roost sites (49.5±2.34 cm) and day-use sites (41.9±3.62 cm) in areas in close proximity to oak cover. Both of these are considerably lower than the mean vegetation heights of sacaton (171.9±41.5 cm) reported in the literature for the AWRR (Bock and Bock 1978). Observations similar to Stromberg (1990) have been reported by Bristow and Ockenfels (2004) and Bristow and Ockenfels (2000) in regards to specific heights of grass and canopy cover used by Montezuma quail. Yet, an overwhelming majority of coveys of Montezuma quail at the AWRR made more intensive use of the tall sacaton during the daytime and rarely used higher canopy cover even the closest available oak trees were within 50–100m from the common daytime activity areas. The majority of flush sites at the AWRR were not in proximity to large trees and quail densities at the AWRR were actually higher in the open sacaton bottomlands than areas lined with oak trees. These results are opposite of those reported by Bristow and Ockenfels (2000) and Brown (1973), which reported that quail densities are often lower in vegetation types other than those typically observed in oak woodland habitats. Habitat use models thus must not conform to those habitat characteristics typically observed of Montezuma quail within Madrean evergreen woodlands in southeast Arizona. This new data needs to be considered especially for habitat management actions regarding the conservation of this species throughout diverse habitats.

Despite these differences, some similarities in choice of grass density, percent cover, elevation, and slope were corroborated between this study and past research. Observations made in the Hog Canyon and Steven Canyon study sites, which have greater representation of Madrean oak woodlands, mirror statistics provided in previous studies (Stromberg 1990, Bristow and Ockenfels 2004, Bristow and Ockenfels 2000) for choice of percent grass cover, density, and height. This is particularly true for vegetation parameters collected on roost sites. With the exception of the AWRR, most coveys of Montezuma quail were observed roosting on the hillsides rather than in arroyo bottoms. Further, though time-stratified tests could not be conducted due to a limited sample size, all the effect-likelihood ratio tests note strong significance in habit use for higher elevation ($P = 0.0052$), rugged topography ($P = 0.0002$), and the positive interaction of elevation and rugged topography ($P = 0.0493$) at Hog Canyon. By contrast, most coveys at the AWRR were observed to heavily utilize the less rugged and lower elevation sacaton bottoms for roost sites, as observed in results for time interval 4 ($P < 0.0001$). This preference to utilize lower elevation areas at the AWRR also was observed in the time-independent test ($P < 0.0001$), and all the time-dependent tests for intervals 1–3 (all $P < 0.0001$).

