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ABSTRACT

Habitat conditions during brood season can affect Montezuma quail (*Cyrtonyx montezumae*) population levels in Arizona, and land use practices can affect these habitat conditions. General habitat affinities of Montezuma quail are known, however, information on specific habitat selection patterns is limited. We investigated seasonal habitat selection by Montezuma quail in the foothills of the Huachuca and Santa Rita mountains in southeastern Arizona. We used pointing dogs to locate quail during brood seasons (Aug–Oct) of 1998 and 1999. We measured habitat components at 60 flush sites and 60 associated (<100 m) random plots. Compared to random plots, quail used areas with higher grass and forb species richness, and more trees ($P < 0.10$). Low level (≤50 cm) visual obstruction, usually associated with bunchgrass cover, was greater ($P < 0.10$) at flush sites than at random plots. Optimum brood season habitat for Montezuma quail should contain ≥ 6 species of forbs/0.01 ha, tree canopy cover between 10 and 50%, and grass canopy cover between 50 and 85% with a minimum average height of 25cm. Maintaining these habitat characteristics could minimize negative impacts of land-use practices on Montezuma quail.

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Key words: Arizona, *Cyrtonyx montezumae,* grazing, habitat selection, livestock, Madrean evergreen woodland, Montezuma quail

INTRODUCTION

Montezuma quail population levels are affected by seasonal precipitation patterns and land-use practices that impact habitat conditions (Brown 1979). Habitat conditions during brood season are important to survival of young quail and can have a great impact on population levels (Stanford 1972). Brown (1978) considered survival more important than productivity in determining Montezuma quail population levels. General habitat affinities of Montezuma quail have been described (Wallmo 1954, Leopold and McCabe 1957, Bishop 1964, Brown 1978), however, brood season habitat selection has not been studied.

Montezuma quail populations are affected by climatic and habitat conditions prior to and during brood season. Montezuma quail feed primarily on subterranean bulbs and tubers (Bishop and Hungerford 1965), and seem dependent on perennial bunchgrasses for hiding and thermal cover (Brown 1979, Brown 1982). Most of these perennial bunchgrasses, and forbs that Montezuma quail consume, are dependent upon summer precipitation. Summer rains usually begin in July, coincidental with onset of Montezuma quail nesting. Brown (1979) found a positive correlation between summer rainfall amounts and percent young harvested during subsequent hunting seasons.

Reduction of grass cover by livestock grazing is considered an important factor affecting distribution and abundance of Montezuma quail (Leopold and McCabe 1957, Bishop 1964, Brown 1978, Brown 1982). Limited livestock grazing can increase availability of food for Montezuma quail, but excessive removal of grass cover could eliminate quail from an area (Brown 1982). Brown (1982) considered available grass cover during spring the most important factor affecting Montezuma quail survival and reproduction in grazed areas, however, the relative importance of grass cover during brood season is unknown.

Because most grasses that provide cover for Montezuma quail grow in summer, cover availability should be greater during brood season (Aug–Oct), which occurs after the summer growing season. Some studies have indicated that Montezuma quail habitat selection is less affected by grass cover in ungrazed than in grazed areas (Albers and Gelbach 1990, Stromberg 1990). Although Brown (1982) found Montezuma quail were absent from heavily grazed but otherwise suitable areas, Stromberg (1990) found quail in ungrazed habitats used areas with less understory cover than randomly selected sites. This suggests that a range of cover is important to Montezuma quail.

Relative importance of specific habitat factors, and their impacts on brood season habitat selection are unclear. Information on preferred vegetative characteristics is necessary for managing land to protect or enhance Montezuma quail habitat. Some authors have described the general habitat associations of Montezuma quail (Leopold and McCabe 1957, Bishop 1964, Brown 1978), however, only Stromberg (1990) attempted to relate habitat characteristics quail use to the range of available habitat characteristics. We quantified brood season habitat selection and contrasted habitats used in grazed and ungrazed areas. Our goal was to provide data to help land managers better design management strategies that will maintain or enhance Montezuma quail habitat.

