The Condor 92:229–236

HABITAT, MOVEMENTS AND ROOST CHARACTERISTICS OF MONTEZUMA QUAIL IN SOUTHEASTERN ARIZONA[1]

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Abstract. Movements, survivorship, covey size, roosting behavior, and habitat use of Montezuma Quail (*Cyrtonyx montezumae*) marked with radio transmitters were studied in the foothills of the Huachuca Mountains of southeastern Arizona from October 1986 through November 1987. Coveys used small areas (0.09–6 ha) and during midwinter, the same small area would be used for long periods. In late winter and early spring, coveys occupied much larger areas by sequentially spending 3–10 days on adjacent, nonoverlapping areas as large as 50 ha. Daily movements were small (15–60 m) for most of the year, and movements between days were often ≤100 m. Birds with radios persisted on the study site as long as 133 days, but most were followed for <30 days. Covey size varied seasonally, with pairs observed from April–May through September. Individually followed coveys of up to six to eight birds declined in numbers from September through April. Slope, aspect, basal vegetation cover, dominant plant species, and distance to the nearest oak tree was measured at each location or flush site. When compared to randomly selected points in the oak savanna habitat, quail preferred southeast-facing hillsides in tall grasses for night roosts. Day-use areas were selectively on north-facing hillsides. Areas used by quail during the day were generally on hillsides, about 16 m from the nearest oak tree and had grass cover intermediate between barren areas under oak trees and more dense grass cover farther away from the oaks.

Key words: Montezuma Quail; Cyrtonyx montezumae; *habitat; movements; radio tracking; Arizona.*

INTRODUCTION

Montezuma Quail (*Cyrtonyx montezumae*) are typically found in the understory vegetation of oak (*Quercus* spp.) and oak-pine (*Pinus* spp.) woodlands of the southwestern United States and Mexico (Leopold and McCabe 1957). Populations of these quail can be locally eliminated with removal of more than about 55% of the understory vegetation (combined annual productivity and standing crop) by livestock grazing (Ligon 1927, Miller 1943, Wallmo 1954, Brown 1982). Previous research on habitat use by Montezuma Quail has been restricted to sites grazed by livestock (Brown 1982) which has a dramatic influence on the landscape (Hastings and Turner 1965). The purpose of this paper is to describe the habitats, home ranges, and movement patterns of Montezuma Quail on land that has recovered from the effects of grazing by domestic livestock. Specific comparisons were made to learn how Montezuma Quail use available habitat in relation to the range of habitats available (e.g., Brennan et al. 1987).

STUDY AREA AND METHODS

Observations were made on the Research Ranch Sanctuary of the National Audubon Society managed in cooperation with the Bureau of Land Management in Santa Cruz County in southeastern Arizona. This site has changed significantly after removal of livestock grazing and was very different from adjacent grazed lands (Bock et al. 1984). Brady et al. (1989) reported that cover of grasses on the study area increased from 29% in 1969 to 85% in 1984 and that the number of plant species nearly tripled (from 22 to 63). The largest increase in species number was in leafy forbs (from 10 to 35) and the most dramatic increase in dominance was in the taller midgrasses (*Eragrostis intermedia, Bouteloua curtipendula*). Changes in the vegetation on the study

[1] Received 18 August 1989. Final acceptance 1 November 1989.
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site were primarily attributed to the removal of grazing (Brady et al. 1989).

Coveys were located and use sites mapped from 1983 to 1987. Birds were trapped and marked from October 1986 to November 1987. The Research Ranch is located on the northwestern side of the Huachuca Mountains and includes rolling foothill grassland and oak savanna at elevations from 1,400 to 1,560 m. Mean precipitation was 43 cm/year, with most rain falling during monsoon thunderstorms of July, August, and early September. Soils were gravelly loams with scattered limestone outcrops. Dominant grasses included grama (*Bouteloua* spp.), curly mesquite (*Hilaria belangeri*), and plains lovegrass (*Eragrostis intermedia*). Emory oak (*Quercus emoryi*) and Arizona white oak (*Q. arizonica*) were common in the study site. Both oaks occurred in dramatically higher densities on north-facing slopes, although a few were scattered on level alluvial flats at the base of rolling hills (Bonham 1972, Bock and Bock 1986). More detailed descriptions of the study site can be found elsewhere (Bahre 1977, Bock et al. 1984, Bock and Bock 1986, Brady et al. 1989).

