National Quail Symposium Proceedings

Volume 8

Article 95

2017

Survival Demographics of Montezuma Quail in Southeast Arizona

Pedro M. Chavarria
New Mexico State University

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

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

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

Angel Montoya
U.S. Fish and Wildlife Service

Recommended Citation

Chavarria, Pedro M.; Silvy, Nova J.; Lopez, Roel R.; Davis, Donald S.; and Montoya, Angel (2017) "Survival Demographics of Montezuma Quail in Southeast Arizona," *National Quail Symposium Proceedings*: Vol. 8 , Article 95.
Available at: http://trace.tennessee.edu/nqsp/vol8/iss1/95

SURVIVAL DEMOGRAPHICS OF MONTEZUMA QUAIL IN SOUTHEAST ARIZONA

Pedro M. Chavarria[1]
Department of Fish, Wildlife, and Conservation Ecology, New Mexico State University, Las Cruces, NM 88003, USA

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

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

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

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

ABSTRACT

Many facets of Montezuma quail (*Cyrtonyx montezumae mearnsi*) population dynamics, such as survival and causes of mortality, are unknown because of 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. We evaluated survival and causes of mortality of Montezuma quail in southeastern Arizona from winter 2007 to spring 2010. Survival was determined from quail captured, radiotagged, and monitored among 3 separate study sites. In 2 of these sites hunting was permitted; and in 1 site (the control) hunting was not permitted. Estimation of accurate mortality rates in hunted sites was complicated by large quantities of censored data, some of which was attributable 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 study. Mortality rate for all sites were higher than any estimates reported or hypothesized in known scientific literature. The estimated rate of survival, combined among the 3 sites, was 21.9% from autumn 2008 to autumn 2009.

Citation: Chavarria, P. M., N. J. Silvy, R. R. Lopez, D. S. Davis, and A. Montoya. 2017. Survival demographics of Montezuma quail in southeast Arizona. National Quail Symposium Proceedings 8:369–374.

Key words: Appleton–Whittell Research Ranch, Coronado National Forest, *Cyrtonyx montezumae,* demographics, dog surveys, Mearn's quail, Montezuma quail, mortality, radiotelemetry, survival

Although past research has provided much insight into the natural history of the Montezuma quail (*Cyrtonyx montezumae mearnsi;* Wallmo 1954, Leopold and McCabe 1957, Bishop and Hungerford 1965), few studies have provided in-depth analysis of their population dynamics as derived from radiotelemetry analysis (Stromberg 1990). The few studies that have attempted monitoring of wild Montezuma quail populations through radiotelemetry have had complications associated with trapping a sufficient sample size, transmitter failure, negative impact of transmitters on radiomarked quail, or combinations of these effects (Stromberg 1990, Hernandez et al. 2009). Lack of successful mark–recapture and telemetry studies has contributed to gaps in knowledge about quail life history and poor 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 (Chavarria 2013); it 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-affected habitats (i.e., prescribed burns, wildfires).

Our goal was to evaluate survival of Montezuma quail on 3 separate study sites in southeastern Arizona and determine causes of quail mortality. Our objectives were then to test whether differences occurred within and among study sites, treatments (hunting vs. nonhunting), sex, and age classes. Where possible, we examined

---

[1] *E-mail: pedro.chavarria@nnmc.edu*

differences in mortality rate among seasons as well as across the aforementioned strata. High rates of mortality are thought to occur within younger age classes of this species immediately following the hatch season (autumn–winter). This is mostly attributed to naïve behavior and undeveloped survival instincts by the younger age classes. High rates of mortality among adult age classes of this species are thought to occur during the breeding season, from May to August, because of risky behaviors associated with reproduction (i.e., courting displays and calls) or increased movements. Our objective was to evaluate survival and test for differences among study sites, sex, and age if data permitted.