Another point of difference between past research and results from this study is that of choice of aspect, or azimuth, in terms of habitat use during the day or night. Bristow and Ockenfels (2004) observed that “selection for east-facing slopes on ridge tops likely was related to the proximity of tree canopies at the Research Ranch”. Stromberg’s (1990) telemetry data provides a more precise depiction of their habitat use—noting in particular that roost sites faced southeast, with a mean aspect of 74.4^0 and differed significantly from randomly selected sites which faced northeast. One reasonable explanation for those results observed by Stromberg (1990) for roost sites is that quail may prefer to remain on terrain that faces the early sun in the morning and thus retains solar radiation from early in the day. For daytime activities, Stromberg (1990) reported that “quail prefer north-facing slopes and thus by association, are more likely to be near oaks”, although he also adds that “on rare occasions, I observed Montezuma quail at least 3 km from any trees, well out in open grassland”. Daytime sites used by quail in his study noted a north-facing mean aspect of 16.3^0, and differed significantly in aspect from randomly selected sites (Stromberg 1990). Our research noted some similarities to Stromberg’s (1990) results—in particular for the time-independent analysis conducted for Hog Canyon where quail strongly selected for N, NE, and NW-facing slopes much more than S, SE, SW, or W-facing slopes when compared to randomly selected sites (Table 5.2 and Table 5.9). The time-stratified analysis of selection for aspect conducted for the AWRR produced much different results. For time interval 1 (0700–1059 hours), quail selected more for N, NW, and W-facing slopes as opposed to E, NE, S, SE, and SW-facing slopes when compared to randomly selected sites (Table 5.3). As temperatures gradually increased in the later morning during time interval 2 (1100–1459 hours), quail selected more for N, NW, and W-facing slopes than E, NE, S, and SE-facing slopes (Table 5.4). In the later afternoon, during time interval 3 (1500–1859 hours), quail were observed to use N, NE, NW, and W-facing slopes more so than E, S, SE, and SW-facing slopes (Table 5.5). This is most likely due to quail seeking shelter from peak temperatures observed during the early afternoon. For roost locations, however, during time interval 4 (1900–0659 hours), our research notes that quail selected for NW, SW, and W-facing slopes more so than E, NE, S, and SE-facing slopes (Table 5.6). This is contrary to that observed by Stromberg (1990)—so much so that quail actually were 2.4 times more likely to select for NW-facing slopes than SE-facing slopes (Table 5.23). One reason for the difference may be related to the larger sample size of our study and the important fact that our telemetry results included subpopulations of coveys within the AWRR that were most likely overlooked in Stromberg's (1990) study. Another important explanation may be that our data notes habitat use from later winter to early summer, whereas Stromberg's (1990) study focuses particularly on habitat use in late fall to early winter. The closer we examine our results, however, we can speculate that perhaps the reason why quail select for NW-facing slopes in the later part of the evening would be to make better use of the heat absorbed in the surrounding landscape from solar radiation retained from the late afternoon sun. This makes ecological sense especially since temperatures tend to decline rapidly in the early evening and quail can avoid cooler temperatures in the N and W-facing slopes in the early morning by simply moving out to bask and feed in warmer zones in the surrounding topography.

A matter that complicates interpretation of selection for vegetation type at the 3 sites is variation in density and abundance of native grass cover and the impact of anthropogenic land-use at each particular site. Grazing and hunting are activities which have high potential to influence the distribution of this species (Brown 1972) at Stevens Canyon and Hog Canyon, where they are permitted by law. Of these 2 activities, grazing has the most impact on this species because the amount of available understory cover for quail is directly related to the grazing pressure impacted at a particular site. At Stevens Canyon, the number of cattle observed within a given year, from 2008–2010, was 10–20 head, although the number was probably higher. Grazing pressure at Stevens Canyon was often observed in early spring and summer and had mixed consequences on recovery depending on patterns of precipitation that followed grazing activity. Moderate grazing activity was observed from 2008–2009, allowing some grass to recover and populations of quail to persist at moderate densities. In March 2010, however, heavy grazing at Stevens Canyon was estimated to have reduced available grass cover for quail to less than 20%. The amount of reduced cover did not just include bottomlands, flats, and valleys where cattle are more likely to graze, but also grass cover near the base of trees and on hills where quail would often roost or flee from predation.

Like Stevens Canyon, grazing at Hog Canyon had the potential to negatively impact amount of available cover and influence their selection for available habitat. The number of cattle at Hog Canyon was never observed to be more than 10 head although its proximity to nearby ranches, and grazing allotments permitted the by United States Forest Service (USFS), should make that estimate higher than what was observed in the field. Grazing impact was generally low to moderate within the buffered MCP range derived for Hog Canyon. Most of the grazing impact was contained within the lower elevations and low hills found in the eastern portion of the MCP range, where most of the quail were not generally observed. Sufficient height and density of grass cover was generally found within the eastern portion of the MCP to allow coveys to persist, but, reduced cover associated with seasonal grazing pressure probably accounts for reduced presence and selection by quail at these lower-elevation hills and valleys. Cattle were rarely observed to graze in the higher elevation hills dominated by oak trees where Montezuma quail predominantly resided. In October 2009, however, heavy grazing during the summer contributed to a considerable loss of ground cover throughout the lower valleys, low hills, and high ridges. The direct impact on the quail population could not be evaluated because there were no marked individuals being followed at the time. Cow dung, not normally found at the highest ridges of Hog Canyon, was found in higher abundances in 2009–2010. The impact of reduced grass cover throughout all elevations at Hog Canyon may have had significant consequences on available habitat for Montezuma quail to utilize for that summer nesting season and the fall season that followed.