Locating and capturing these quail proved extremely difficult, so several survey and trapping techniques were used, including using trained dogs, groups of people walking through an area in close ranks, and continuous recording of encounters. I used these data to locate every covey in the central 2,331-ha area of the study site. Traps were set in areas used by several coveys. In an effort to attract birds to traps, I briefly held chicks in cages and recorded the repetitive *cheep* call they gave when separated from their parents. I recorded similar calls from free-ranging chicks separated after flushing adults from the chicks. I played back recordings of these chick calls and the descending burr or trill of adults. Responses from known coveys to playback were erratic and unpredictable, although elsewhere in Santa Cruz County, Arizona, Montezuma Quail would approach playbacks of adult vocalizations (R. Bowers, pers. comm.).

Funnel traps (Reeves et al. 1968, Braun 1976) were placed over commercial "mixed wild bird seed" bait and tended every hour during trapping. Drift fences made from woven hardware cloth, 0.3 m tall and 30 m long, extended from each funnel entrance. Bait stations were maintained throughout the year. Traps were opened between trapping sessions. Traps were modified to include a flexible nylon netting roof (below the wire mesh roof) to minimize damage to the birds' heads while in the traps. Bishop (1964) and Brown (1975) reported attempts to capture adult Montezuma Quail with funnel traps failed because quail relied on underground plant parts for food and would not respond to bait. Quail on this site were consistently captured with crops full of bait grain.

Montezuma Quail are cryptic and are virtually impossible to see when they crouch and freeze in the oak woodland litter (Leopold and McCabe 1957, Brown 1982). Thus, observations on free-ranging birds were limited, without radios, to surprise flushes. Because preliminary studies indicated that poncho-mounted transmitters (Hegdal and Colvin 1986, Cochran 1980) interfered with crouching and foraging behaviors and contributed to mortality, I used backpacks to attach transmitters. Radio transmitters were glued and tied to small tabs of auto upholstery material. These tabs were tied on quail as backpacks with ribbon loops beneath the wings. Radio packages weighed less than 4 g with a 10-cm antenna arranged to lie along the bird's back (Custom Telemetry, Athens, Georgia). I used a hand-held three-element Yagi antenna and radio receiver (Custom Electronics, Urbana, Illinois). When radio signals could not be found after extensive ground searches, aerial surveys from fixed-wing aircraft were conducted.

Of 16 coveys consistently located on the study site, radios were placed on birds in eight. Forty-six birds were captured and marked; 15 were radio-marked. Only one bird per covey was radio-marked at a given time.

Birds were marked and released at the capture site as quickly as possible because those held overnight or moved from one study site to another did not join local coveys, even if coveys were within 100 m of repeated radio relocations of the bird. Small metal tags (National Band and Tag Co., Newport, Kentucky) were placed through the patagium to identify individuals. Birds were weighed and classed to age and sex at capture. Young of the year were not classified by sex.