STUDY AREAS

We conducted surveys of Montezuma quail throughout Arizona Game and Fish Department's Management Unit 35 in southeastern Arizona 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 Appleton–Whittell Research Ranch (AWRR) near Elgin (Chavarria 2013). Trapping and long-term monitoring of radiomarked individuals occurred primarily in Stevens Canyon, Hog Canyon, and AWRR.

METHODS

Capture and Handling

Man-hours and dog-hours invested in trapping effort varied among study sites, but generally did not exceed 2–3 trap sessions/week, with sessions conducted ≥ 2 days apart, totaling no more than 15 man-and-dog hours/week (Chavarria et al. 2012a). We generally invested more trap-hours at the control site because potential conflicts with hunters at the experimental sites reduced opportunities for trapping during the hunting season (mid-Nov to early Feb).

We used a combination of techniques to capture Montezuma quail: wire-cage funnel traps, day trapping with hoop-nets and dogs, and night trapping with hoop-nets and dogs. Our primary means of trapping quail was initially to track birds with assistance of trained dogs, which held point until researchers cautiously approached and captured the quail with large hoop-nets (Brown 1976, Chavarria et al. 2012a) or throw-nets. At times we used a lightweight and transportable Forward Looking Infra-Red camera (FLIR Systems, North Billerica, MA, USA) to locate quail by tracking their heat signature at a location where a dog had gone "on point" (Chavarria et al. 2012a).

Upon capture, we placed birds into individual cloth sacks and then transported birds in a small and mobile field-holding pen at the trap location until we fitted them with a backpack radiotransmitter ($\sim$5–8 g, $<$5% of body mass; Wildlife Materials, Murphysboro, IL, USA) and evaluated them for morphological characteristics. We recorded gender, age, weight, wing length, tail length, head and bill length, culmen length, bill width, bill depth, and tarsus length for each individual bird. We determined age of birds 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). We referred to adult birds as After-Hatch-Year and juveniles and subadults as Hatch-Year. We fitted all captured birds with numbered aluminum leg bands. In the case of multiple captures or birds caught in night-trapping sessions, we held birds overnight in a holding pen at the research station in Patagonia, Arizona, or at the Appleton–Whittell Research Ranch and released them before daybreak the following morning. We did this to reduce possible mortality from hypothermia caused by releasing birds at night after covey displacement. We flight-tested radiotagged quail prior to releasing them to ensure that the attachment did not affect their ability to fly and thus did not reduce their chances of survival. Once ≥ 1 members of a covey were radiotagged, other members of the same covey could be trapped via Judas telemetry (Taylor and Katahira 1988). We recaptured many birds on >1 occasion so as to trap other members of their coveys in subsequent trapping sessions, or to replace transmitters with drained or fading batteries. We kept birds that were injured during trapping for 1–2 days in a holding pen at the research station and allowed them time to recuperate. If a bird was nonreleaseable after 1–2 days due to serious injury, we took it to a wildlife rehabilitation center (Liberty Wildlife Rehabilitation, Prescott, AZ, USA) and had it treated for injuries. If treatment at the rehabilitation center was successful, we radiotagged birds once again and released them back into the wild. If not, the wildlife rehabilitation center became responsible for the care and oversight of nonreleasable birds.

Radiotelemetry

We tracked radiotagged birds on a weekly basis. We monitored birds via triangulation of radio signal approximately 3–5 times/week at random times stratified by morning or afternoon. We conducted walk-ins and flush counts periodically on each radiotagged bird at least once every 3 weeks during the nonbreeding season. We did this to determine the health status of the radiotagged bird and size of the covey with which it was interacting, as well as to note habitat use, roost selection, nest-site selection, and other behavioral components (i.e., feeding, reproduction). We reduced frequency of walk-ins and flush counts during the breeding season to reduce potential impact to reproduction. We conducted night-time walk-ins at least once every 2 weeks during the breeding season to determine clutch size and hatch size if nests had been established. We took extra precautions not to flush birds during night-time walk-ins, especially during the breeding season so as to avoid disruption to breeding behavior and nesting.