Impact from recent grazing is not a factor that would influence contemporary populations at the AWRR, where it is has not been permitted for many years. However, the dominance of invasive grass species throughout the northern part of the AWRR and the occurrence of a large wildfire in 5 May 2009 (Chavarria et al. 2012*c*) are important factors to consider in the interpretation of our results. The impact of the wildfire requires more in-depth analysis especially because it temporarily restructured the vegetation and available habitat for Montezuma quail (Chavarria et al. 2012*c*). Whereby in one instance available habitat is reduced, fire also may serve to make new habitat available where there was reduced potential for use before. This topic thus requires further review in regards to how Montezuma quail make use of the habitat at the AWRR in pre- and post-fire conditions.

CHAPTER V

SUMMARY AND CONCLUSIONS

My research on Montezuma quail (*Cyrtonix montezumae mearnsi*) sought to examine several knowledge gaps about this species' life history—particularly its survival demographics and range size. My objectives were to: (1) improve or develop new methods for capturing, marking, and monitoring Montezuma quail through radio telemetry, (2) determine actual rate of survival and causes of mortality for this species, (3) determine range size and habitat use from locations gathered through radio telemetry, (4) evaluate differences in survival, range, and habitat use for this species between hunted and non-hunted sites in southeast Arizona.

I adapted old methods for locating and capturing Montezuma quail by now integrating the use of GPS collars on pointing dogs to facilitate keeping track of dogs at night and thus facilitate finding roost locations at night once a dog went on point. I used portable infrared cameras to approximate roost locations of marked and unmarked birds at night. This method was most effective when used when 3 crew members and a dog were actively trapping birds or when birds had already been radio-marked. Tracking of radio-marked birds allowed me to estimate survival demographics, causes of mortality, and compare these results between hunted and non-hunted sites. In seasons with average precipitation and temperatures, survival rate of Montezuma quail in southeast Arizona are similar to those of most North American quail. However, above-average amount of winter precipitation coupled with extreme low temperatures caused massive mortality in

2010. Other highly detrimental sources of mortality in this species include the impact of wildfire to their habitat. Montezuma quail survival and abundance was greatly reduced in semi-desert grasslands that did not recover as quickly as those that included sacaton bottomlands. Despite reduced cover, Montezuma quail were observed feeding in burned areas within days, roosting within burned areas within weeks, and nesting within burned areas less than 3 months following a wildfire.

Range size for Montezuma quail in southeast Arizona is small during winter but expands during the late spring and early summer season. Small sample size in my study limited statistical analysis of range size across different seasons, but my observations reinforce previous assumptions in the literature about the sedentary nature of this species. My observations also provide evidence for strong site fidelity even in the midst of potentially catastrophic stochastic events such as wildfire and severe weather. Montezuma quail in my research were not observed to conduct long-range migrations and several were observed to return to their former winter range after having moved away a short distance temporarily during the breeding season. I also used radiotelemetry locations to analyze habitat use in regards to landscape features such as topography, vegetation type, and aspect. My results support most assumptions about the distribution of this species within forested habitats as reported in the literature or in GIS models (e.g., Gap Analysis). However, my results show that Montezuma quail in Arizona also thrive in semi-desert bottomlands that provide sufficient cover (i.e., sacaton). Current GIS models provided through Gap Analysis do not account for their distribution in sacaton bottomlands and there is a need to reevaluate them to improve habitat conservation efforts for this species.

The combined results from my research provide conservation biologists with vital information for better managing this species as game or non-game. Information on actual survival rate at the population level, which was lacking in the literature, is now available to help guide more informed and accurate decisions about the potential impact of anthropogenic activities and climate change on the conservation of this species. Prescribed fire should be used with extreme caution in semi-desert grasslands where Montezuma quail are present since vegetative recovery tends to be delayed and my results note extreme reductions in their abundance in fire-affected areas. Extreme caution is also warranted for managing hunting of Montezuma quail without change in regulations when their abundance are overwhelmingly reduced as a result of severe winter weather.