Radio-marked birds which joined flocks were relocated. Birds were relocated usually only once a day and then we left the covey use area to minimize disturbance to the birds. Night roosts were located in an effort to capture more birds from January to March 1987. Tall and dense grass on the ungrazed study site made it difficult to capture birds on night roosts with trained dogs as reported from nearby grazed study sites (Brown 1982). I flagged night roost sites as determined by flushing the covey at night; habitat measurements were taken later during the day. I relocated birds with transmitters by triangulation during daylight hours. Distances between radio transmitters and the receiver were usually less than 20 m. Birds with radios could be located within 2–3 m^2 and could be mapped to an accuracy of about 5 m^2. Care was taken not to flush the covey during daylight observations. I mapped locations of individual birds with transmitters on aerial photos (1″ = 1,000′). Sometimes, the bird in the covey with the transmitter was inadvertently flushed, as would happen when a member of the covey without a transmitter was disturbed some distance from the bird with the transmitter. After such flushes, the number of birds in the covey was recorded by walking the general area and flushing all possible quail, including the bird with the radio transmitter. Not all birds in the covey may have been flushed, so the number of birds counted each time the covey was flushed was an estimate. Repeated counts of coveys usually differed between days by only one or two birds. Original radio relocations of the covey member with the transmitter were marked and several quantitative habitat measures were taken at that sample point ("day-use site"). When making hourly observations of covey movements, triangulations were made from greater distances (ca. 50 m) and I included only the hourly movement records of coveys which were not flushed during that day's observations. Use areas were calculated by the minimum convex polygon method (Jennrich and Turner 1969).

Six measures were used at each flush site (roosts, some day-use sites) or day-time radio relocations (day-use sites) to characterize the habitat used by the quail. Slope was measured with a clinometer. Aspect was measured by locating a line perpendicular to the slope at each sample point and obtaining a compass reading for that line. Total basal cover of vegetation was estimated visually from four 50- × 20-cm quadrats (Daubenmire 1959) which were placed together to share a common corner centered on the flush site. Midpoints of the ranges of each Daubenmire cover class were averaged. When the exact site of the bird was not seen as it flushed, quadrats were tossed into an area within a few meters from the flush site. Plant species with frequency < 1% were not included in the analysis. Distance to the nearest oak tree (> 3 cm dbh) was measured with a range finder or tape. Height of vegetation was estimated by measuring the tallest understory plant above the four outermost corners of the quadrats. Data from trap sites were not included in the descriptions of habitat utilization. Ordinations were based on slope, cover, distance to oak trees, and presence/absence of plant species (Beals 1984, McCune 1987).

A stratified random sample of the study site was established with transects oriented north–south. Three transects were placed roughly along shared boundaries of areas which would divide the study site into quarters. Fifty-one random points were selected along the transects and habitat variables were measured as above. These were compared to the sites used by the quail. Nonparametric, parametric, and radial statistics were calculated (Siegel 1956, Zar 1984, respectively) to compare sites used by the quail to randomly selected points. Sample sizes varied between analyses due to missing data values; a few birds escaped during handling.

RESULTS AND DISCUSSION

PERSISTENCE ON THE STUDY SITE

Forty-six birds were captured with capture rates varying from 0.008 to 0.12 bird/trap day. Recapture rates were low, with only 19 birds providing data on number of days the birds were known to survive beyond their capture dates. Causes associated with the last observations of these 19 birds were: radio failure (7); raptor predation (5); recapture (4); and canid predation—most likely by coyote *Canis latrans* (3). Mean number of days known alive was 28.4 (SE = 8.9). No differences were observed between number of days birds with or without radios persisted. For example, bird #371 carried a radio transmitter for 133 days. That radio was replaced upon recapture; 7 days later the bird was killed by a predator (bobcat or coyote). Bird #370 was recaptured after 124 days with only a wing tag. A transmitter was placed on this bird, and it was killed by a Cooper's Hawk (*Accipiter cooperi*) 2 days later. The covey of this adult was subject to intense predation by an adult female Cooper's Hawk. From 25 October to 12 November, presumably the same hawk was located each day in a local use area of this covey. Four young of the year and two adults were found in this raptor's

TABLE 1. Frequency (%) of plant species at Montezuma Quail day-use, random, and roosting sites.

Species	Day-use $n = 116$	Random $n = 51$	Roost $n = 20$
Bouteloua curtipendula	68.1	66.6	95.0
Heterotheca subaxillaris	27.6	47.1	60.0
Eragrostis intermedia	27.6	19.6	20.0
Bouteloua gracilis	21.5	11.7	5.0
Heteropogon contortus	11.2	19.6	55.0
Lycurus phleoides	10.3	1.9	0
Sporobolus wrightii	7.7	5.8	0
Aristida spp.	6.9	3.9	0
Bouteloua hirsuta	4.3	11.7	0
Hilaria belangeri	3.4	0	0
Panicum obtusum	2.6	0	0
Bouteloua chondrosioides	2.6	0	0

feeding roost during this period. Apparently, once a raptor can locate a covey, it is able to localize its hunting efforts.