Transmitters included built-in "mortality signals" to indicate long periods of inactivity or lack of movement, which alerted us that a marked bird was potentially

Table 1. Finite survival probability estimates (S ± SE) calculated using Kaplan–Meier staggered entry design (Pollock et al. 1989) for radiotagged Montezuma quail in southeastern Arizona for autumn 2008–2009 and winter 2009–spring 2010. Included in the table is sample size (n) for individuals trapped, and mean ± standard deviation (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 M	13	41.86 ± 39.39	2–112	0.238	0.191	0.00	0.612
Subadult Fs	9	71.4 ± 68.08	7–211	0.169	0.151	0.00	0.465
Adult M	4	60.0 ± 61.23	13–150	0.667	0.272	0.133	1.00
Adult F	5	112.0 ± 52.24	70–185	1.00	0.00	1.00	1.00
M (All)	17	83.0 ± 64.81	2–150	0.223	0.177	0.00	0.571
F (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 autumn 2008–2009.

deceased or the transmitter was nearing battery failure. We investigated mortality signals and recovered carcasses if possible. We collected and preserved in a freezer any carcasses that remained mostly intact. We submitted some of these remains to Dr. Mark Stromberg at the collections facility at the University of California, Berkeley. We georeferenced locations of visually relocated birds using Universal Transverse Mercator coordinates, in the NAD83 datum, with a Garmin Legend (Garmin, Ltd., Olathe, KS, USA) Global Positioning System unit in ArcView. We also recorded aspects of their habitat use such as home range, vegetation selection, and topography.

Statistical Analysis

Survival.—We used the Kaplan–Meier staggered entry estimator (Pollock et al. 1989) to calculate survival rate (S) and distribution by treatment (hunting vs. nonhunting), sex, and age-class for tagged birds. We estimated annual survival rates from the beginning of one autumn season (starting 21 Sep) to the start of autumn season the following year. We determined seasonal survival rates for birds captured postautumn. We considered 4 seasons for analysis: 21 September–20 December (autumn), 21 December–20 March (winter), 21 March–20 June (spring), and 21 June–20 September (summer). We censored from analysis birds that survived from one autumn season to the next and readmitted them that following season. We also noted the total number of days during which we observed a bird during the study. We calculated survival rate and standard errors using the software program ECOLOGICAL METHODOLOGY (Krebs 2002). Where data allowed, we used the log-rank Chi-square test (Krebs 2002) to determine differences among annual or seasonal survival distributions by treatment (hunted vs. nonhunted), sex, and age-class, with significance value set at $P = 0.05$.

Mortality.—We categorized censored observations or losses from mortality into groups based on any available evidence at the recovery site: predation (avian, mammalian), hunted, unknown, and other (trap injury, trap stress, dropped transmitter).

RESULTS

Capture Success and Survival

We began trapping at the AWRR in February 2009 and captured 54 individual birds from 12 February 2009 to 11 March 2010: 7 adult males, 11 adult females, 21 juvenile males, and 15 juvenile females. We did not tag one other bird captured during this time because it died from dog-inflicted injury. In the 2009 season, we observed tagged individuals for an average of 62.13 ± 56.19 days (range = 2–211 days; Table 1). We observed a subadult male for the fewest days and a subadult female the most days. We confirmed 29 mortalities: 7 confirmed raptor kills (including 1 northern harrier [*Circus cyaneus*], 1 owl, and 1 Harris's hawk [*Parabuteo unicinctus*]), 1 confirmed mammal kill, 3 frozen on roost, 1 trap injury, and 17 mortalities with unknown cause. We censored 25 individual birds for reasons including fallen transmitters ($n = 3$), transmitter failures ($n = 9$), injury-rehabilitation ($n = 1$), untagged ($n = 1$), and unknown cause ($n = 11$). Finite survival probability of quail for autumn 2008–autumn 2009 was $S = 0.236 \pm 0.128$ for all sexes and age classes combined. Finite survival probabilities were all males only, $S = 0.223 \pm 0.177$; all females only, $S = 0.360 \pm 0.171$; adult males, $S = 0.667 \pm 0.272$; adult females, $S = 1.00 \pm 0.00$; juvenile males, $S = 0.238 \pm 0.191$; and juvenile females, $S = 0.169 \pm 0.151$. Finite survival probability for winter 2009–spring 2010 was $S = 0.048 \pm 0.037$ (Table 1). We did not calculate finite survival probabilities for separate sex and age classes for winter 2009–spring 2010. We tracked birds at the AWRR in 2010 for an average (±SD) of 12.52 ± 8.47 days (range = 2–44 days; Table 1).