LITERATURE CITED

Arizona Game and Fish Department. 2006. Comprehensive wildlife conservation Strategy: 2005–2015. Arizona Game and Fish Department, Phoenix, USA.

Bailey, F. M. 1928. Birds of New Mexico. New Mexico Department of Game and Fish, Santa Fe, USA.

Bishop, R. A. 1964. The Mearns quail (*Cyrtonyx montezumae mearnsi*) in Southern Arizona. Thesis, University of Arizona, Tucson, USA.

Bishop, R. A., and C. R. Hungerford. 1965. Season food selection of Arizona Mearns quail. Journal of Wildlife Management 29:814–819.

Bock, C. E., and J. H. Bock. 1978. Response of birds, small mammals, and vegetation to burning sacaton grasslands in southeastern Arizona. Journal of Range Management 31:296–300.

Braun, C.E., editor. 2005. Techniques for wildlife investigations and management. Sixth edition. The Wildlife Society, Bethesda, Maryland, USA.

Brennan, L.A. 1991. How can we reverse the northern bobwhite population decline? Wildlife Society Bulletin 19:544–555

Brennan, L.A., editor. 2007 Texas quails: ecology and management. Texas A&M University Press, College Station, USA.

Bristow, K. D. and R. A. Ockenfels. 2000. Effects of human activity and habitat conditions on Mearns' quail populations. Technical Guidance Bulletin No. 4, Federal Aid in Wildlife Restoration Project W-78-R, Arizona Game and Fish Department Research Branch, Phoenix, USA.

Bristow, K.D., and R.A. Ockenfels. 2004. Pairing season habitat selection by Montezuma quail in southeastern Arizona. Journal of Range Management 57(5):532–538

Bristow, K. D., S. R. Boe, and R. A. Ockenfels. 2005. Predicting habitat suitability for wildlife in southeastern Arizona using geographic information systems: scaled quail, a case study. Pages 57–61 *in* USDA Forest Service Proceedings RMRS-P-36, U.S. Forest Service, Rocky Mountain Research Station, Department of Agriculture,Tucson, Arizona, USA.

Brown, D. E. 1979. Factors influencing reproductive success and population densities in Montezuma quail. Journal of Wildlife Management 43:522–526.

Brown, D. E. 1989. Mearns' (Montezuma) quail. Pages 105–121 *in* Arizona game birds. University of Arizona Press and Arizona Game and Fish Department, Tucson, USA.

Brown, R. L. 1982. Effects of livestock grazing on Mearn's quail in southeastern Arizona. Journal of Range Management 35:727–732

Brown, R. L . 1975. Mearns' quail capture method. Federal Aid Project W-78-R-15, Work Plan 1, Job 2. Final Report, Arizona Game and Fish Department. Phoenix, USA..

Brown, R. L. 1976. Mearns' quail census technique. Federal Aid in Wildlife Restoration Project W-78-R-15, Work Plan 1, Job 1. Arizona Game and Fish Department, Phoenix, USA.

Brown, R. L. 1978. An ecological study of Mearns' quail. Federal Aid in Wildlife Restoration Project W-78-R-22, Work Plan 2, Job 2, Final Report, Research Division Arizona Game and Fish Department. Phoenix, USA.

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*a*. Use of portable infrared cameras to facilitate detection and capture success of Montezuma quail. Proceedings of the National Quail Symposium 7:333–338

Chavarria, P. M., A. Montoya, N. J. Silvy, and R. R. Lopez. 2012*b*. Impact of inclement weather on overwinter mortality of Montezuma quail in southeast Arizona. Proceedings of the National Quail Symposium 7:346–351

Chavarria, P. M., N. J. Silvy, R. R. Lopez, C. Hass, and L. Kennedy. 2012*c*. Post-fire succession and Montezuma quail in a semi-desert grassland of southeast Arizona. Proceedings of the National Quail Symposium 7:339–345

Cooper, A. B., and J. J. Millspaugh. 1999. The application of discrete choice models to wildlife resource selection studies. Ecology 80: 566–575

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

Fox, J. 1997. Applied regression analysis, linear models, and related methods. Sage Publications, Thousand Oaks, California, USA.