CAPTURE WEIGHTS, SEX RATIOS, BREEDING SEASON

Weights of the birds captured indicated that the habitat was adequate to support the bird's body weight at levels reported by Leopold and McCabe (1957). Mean female weight was 192.7 g ($n = 14$, SE = 3.79). Mean male weight was 208.8 g ($n = 16$, SE = 4.46). Mean weight reported by Leopold and McCabe (1957) was 176 g and 195 g for females and males, respectively. Of 32 birds captured for which gender data were available, 17 (53%) were male. This slight bias towards more males is similar to that reported by Leopold and McCabe (1957) and Brown and Gutiérrez (1980). Mean male capture weight was greater than mean female capture weight ($t = 2.41$, two-tailed, $P < 0.05$). Capture weight of young of the year was 152.1 g ($n = 14$, SE = 6.51). Young of the year were captured only in October and November. My data on capture weight of adult females and young of the year are consistent with those reported by Leopold and McCabe (1957). I observed breeding behavior (calling males) as early as March or April, probably in response to unusually wet winters. Nesting occurred after rains in July and August that resulted in green vegetation; similar observations are reported by Brown (1982).

HABITAT USE

Frequency of dominant plant species from day-use sites, randomly selected sites and roost sites varied (Table 1). Sites where birds were relocated during the day differed ($\chi^2 = 32.3$, 2×12, $P < 0.001$) from randomly selected sites. Major contributions to the chi-square value came from apparent avoidance of sites with a biennial forb, camphor weed (*Heterotheca subaxillaris*), and selection of sites with relatively tall grasses, including plains lovegrass (*Eragrostis intermedia*) and wolftail (*Lycurus phleoides*). Roost and randomly selected sites were not significanlty different ($\chi^2 = 8.0$, 2×5, $P > 0.05$). These winter roost sites had far fewer species compared to day-use sites and were dominated by the tall grasses including side oats grama (*Bouteloua curtipendula*) and tanglehead (*Heteropogon contortus*). The latter tall grass was rare on the reserve and limited to south-facing slopes where it formed dense, almost monotypic stands (Bock and Bock 1986).

Ordination of roost, day-use sites, and randomly selected sites revealed a complex interaction between cover, slope of the hillsides, and distance from oak trees. Both Kendall's and Pearson's correlations were high (0.87–0.93) between the first axis (reflecting many variables) and distance to oak trees.

Given this suggestive pattern, a series of regressions between several original variables measured in the field were calculated. Linear regression between variables sampled at randomly selected sites revealed that cover increased with distance from oak trees ($R^2 = 0.093$, $F = 5.05$, $P = 0.029$, $n = 51$). At randomly selected points, slope decreased with distance from oak but analysis of variance indicated that the relationship is not quite significant ($R^2 = 0.74$, $F = 3.32$, $P = 0.074$). A similar analysis of data based on measures at day-use sites showed again that cover had a significant positive correlation with distance from oak trees ($R^2 = 0.126$, $F = 16.3$, $P < 0.001$, $n = 116$), and slope decreased with distance from oak trees ($R^2 = 0.122$, $F = 15.5$, $P < 0.001$). Cover increased as relocation sites were increasingly level ($R^2 = 0.042$, $F = 5.03$, $P < 0.05$). Biologically, these patterns fit together.

At this study site, oaks are at the lower limit of their distribution on the Huachuca foothills. Emory oaks at the lower elevations of the study site are far more common on north-facing hillsides (Sanchini 1981, Bock and Bock 1986) which were rather steep. Areas at the base of oaks were often relatively barren but surrounded by tall and

TABLE 2. Comparison of the number of sites used by Montezuma Quail on hillsides or level areas. Roost and random sites differed ($\chi^2 = 8.75$, $P < 0.01$). Day-use and random sites differed ($\chi^2 = 6.02$, $P < 0.05$).