METHODS

Study Area

We conducted our study in the foothills of the Santa Rita and Huachuca mountains, Santa Cruz County in southeastern Arizona. The area is composed primarily of Madrean evergreen woodlands interspersed with semi-desert grasslands (Brown 1994a). We concentrated efforts within Madrean evergreen woodlands, considered typical Montezuma quail habitat (Brown 1982). These woodlands were dominated by various live oaks, including Mexican blue (*Quercus oblongifolia*), Emory (*Q. emoryi*), and Arizona white oak (*Q. arizonica*) (Brown 1994*a*). Alligator juniper (*Juniperus deppeana*) mimosa, (*Mimosa* spp.), manzanita (*Arctostaphylos* spp.), and mesquite (*Prosopis juliflora*) were found in more xeric locations (Brown 1994*a*). Trees and shrubs dominated north-facing slopes, whereas perennial bunchgrasses (*Aristida* spp., *Bouteloua* spp., *Eragrostis* spp., and *Trichachne* spp.) dominated south-facing slopes and flats (Brown 1994*b*). Riparian areas contained mixtures of cottonwood (*Populus fremontii*), willow (*Salix* spp.), and sycamore (*Platanus wrightii*) (Minckley and Brown 1994).

Topography consisted of rolling hills broken by numerous small canyons, and elevation ranged between 1,200–1,500 m. Mean annual precipitation was 37.2 cm and bimodally distributed, with peaks in winter and late summer. Seasonal temperatures averaged 10.4° and 24.2° C for summer and winter, respectively (Sellers et al. 1985).

We collected data in 2 subunits. The Research Ranch Sanctuary of The National Audubon Society in the foothills of the Huachuca Mountains represented an ungrazed subunit. The Research Ranch (TRR), managed in cooperation with United States Bureau of Land Management and United States Forest Service (USFS), had been protected from grazing since 1968 (Brady et al. 1989). The USFS Coronado National Forest managed the grazed subunit, in the foothills of the Santa Rita Mountains. Recreation and cattle grazing were major land uses within Coronado National Forest (CNF) subunit. The CNF used recommendations from Brown (1982) to manage livestock grazing to protect Montezuma quail habitat. Range conditions within CNF varied from overused to lightly used, with some pastures being temporarily deferred from grazing.

Habitat Measurements

We used pointing dogs to locate Montezuma quail between 31 August and 29 October 1998 and 1999. We avoided sampling each covey more than once per season, however, because we did not have telemetered birds we could not be certain that all flush sites represented independent coveys. We estimated number of males, females, and total covey size at flush sites. We centered habitat component measurements at the approximate center of a flush site. We recorded date, time of day, study area subunit, and used a Global Positioning System unit (GPS) to obtain Universal Transverse Mercator (UTM) coordinates for each site.

At flush site centers, we described landform and substrate of flush sites by classifying terrain type, and measuring aspect of slope and soil compaction. We assigned each site a terrain category based upon position on a slope. Terrain categories were ridge top, upper half of ridge, lower half of ridge, or drainage bottom. We measured slope aspect with a compass and assigned each site an aspect category, of north (316–0°, and 0–45°), east (46–135°), south (136–225°), or west (226–315°). We measured soil compaction (tons/m^2) with a penetrometer at 1-m intervals along 2 perpendicular, 6-m transects that intersected at their midpoints on the site. We averaged the 12 readings as an estimate of soil compaction at the site.

At flush sites, we estimated vegetation species composition within a 100-m^2 circular plot (radius = 5.6 m) by counting the number of grass, forb, shrub, and tree species. We measured distance (m) to and diameter (DBH = diameter cm at 1.2 m high) of the nearest tree (>2 m tall). We also recorded distance to nearest shrub (>0.3 m tall). We estimated percent canopy cover within a 25-m radius circle using 4 perpendicular transects that intersected on flush site centers. This method yielded 100 points oriented in 4 directions at 1-m intervals. We used a random numbers table (Zar 1984) to orient the first transect line, and subsequent lines were oriented by increasing 90° from the previous line. At each 1-m point, we recorded all vegetation that could provide canopy cover for a quail (>10 cm high). We classified canopy cover as grass, forb, shrub, or tree. We calculated percent canopy cover as total number of hits within each class.