We trapped 10 individual birds at Stevens Canyon from January to May 2008: 4 adult males, 1 juvenile male, 3 adult females, and 2 juvenile females. We did not calculate survival estimates for birds captured during that period because of transmitter problems and censored data. We captured 4 additional birds (1 ad M, 3 ad F) in autumn 2008 and monitored them successfully on a more consistent basis. We tracked these birds for an average (±SD) of 24.86 ± 18.91 days (range = 5–60 days; Table 1). We also captured, but did not tag, 3 other birds during this time (2 died from dog-inflicted injury and 1 died from stress during capture). We obtained a limited number of relocations for these birds, however, which led to us censoring them early in winter 2008–2009. Causes of censoring were confirmed hunting mortality ($n = 1$), and suspected hunting mortalities ($n = 3$).We received 1 radiotransmitter from a hunter with a letter describing the location, time, and date the bird had been shot. Finite survival probability estimated within this time interval was $S = 0.750 \pm 0.217$ (Table 1).

We began trapping at Hog Canyon in autumn 2008 and captured 13 individual birds from 6 December 2008 to 31 May 2009: 2 adult males, 1 adult female, 7 juvenile males, and 3 juvenile females. We tracked radiotagged individuals for an average (±SD) of 61.77 ± 47.19 days (range = 7–145 days; Table 1). We confirmed 4 mortalities (of which 2 were confirmed raptor kills), and we also censored 9 individuals. Some suspected hunting mortalities ($n = 2$) were later confirmed from reports submitted through AZGF wing barrel counts. Finite survival probability estimated within this time interval was $S = 0.400 \pm 0.203$. We calculated no survival probabilities within the different sex and age classes because of small sample size. We captured, but did not tag, 3 other birds during this time (2 died from dog-inflicted injury and 1 escaped capture before processing).

Finite rate of mortality for all sites combined for autumn 2008–autumn 2009 was $S = 0.219 \pm 0.090$. We tracked birds from all sites for an average of 42.53 ± 46.54 days (range = 2–211 days) throughout the study (Table 1). During the entire study at all study sites, we tracked females an average of 49.57 ± 53.79 days (range = 2–211 days) and males for an average of 36.47 ± 38.89 days (range = 2–150 days).

Hypothesis Testing

A large sample size and low censor ratio at the AWRR for the 2009 season allowed for log-rank Chi-square comparisons (Pollock et al. 1989) of weekly survival probabilities among different age–sex classes of radiotagged Montezuma quail at that site. We analyzed survival probabilities for these groups where relocation histories overlapped within and between the different age–sex classes. We 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 ($\chi^2 = 0.141$, $P = 0.235$), between juvenile males and juvenile females ($\chi^2 = 0.030$, $P = 0.863$), or between adult males and juvenile males ($\chi^2 = 0.00$, $P = 1.00$). We found no significant difference in weekly survival probabilities between adult females and juvenile females ($\chi^2 = 0.277$, $P = 0.096$), but data showed a trend supporting higher survival probability for adult females.