	Level	Hillside
Roost	0	20
Random	17	34
Day-use	19	97

dense grasses described by Brady et al. (1989). Germination and/or survivorship of many forbs and grasses may be inhibited by a layer of oak leaves and oak litter. Experiments with oak leaves and litter to determine if they alone are capable of reducing other plant growth would be useful. Sites used by quail during the day faced north (mean aspect of 16.3°, $R = 0.32$, $n = 93$) and these sites differed in aspect from randomly selected sites (Rayleigh's test, $F = 10.6$; df = 1, 122, $P < 0.001$). Most day relocations of quail were within 20 m of the nearest oak tree on steep areas (see below) where total vegetative cover was relatively low. At higher elevations on the Huachuca Mountains, where Montezuma Quail also occur, oaks are not as restricted to northerly exposures, and the relationships presented here may not occur.

Night roosts and sites used by quail during the day differed with regard to aspect from randomly selected sites. Roost sites faced southeast (mean angle: 137.6°, $R = 0.86$, $n = 20$) and differed (Rayleigh's test, $F = 13.84$; df = 1, 48, $P < 0.001$) from randomly selected sites which faced northeast (mean angle: 74.4°, $R = 0.45$, $n = 31$). Many sites used by the quail were level and could not be assigned an aspect value (Table 2). Roost sites were limited to hillsides (Table 2) and differed from random sites ($\chi^2 = 8.75$, $P < 0.01$). Day-use sites were on hillsides far more than would be expected from the distribution of level sites at randomly chosen points ($\chi^2 = 6.02$, $P < 0.05$). Data presented here show the quail prefer north-facing slopes and thus by association, are more likely to be near oaks. On rare occasions, I observed Montezuma Quail at least 3 km from any trees, well out in open grassland.

During the winter months, night roosts were small cups, about 15 cm in diameter, often at the base of a rock with tall grass overhanging the shelf. Soil in the covey's night roosts had several successively older layers of fecal material, suggesting repeated use. Roost sites were highly aggregated, limited to a small area (seven to 10 roost sites in 1 ha) dominated by *Heteropogon contortus*. Roosts were at least 100 m distant from areas used by coveys during the day. Orientation and structure of roost sites suggested that they may serve effectively in collecting and storing solar radiation, as the shelf and rock face were exposed to solar radiation during the day. At night, the dense grass overhanging the rock offered protection from radiation heat losses. I did not see quail approach night roost sites, but I suspected that quail arrived just at dark because they were relocated well away from roost sites when it was no longer possible to see clearly. Many roost sites known from winter observations in two widely separated aggregations were checked in the dry season in 1988 and 1989. No evidence of summer use was seen. The night roosts described here were those used in winter only.

Previous research observed the associations between these quail and dense ground cover (Leopold and McCabe 1957, Brown 1982). In this study, quail selected steeper slopes for roosting than random sites ($t = 2.29$, $P < 0.05$, Table 3). During the day, quail were relocated in sites with lower ($t = 2.23$, $P < 0.05$) understory cover than randomly selected sites. Steep slopes had oaks and supported less understory vegetation. Day-use sites tended to be nearer oak trees than randomly selected sites, but one-way analysis of variance indicated that the differences were not

TABLE 3. Sample sizes (n), means ($\bar{x}$), and standard errors (SE) of distances from oak trees, cover values, slope, and vegetation height measurements at various sites used by Montezuma Quail.