Fuertes, L. A. 1903. With the Mearns quail in southwestern Texas. Condor 5:112–116.

Halvorson, W., K. Thomas, and L. Graham. 2001. Arizona Gap Analysis Project vegetation map. The Arizona Gap Project Final Report, Special Technical Report. USGS Sonoran Desert Field Station, University of Arizona. Tucson, USA.

Heffelfinger, J. R., F. S. Guthery, R. J. Olding, C. L. Cochran Jr. and C. M. McMullen. 1999. Influence of precipitation timing and summer temperatures on reproduction of Gambel's quail. Journal of Wildlife Management 63:154–161

Heffelfinger, J. R. and R. J. Olding. 2000. Montezuma quail management in Arizona. Pages 183–190 *in* L. A. Brennan, W. E. Palmer, L. W. Burger, Jr. and T. L. Pruden, editors. Quail IV: Proceedings of the Fourth National Quail Symposium, Tall Timbers Research Station, Tallahassee, Florida, USA..

Hernandez , F., E. Garza, L. A. Harveson, and C. E. Brewer. 2009. Fate and survival of radio-marked Montezuma quail. Pages 426–431 *in* S. B. Cederbaum, B. C. Faircloth,T. M. Terhune, J. J. Thompson, J.P. Carroll, editors. Gamebird 2006: Quail VI and Perdix XII, Warnell School of Forestry and Natural Resources, University of Georgia, Athens, USA

Holdermann, D. A. 1992. The geographic distribution, relative population abundance, and habitat characteristics of Montezuma quail in southwestern New Mexico. Final Report Professional Services Contract Numbers 80–516–41 and 80–516–83, New Mexico Department of Game and Fish, Santa Fe, New Mexico, USA.

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

Judd, S. D. 1905. The bobwhite and other quails of the United States in their economic relations. Bulletin No. 21,U.S. Bureau of Biological Survey, Department of Agriculture,. Washington, D.C., USA.

Kerhnohan, B. J., J. J. Millspaugh, J. A. Jenks, and D. E. Naugle. 1998. Use of an adaptive kernel home-range estimator in a GIS environment to calculate habitat use. Journal of Environmental Management 53:83–89

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.

Krebs, C. J. 2002. Programs for ecological methodology. Second edition. Harper and Row, New York, New York, 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.

Ligon J. S. 1946. Upland game bird restoration through trapping and transplanting. New Mexico Game and Fish Commission. University of New Mexico Press, Albuquerque,USA.

LOAS. 2010. Ecological Software Solutions LLC. Version 4.0.3.7, Hegymagas, Hungary.

Lopez, C. M., and C. Lopez. 1911. Caza Mexicana. Librería Viuda de C. Bouret, México.

Miller, L. 1943. Notes on the Mearns quail. Condor 45:104–109

Natural Resources Conservation Service (NRCS). Web soil survey. U.S. Department of Agriculture, Washington, D.C., USA. <http://websoilsurvey.nrcs.usda.gov/>. Accessed 28 October 2011.

Ott, R. L. 1993. An introduction to statistical methods and data analysis. Duxbury Press, Belmont, California, USA.

Pollock, K. H., S. R. Winterstein, C. M. Bunick, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry approach. Journal of Wildlife Management 53:7–14.

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.

Riley, S. J., S. D. DeGloria, and R. Elliot. 1999. A terrain ruggedness index that quantifies topographic heterogeneity. Intermountain Journal of Sciences 5(1–4):23–27.

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.

Rollins, D. 2002. Sustaining the 'quail wave' in the southern Great Plains. Pages 48–56 *in* S. J. DeMaso, W. P. Kuvlesky, Jr., F. Hernandez, and M. E. Berger, editors. Quail V: Proceedings of the Fifth National Quail Symposium. Texas Parks and Wildlife Department, Austin, USA

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

Sullivan, J. 1994. Cyrtonyx montezumae *in* Fire effects information system, Department of Agriculture, Rocky Mountain Research Station, Fire Sciences Laboratory, U.S. Forest Service, Department of Agriculture . < http://www.fs.fed.us/database/feis/> . Accessed 10 September 2012.