DISCUSSION

From 2008 to 2010, we examined sources of mortality and survival demographics of Montezuma quail in-depth for the first time through the use of radiotelemetry. Existing literature on Montezuma quail provided information about probable sources of mortality from field observations but no actual mortality rates or survival estimates at the population or covey level (Leopold and McCabe 1957, Bishop 1964, Brown 1979). Stromberg's (1990) telemetry study provided the first estimates of survival and documented sources of mortality, but from a limited sample size ($n = 15$). Stromberg's tagged birds lived for an average of 28.4 days (SE = 8.9 days), with the longest time a tagged bird was observed before falling to predation being 140 days. We evaluated survivorship for this species with a larger sample size ($n = 77$ radiotagged birds) over a longer period of time ($n = 3$ yr) replicated across 3 study sites in southeastern Arizona. Our research overcame problems associated with radiotransmitter methods that were demonstrated in previous studies (Stromberg 1990, Hernandez et al. 2009). We made slight modifications to the transmitter design (standard backpack with loop-hole attachment to the wing), and evaluated it for its effect on quail movements and survival. Our modified design had no observable negative impact on flight ability nor reduced survival probabilities. Retrapping 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 climate conditions were observed.

From telemetry data, we evaluated actual estimates of survival probability for the 3 study sites but could not evaluate estimates of survival for each study site each year. A large amount of censored data, attributed mostly to faulty transmitters (Chavarria 2013), resulted in smaller sample sizes at Stevens Canyon and Hog Canyon and prevented estimates of survival for those sites. This issue of faulty transmitters was resolved for the subsequent seasons. For all sites combined from autumn 2008 to autumn 2009, survival probability was low ($S = 0.219$). From winter 2009 to spring 2010, survival probability was extremely low at the AWRR ($S = 0.048$). Estimates of survival in our study were most accurate for results obtained at the AWRR study site. We did not calculate survival probabilities within the different sex and age classes for Steven's Canyon because of small sample size.

Log-rank Chi-square comparison of survival probabilities at the AWRR resulted in no significant differences between all variations comparing age and gender classes. 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 confidence interval (0.326–1.00). Such high survival probability is not very realistic for quail species for the study time frame. The survival estimate for Hog Canyon was more realistic ($S = 0.400$, SE $= 0.203$) but was inflated by birds that went unaccounted for and were censored from December to January during the hunting season. Some studies show that large variation in survival probability may be evident between seasons for some quail species (Terhune et al. 2007). On average, however, most studies on quail species similar to Montezuma quail, such as scaled quail (*Callipepla squamata*), mountain quail (*Oreortyx pictus*), and northern bobwhites (*Colinus virginianus*), reported survival probabilities that were considerably lower (Pleasant et al. 2006, Terhune et al. 2007, Stephenson et al. 2011, Troy et al. 2013) and resembled survival estimates in our study at the AWRR. The combined mean survival probability for all 3 sites from autumn 2008 to autumn 2009 is a more reliable estimate for the southeastern Arizona region and is comparable to survival probabilities observed for other North American quail species.

Most mortality of Montezuma quail is likely not attributable 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 to 2010 following 2 stochastic events—a large and severe wildfire in May 2009 (Chavarria et al. 2012c) and a severe winter storm in winter 2009–2010 (Chavarria et al. 2012b). This is especially true for the winter storm because severe reductions in population abundances were documented across the 3 study sites in 2010 via both radiotelemetry and dog-assisted flush-count surveys (Chavarria et al. 2012b). Natural predation from avian predators such as red-tailed hawk (*Buteo jamaicensis*), Cooper's hawk (*Accipiter cooperii*), and great-horned owl (*Bubo virginianus*) likely accounts for the second greatest proportion of mortalities—especially of hatchlings and naïve juveniles—from early autumn to late winter (Stromberg 1990). Mortality from red-tailed hawk and Cooper's hawk was visually confirmed in this study.