	Distance from oak (m)			Cover (%)			Slope			Vegetation height (cm)		
	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE
Roost	20	19.0	2.74	20	49.2	5.63	20	20.7	1.06	20	49.5	2.34
Random	51	20.9	2.24	51	54.3	3.49	51	13.5	1.89	51	42.3	2.37
Day-use	116	16.4	1.75	116	45.4	2.31	116	15.1	1.21	116	41.9	3.62

significant (Table 3). Slope of day-use sites was not different than slope of randomly selected sites (Table 3). Height of vegetation in roost, random, and day-use sites did not differ. This is probably because all sampling sites (roost, random, and day-use) had been protected from grazing for many years and all sites supported taller grasses. Overall density and height of the vegetation on the reserve was markedly higher than that on surrounding grazed land (Brady et al. 1989). Mean grass cover on the reserve, for example at roost sites (49.2%) and day-use sites (45.4%), was much higher in 1987 than the average understory cover of these vegetation associations when grazing was halted in 1968 (11.7% to 29%; Bonham 1972). No data were taken on comparable adjacent lands with quail coveys, but there the grasses were clearly clipped low as a result of intensive grazing by cattle.

MOVEMENTS

Daily movement patterns were revealed by frequent observations of birds with radio transmitters. These birds were extremely tolerant of close approach, often flushing only after being approached to within 1 m. Many birds with transmitters were approached to within a square meter, but could not be seen until they moved. On two occasions, birds remained motionless while allowing us to capture them as they crouched at the base of a clump of grass. Leopold and McCabe (1957) also observed the tendency of these quail to restrict their flight. From January to March, three coveys were relocated on 27 pairs of sequential days. Mean distance between relocations was 97.8 m (SE = 15.1). From 28 March to 31 May, bird #368 was relocated with its covey as it increased its wanderings. During that period, distance moved between days almost doubled ($\bar{x}$ = 194.9 m, SE = 56.8, n = 11). Only pairs were flushed during June and July (Table 4). This period corresponds to the time of pair formation and nest construction (Leopold and McCabe 1957). From July through October, the mean distance moved between successive days dropped to 83.8 m (SE = 9.84, n = 7). From October through December, the mean distance moved between days was 79.2 m (SE = 47.4, n = 5). Many additional sequential relocations which spanned more than 24 hr agreed with this pattern of reduced movements. Multiple, nonoverlapping use areas were not observed at these times; use areas defined home range of coveys from June to November (Table 4).

Observations of hourly movements of a covey over several days revealed that baited trap stations were rarely approached by birds with transmitters, even when the traps were removed. I would suggest that tests of various baits with radio-tagged birds may be productive in developing a more efficient means of trapping birds and thus facilitate future studies.

On a given day, coveys tended to stay in small areas. A covey at Post Canyon was relocated at 30-min intervals for 3 days. On 21 November, the mean distance this covey of eight moved between observation intervals was 18.6 m (SE = 8.2, n = 10). On 28 November, the mean distance moved between observations was 15.1 m (SE = 3.5, n = 12). On 12 December, when six covey members were known, the mean distance moved was 63.8 m (SE = 46.4, n = 15). A flock in Turkey Creek was similarly tracked in January 1987 with a mean of hourly moves of 20.1 m (SE = 3.6, n = 9).

DAILY AND SEASONAL SPACING PATTERNS

Members of a covey were flushed between 0.5 and 15 m from each other during the day. Repeated observations documented small "use areas" which lasted from a few days to months (Table 4). A "use area" is a minimum convex polygon estimate of spatial use within this time period. Basically, a covey used the same small area day after day. For most of the year, the covey would restrict their activity to a small area and then (often overnight) a covey would shift to another, nonoverlapping area which became the new use area where they restricted their daily movements. Longer observations revealed that coveys had several of these use areas. I combined successive use areas into a covey's "home range." Separate coveys (that is, a covey without a bird carrying a radio) were sometimes flushed near a covey under study. Although I have no evidence of exclusive use of the smaller use areas by a given covey, coveys seemed to generally stay apart. From November to January, the use areas were about 1–5 ha (Table 4). During late winter and early spring, the use areas would shift rapidly and relatively far from each other, and thus home ranges were far larger (up to 50 ha). This spring home range expansion coincided with the time when covey size reduced to pairs and reflects pair spacing (Table 4). Data here on covey size agree with the general range observed by Leopold and McCabe (1957) from four to 10.