Taylor, D., and L. Katahira. 1988. Radio-telemetry as an aid in eradicating remnant feral goats. Wildlife Society Bulletin 16:297–299.

University of Arizona. 1999. Arizona GAP 1999 COVERAGE B058RS -- Montezuma quail. USGS Cooperative Park Studies Unit, USGS Sonoran Desert Research Station, University of Arizona. Tucson, USA.

United States Geological Survey. 2007. USGS high resolution state orthoimagery for Arizona. SDE raster digital data, U.S. Geological Survey, Sioux Falls, South Dakota, USA.

United States Geological Survey. 2009. 1-Arc second national elevation dataset. SDE raster digital data, U.S. Geological Survey, Sioux Falls, South Dakota, USA

United States Geological Survey. 2010. 3001 high resolution orthoimage. USNG 12RWA250040, Nogales AZ AOI, OBP Sector Tucson, Urban Area Orthoimagery, U.S. Geological Survey, Sioux Falls, South Dakota, USA.

Vorhies, C. T. 1928. Do southwestern quail require water? American Naturalist 62:446–452.

Wallmo, O. C. 1954. Nesting of Mearns quail in southeastern Arizona. Condor 56:125–128.

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.

Wilson, M. F. J., B. O’Connell, C. Brown, J. C. Guinan, A. J. Grehan. 2007. Multiscale terrain analysis of multibeam bathymetry data for habitat mapping on the continental slope. Marine Geodesy. 30:3–35.

Wilson, M. M. and J. A. Crawford. 1979. Response of bobwhites to controlled burning in South Texas. Wildlife Society Bulletin 7:53–56.

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

Yeager, W. M. 1966. Mearn's quail management information. Special Report, Federal Aid Project W-53-R-16, Arizona Game and Fish Department, Phoenix, USA.

APPENDIX I

Individual records showing age, sex, capture date, date of last observation, total days observed (days), number of radio locations (locations) condition at last observation (condition), and specific cause of last observation (comment) for all radio-marked Montezuma quail in southeast Arizona, 2008–2010

Band	Study Site	Age	Sex	Capture date	End date	Days	Locations	Condition	Comment
201	Stevens	Adult	Male	16-Feb-08	16-Apr-08	60	3	Censored	transmitter fail
202	Stevens	Adult	Female	16-Feb-08	16-Apr-08	60	3	Censored	transmitter fail
203	Stevens	Adult	Male	11-Mar-08	17-Mar-08	6	3	Censored	transmitter fail
204	Stevens	Adult	Female	26-Mar-08	16-Apr-08	21	6	Censored	transmitter fail
205	Stevens	Juvenile	Female	4-Apr-08	25-Apr-08	21	6	Censored	transmitter fail
206	Stevens	Juvenile	Male	4-Apr-08	16-Apr-08	12	1	Censored	transmitter fail
207	Stevens	Adult	Male	4-Apr-08	16-Apr-08	12	1	Censored	transmitter fail
208	Stevens	Juvenile	Female	4-Apr-08	9-Apr-08	5	1	Censored	transmitter fail
209	Stevens	Adult	Female	17-Apr-08	25-Apr-08	8	1	Censored	transmitter fail
210	Stevens	Adult	Male	22-Apr-08	18-May-08	26	5	Censored	transmitter fail
211	Hog Cyn	Juvenile	Female	23-Feb-09	5-Jul-09	132	64	Censored	transmitter fail
212	Hog Cyn	Juvenile	Male	23-Feb-09	19-Jun-09	116	69	Death	Owl suspected
213	Hog Cyn	Adult	Female	23-Feb-09	31-May-09	97	53	Censored	transmitter fail
214	Ranch	Juvenile	Male	2-Mar-09	10-Mar-09	8	6	Death	Northern Harrier-confirmed
215	Ranch	Juvenile	Female	2-Mar-09	25-Jul-09	145	70	Death	mammal suspected
216	Ranch	Juvenile	Male	4-Mar-09	19-Jun-09	107	60	Death	confirmed raptor
217	Ranch	Juvenile	Male	15-Mar-09	26-Apr-09	42	18	Censored	raptor suspected
218	Ranch	Juvenile	Male	15-Mar-09	5-Jul-09	112	63	Censored	raptor suspected
219	Ranch	Juvenile	Female	15-Mar-09	22-Mar-09	7	2	Death	mammal suspected