We measured vertical structure around flush sites by estimating visual obstruction using a 50-cm^2 visibility board with a 5-cm grid. Thus, the board had 10 height classes, each with 10 intersections. We centered the board vertically on the flush site and counted number of intersections visible, from a 1-m height, within each height class from a distance of 4 m, similar to Thomson (1975). We took measurements oriented along the 4 transect lines, then averaged values for each height class. We also recorded maximum height of 50% obstruction as the height category at which the mean number of visible intersections was ≤5.0 (i.e., visual obstruction ≥50%).

Random Plots

We measured the same habitat variables in the same manner at flush sites and associated (<100 m) random plots. We located random plots by travelling a random number of paces (0–100), in a random di-

Table 1. Means (± SD) of habitat variables at Montezuma quail flush sites (n = 29) and associated random plots (n = 29) in the foothills of the Huachuca Mountains, southeastern Arizona, Aug–Oct 1998 and 1999.

Variable	Flush	Random	P^a
Soil compactness (tons/m²)	19.2 ± 10.5	23.1 ± 11.7	0.184
Grass species richness	5.3 ± 14	4.1 ± 1.5	0.003
Forb species richness	6.1 ± 1.3	4.3 ± 1.5	<0.001
Tree species richness	0.5 ± 0.5	0.3 ± 1.5	0.186
Shrub species richness	1.2 ± 1.0	1.6 ± 1.3	0.136
Distance to nearest tree (m)	10.3 ± 11.3	16.3 ± 14.3	0.079
DBH of nearest tree (cm)	12.5 ± 8.7	10.3 ± 7.3	0.305
Distance to nearest shrub (m)	6.4 ± 9.7	4.3 ± 4.5	0.290
Percent grass canopy cover	73.3 ± 10.8	65.6 ± 16.5	0.040
Percent forb canopy cover	19.7 ± 11.5	15.6 ± 9.6	0.142
Percent tree canopy cover	21.1 ± 14.3	10.4 ± 10.1	0.002
Percent shrub canopy cover	7.3 ± 10.1	10.7 ± 12.5	0.262
Maximum 50% obstruction (cm)[b]	26.2 ± 12.4	16.9 ± 13.7	0.009

[a] Differences determined by 2 sample *t*-tests.
[b] Average maximum height at which the visual obstruction ≥50%.

rection (0–360°), from each flush site. We used a random numbers table to determine random direction and number of paces (Zar 1984). Transect lines at plots were oriented in the same random direction as the associated flush site.

Statistical Analysis

Using data collected at TRR (ungrazed subunit), we compared habitat measurements from quail flush sites with habitat measurements collected at random plots to determine factors that influenced habitat selection. To determine if the grazing program administered by the USFS on CNF impacted Montezuma quail habitat use, we compared flush site habitat measurements between study area subunits. To describe habitat preferences of Montezuma quail over a range of habitats, we pooled data collected at flush sites from both study area subunits and calculated means (± SD) of habitat variables that differed between flush sites and random plots at TRR.

We realized that we performed multiple tests of variables with a potential lack of independence, and the experimentwise error rate could have been high. However, because this study was designed to provide improved guidelines for habitat management of Montezuma quail, and relatively little is known about their habitat selection patterns, we accepted Type I errors as preferable to Type II errors. Therefore, to minimize potential for Type II errors, we chose not to apply Bonferroni corrections to α levels. We considered differences to be statistically significant if $P \leq 0.10$.

We used 2 sample *t*-tests for all continuous data sets (Zar 1984). For categorical data on TRR, we calculated Bonferroni confidence intervals for habitat parameters at flush sites (Neu et al. 1974, Byers et al. 1984). If availability, as determined from random plots, differed from use, we calculated a Jacobs' *D* selectivity index (Jacobs 1974) to determine magnitude of selection.