I have no data to suggest that coveys ever form

TABLE 4. Summary of use and home range areas of eight coveys of Montezuma Quail. Covey sizes listed are the maximum counted in repeated flushes during a given observation period. Covey one had three different use areas, covey two had five different use areas, etc. The single use areas for coveys four to seven defined their home ranges.

Period	Days	Relo-cations	Use area (ha)	Covey size	Home range (ha)
7–14 Jan	8	4	1.04	3	6.56
27 Jan–1 Feb	7	6	1.11	4	—
2–6 Feb	5	7	2.46	4	—
20–27 Jan	8	5	0.47	2	12.8
28 Jan–2 Feb	6	5	5.56	6	—
2–9 Feb	8	6	0.79	3	—
10–16 Feb	7	8	1.43	3	—
18–24 Feb	7	5	0.76	2	—
28 Mar–4 Apr	8	4	0.34	9	50.65
8 Apr–15 Apr	8	3	0.17	5	—
17 Apr–6 May	20	3	1.69	3	—
9 May–14 May	6	4	1.36	2	—
15 May–31 May	16	7	6.67	2	—
7 Jun–12 Jun	6	5	1.65	2	1.65
7 Jun–15 Oct	124	5	1.87	2	1.87
16 Sep–26 Sep	11	7	1.64	2	1.64
17 Oct–23 Oct	7	5	1.32	12	1.32
16 Nov–19 Nov	4	4	0.09	8	6.26
20 Nov–26 Nov	7	14	0.70	8	—
28 Nov–29 Nov	2	14	0.09	8	—
9 Dec–12 Dec	4	14	0.12	6	—

large aggregations. From June to October, pairs or coveys remained sedentary in small areas, often smaller than 2 ha (Table 4). Such small use areas typically had many (5–20/m^2) small, scattered pits dug at the base of plants which produce tubers (*Ipomea* sp.) and clumps of grass. These characteristic diggings are described in detail by Leopold and McCabe (1957). No obvious food resource was particularly more abundant in the observed use areas than in adjacent similar habitats. Winter diet was not analyzed in detail, but my observations of crop contents from 45 birds harvested by hunters included larval insects, vegetation, and acorns. These foods are similar to those reported by Bishop and Hungerford (1965) except that *Oxalis amplifolia*, an important plant to quail in grazed sites, was virtually absent on this study site.

Overall density of quail can be estimated by using the number of quail/covey (Table 4) in the most intensively surveyed 2,331 ha on the reserve where 16 coveys were consistently relocated from 1983–1987. Not all of this area was oak woodland, and could not be expected to support coveys. The most densely occupied habitat had up to four coveys/259 ha.

During census surveys of the reserve, coveys of Montezuma Quail were consistently relocated in the same small areas, not only in 1987, but from year to year. From 1983 to 1987, coveys were found in 16 specific sites (usually within the same 50-m^2 area) with great regularity. Site fidelity between years and during a given year seem especially characteristic of Montezuma Quail. Because Montezuma Quail have such small use areas, and have such high site fidelity, 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.

ACKNOWLEDGMENTS

Funding for this study was provided by the National Audubon Society, Joe and Helen Taylor, and the Research Ranch Foundation. Bob Hazen shared the services of his trained hunting dogs. Rukin Jelks III provided aircraft time and accompanied the author on many successful quail searches. Interns who assisted in the field research include Brent Bibles, Chris Monovich, Duncan Halley, and David Manry. Suggestions and assistance from Carl Bock, Jane Bock, Barbara Stromberg, and Jane Church were most helpful. Paul Zimmerman provided radio transmitters, photographs, and field assistance. Pat O'Brien and Terry Johnson (Arizona Game and Fish Department) provided useful advice, field assistance, and state permits. Reviews by Carl Bock, Clait Braun, Rocky Gutiérrez, and Jerry Hupp clarified the manuscript. During this study, the Arizona state office of the Bureau of Land Management, particularly Dean Bibles, was most helpful in establishing permanent protection of the study site from subdivision for home sites.

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