Band	Study Site	Age	Sex	Capture date	End date	Days	Locations	Condition	Comment
220	Ranch	Juvenile	Male	17-Mar-09	21-Apr-09	35	17	Censored	raptor suspected
221	Ranch	Adult	Female	17-Mar-09	9-Jul-09	114	57	Censored	raptor suspected
222	Ranch	Juvenile	Male	17-Mar-09	19-Mar-09	2	1	Censored	rehab; non-release
223	Ranch	Juvenile	Male	17-Mar-09	22-Mar-09	5	1	Death	Injured
224	Ranch	Juvenile	Male	22-Mar-09	27-Apr-09	36	2	Censored	transmitter fail
225	Ranch	Juvenile	Female	22-Mar-09	21-Apr-09	30	16	Death	Owl and Mammal
226	Ranch	Juvenile	Female	22-Mar-09	19-Oct-09	211	92	Censored	fallen transmitter
227	Ranch	Adult	Male	22-Mar-09	27-Apr-09	36	15	Censored	transmitter fail
228	Ranch	Juvenile	Male	22-Mar-09	26-Mar-09	4	2	Death	raptor suspected
229	Hog Cyn	Juvenile	Male	3-Apr-09	24-May-09	51	24	Censored	transmitter fail
230	Ranch	Juvenile	Male	19-Apr-09	21-Apr-09	2	2	Death	raptor suspected
231	Ranch	Juvenile	Female	19-Apr-09	27-Apr-09	8	8	Censored	suspect mortality
232	Ranch	Adult	Male	25-May-09	5-Jul-09	41	11	Censored	raptor suspected
233	Ranch	Adult	Male	26-May-09	8-Jun-09	13	8	Death	raptor suspected
234	Ranch	Juvenile	Male	26-May-09	25-Aug-09	91	50	Censored	transmitter fail
235	Ranch	Adult	Male	27-May-09	24-Oct-09	150	57	Censored	transmitter fail
236	Ranch	Juvenile	Female	29-May-09	5-Jul-09	37	21	Death	confirmed raptor
237	Hog Cyn	Juvenile	Male	31-May-09	5-Jul-09	35	12	Censored	transmitter fail
238	Ranch	Juvenile	Male	19-Jun-09	16-Jul-09	27	13	Censored	fallen transmitter
239	Ranch	Adult	Female	16-Jun-09	25-Aug-09	70	41	Censored	transmitter fail
240	Ranch	Juvenile	Female	19-Jun-09	19-Oct-09	122	42	Death	confirmed raptor
241	Ranch	Juvenile	Female	19-Jun-09	20-Aug-09	62	20	Censored	transmitter fail
242	Ranch	Juvenile	Male	19-Jun-09	28-Jul-09	39	12	Censored	transmitter fail
243	Ranch	Adult	Female	10-Jul-09	11-Jan-10	185	33	Death	mammal suspected
244	Ranch	Adult	Female	1-Aug-09	19-Oct-09	79	13	Censored	fallen transmitter
245	Ranch	Juvenile	Female	23-Oct-09	7-Jan-10	76	2	Censored	transmitter fail