Estimates of hunting mortality for this quail are likely to be higher than that reported in the literature, particularly when disease, stochastic events, and unfavorable environmental conditions (or a combination of those) combine with high season-specific harvest pressure to create additional stress to this species. Studies on bobwhite quail (Rolland et al. 2010) and other galliformes (Besnard et al. 2010, Sandercock et al. 2011) provide cautionary evidence to support this claim. Most literature on the impact of hunting mortality on Montezuma quail is based on evidence drawn from hunter surveys, counts of wings voluntarily submitted by hunters, check-station surveys, or estimates of abundances conducted from flush counts (Yeager 1966, Bristow and Ockenfels 2000, Heffelfinger and Olding 2000). Our study, however, also provides evidence of how censored data, resulting from unreported hunting mortalities that were later verified, artificially inflated survival estimates. Similarly, information drawn from hunter surveys, wing-counts, and check-stations are limited in many ways and thus reduce accuracy of estimating wild populations. Those data should be compared with data generated by more accurate means of estimating population abundances and densities, such as those provided by a combined use of flush-count surveys with monitoring via radiotelemetry.

MANAGEMENT IMPLICATIONS

Historical estimates of population abundances and densities of Montezuma quail in southeastern Arizona lack accuracy because there are 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, should 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 overestimating the local population by double-sampling 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, should be incorporated into future studies to more accurately evaluate actual rate of mortality throughout southeastern Arizona—with particular emphasis in areas where they are exposed to more frequent and intense anthropogenic pressures such as grazing and hunting.

ACKNOWLEDGMENTS

Several volunteers, including A. Kocek, L. Ng, R. Chasey, and L. Reifl, assisted with this research. Generous support was provided by a Sloan Foundation Fellowship, Ariel-Appleton Fellowship, and a National Audubon Society Apacheria Fellowship. I thank my graduate assistant dogs Blanca, Chico, and Choco for putting in countless hours in the field from the earliest hours of the day to the latest hours at night searching for birds in the field. Much thanks also to Dr. L. Kennedy, Dr. C. Hass, and R. Cogan for logistical and moral support at the Appleton–Whittell Research Ranch. Dr. M. Stromberg's mentoring and previous work with this species served to inspire our success with this project.

LITERATURE CITED

Besnard, A., C. Novoa, and O. Gimenez. 2010. Hunting impact on the population dynamics of Pyrenean grey partridge *Perdix perdix hispaniensis*. Wildlife Biology 16:135–143.

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.

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.

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

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.

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

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

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

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

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. National Quail Symposium Proceedings 4. 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, and J. P. Carroll, editors. National Quail Symposium 6:426–431.

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

Leopold, A. S., and R. A. McCabe. 1957. Natural history of the Montezuma quail in Mexico. Condor 59:3–26.

Pleasant, G. D., C. B. Dabbert, and R. B. Mitchell. 2006. Nesting ecology and survival of scaled quail in the southern high plains of Texas. Journal of Wildlife Management 70:632–640.

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.

Rolland, V., J. A. Hostetler, T. C. Hines, H. F. Percival, and M. K. Oli. 2010. Impact of harvest on survival of a heavily hunted game bird population. Wildlife Research 37:392–400.

Sandercock, B. K., E. B. Nilsen, H. Broseth, and H. C. Pedersen. 2011. Is hunting mortality additive or compensatory to natural mortality? Effects of experimental harvest on the survival and cause-specific mortality of willow ptarmigan. Journal of Animal Ecology 80:244–258.

Stephenson, J. A., K. P. Reese, P. Zager, P. E. Heekin, P. J. Nelle, and A. Martens. 2011. Factors influencing survival of native and translocated mountain quail in Idaho and Washington. Journal of Wildlife Management 75:1315–1323.

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

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

Terhune, T. M., D. C. Sisson, J. B. Grand, and H. L. Stribiling. 2007. Factors influencing survival of radiotagged and bandged northern Bobwhites in Georgia. Journal of Wildlife Management 71:1288–1297.

Troy, R. J., P. S. Coates, J. W. Connelly, G. Gillette, and D. J. Delehanty. 2013. Survival of mountain quail translocated from two distinct source populations. Journal of Wildlife Management 75:1031–1037.

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

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.