Band	Study Site	Age	Sex	Capture date	End date	Days	Locations	Condition	Comment
246	Ranch	Juvenile	Male	23-Oct-09	7-Jan-10	76	2	Censored	transmitter fail
247	Ranch	Adult	Male	13-Jan-10	17-Jan-10	4	5	Death	raptor suspected
248	Ranch	Adult	Female	13-Jan-10	24-Jan-10	11	10	Death	raptor suspected
249	Ranch	Juvenile	Male	13-Jan-10	22-Jan-10	9	7	Death	mammal suspected
250	Ranch	Juvenile	Female	13-Jan-10	26-Jan-10	13	13	Death	mammal suspected
251	Stevens	Adult	Male	22-Nov-08	5-Jan-09	44	10	Censored	hunting suspected
252	Stevens	Adult	Female	22-Nov-08	8-Dec-08	16	7	Censored	hunting suspected
253	Stevens	Adult	Female	25-Nov-08	5-Jan-09	41	7	Censored	hunting suspected
254	Stevens	Adult	Female	25-Nov-08	11-Dec-08	16	4	Death	hunted; confirmed
255	Hog Cyn	Juvenile	Female	6-Dec-08	16-Dec-08	10	3	Death	unknown; on roost
256	Hog Cyn	Juvenile	Female	6-Dec-08	26-Feb-09	82	15	Death	confirmed raptor
257	Hog Cyn	Juvenile	Male	6-Dec-08	15-Jan-09	40	5	Censored	hunting suspected
258	Hog Cyn	Juvenile	Male	9-Dec-08	16-Dec-08	7	3	Death	confirmed raptor
259	Hog Cyn	Juvenile	Male	16-Dec-08	10-May-09	145	50	Censored	transmitter fail
260	Hog Cyn	Adult	Male	16-Dec-08	5-Jan-09	20	2	Censored	hunting suspected
261	Hog Cyn	Adult	Male	16-Dec-08	19-Jan-09	34	5	Censored	hunting suspected
262	Hog Cyn	Juvenile	Male	16-Dec-08	19-Jan-09	34	4	Censored	mortality suspected
263	Ranch	Juvenile	Female	12-Feb-09	28-Feb-09	16	4	Censored	mortality suspected
701	Ranch	Juvenile	Female	13-Jan-10	24-Jan-10	11	10	Death	Frozen on roost
702	Ranch	Juvenile	Male	13-Jan-10	23-Jan-10	10	8	Death	Frozen on roost
703	Ranch	Adult	Male	23-Jan-10	1-Feb-10	9	9	Death	Harris hawk confirmed
704	Ranch	Adult	Female	23-Jan-10	29-Jan-10	6	2	Censored	mortality suspected
705	Ranch	Juvenile	Male	23-Jan-10	10-Feb-10	18	22	Death	mammal suspected
706	Ranch	Juvenile	Male	23-Jan-10	1-Feb-10	9	8	Death	Frozen on roost
707	Ranch	Adult	Female	26-Jan-10	14-Feb-10	19	15	Censored	mortality suspected

Band	Study Site	Age	Sex	Capture date	End date	Days	Locations	Condition	Comment
709	Ranch	Adult	Female	2-Feb-10	14-Feb-10	12	14	Death	mammal suspected
710	Ranch	Adult	Female	2-Feb-10	18-Mar-10	44	36	Death	raptor suspected
711	Ranch	Juvenile	Male	2-Feb-10	14-Feb-10	12	14	Death	raptor suspected; Owl
712	Ranch	Juvenile	Female	5-Feb-10	17-Feb-10	12	12	Death	raptor suspected
713	Ranch	Juvenile	Female	5-Feb-10	24-Feb-10	19	21	Death	confirmed raptor
714	Ranch	Juvenile	Male	17-Feb-10	24-Feb-10	7	7	Death	confirmed mammal
715	Ranch	Juvenile	Male	17-Feb-10	25-Feb-10	8	7	Death	mortality suspected
716	Ranch	Adult	Male	25-Feb-10	11-Mar-10	14	8	Censored	mortality suspected
717	Ranch	Adult	Female	25-Feb-10	11-Mar-10	14	10	Death	unknown cause
718	Ranch	Juvenile	Female	11-Mar-10	13-Mar-10	2	2	Censored	mortality suspected
777	Ranch	Adult	Female	16-Jul-09	8-Aug-09	23	0	Censored	untagged; observed
350	San Rafael Valley	Adult	Female	17-Nov-08	17-Nov-08	0	0	Censored	fallen transmitter
708	Ranch	Juvenile	Male	2-Feb-10	10-May-10	97	2	Censored	Rehabilitated