RESULTS

We located 60 coveys of Montezuma quail during brood seasons of 1998 (n = 30) and 1999 (n = 30). Based on distribution of flush sites and the average brood season home-range size of Montezuma quail coveys calculated by Stromberg (1990), we were confident that we sampled ≥21 coveys each year. We located equal numbers of flush sites on both study areas in 1998, and located 16 coveys on CNF and 14 coveys on TRR in 1999. We found 97% of the coveys in September (40%) and October (57%). Locating coveys in August was difficult due to higher daily temperatures that made it difficult to effectively and safely use dogs to locate Montezuma quail.

We flushed 520 birds; most (≥55%) coveys were male female pairs with their broods. However, as the brood season progressed into October, it became difficult to discern adult quail from young of the year. We estimated 74% of birds found were young of the year. Mean covey size was 8.7 birds/covey, and 82% of the coveys contained broods. Brood sizes ranged from 1 to 16, with a mean of 6.6. We were able to classify 80% of adult birds encountered as male or female. We were able to classify activity of 60% of coveys found. We classified 57% of the coveys as feeding, 2% roosting, and 1% travelling.

Habitat Measurements

At TRR, species richness was greater at flush sites for grasses and forbs than at random plots ($P \geq 0.10$) (Table 1); species richness for trees and shrubs did not differ between flush sites and random plots. Flush site centers were closer to trees than were centers of random plots, but DBH of the closest trees were not different between flush sites and random plots (Table 1). Percent canopy cover characteristics differed between flush sites and random plots. Flush sites had more grass and tree canopy than did random plots (Table 1).

Both methods we used to measure visual obstruction indicated that Montezuma quail used areas with more vertical cover than that found at random plots. Maximum heights at which 50% of the visibility board was fully obstructed from view were higher at flush sites than at random plots (Table 1). Visual obstruction was greater at flush sites for all 10 height levels of the visibility board than that seen at random plots ($P \leq 0.027$) (Fig. 1).

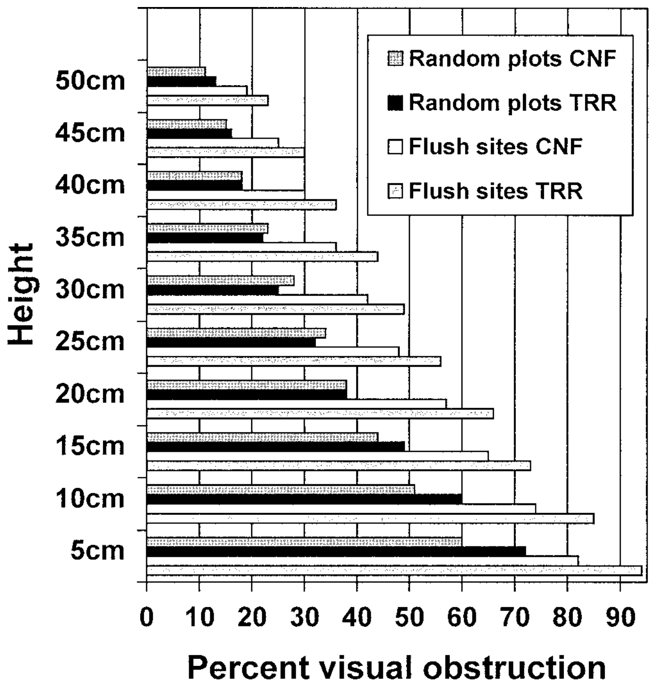

Fig. 1. Mean visual obstruction by height class determined by visibility board readings taken at Montezuma quail flush sites at the Research Ranch (TRR, n = 29) and Coronado National Forest (CNF, n = 31) study area subunits, compared to associated random plots (n = 60), in the Huachuca and Santa Rita mountains, southeastern Arizona, 1998 and 1999. All differences significant ($P \leq 0.10$) according to 2 sample t-tests.

Montezuma quail at CNF used sites that were closer to trees and had higher tree canopy cover than at TRR. Whereas flush sites at TRR had higher grass canopy cover. All other habitat variables were similar for flush sites at different study area subunits (Table 2).

Montezuma quail flush sites on TRR and CNF (n = 60) contained a mean of 6.4 (± 2.3) species of forbs/0.01 ha, mean tree canopy cover of 31.8% (± 20.3) and mean grass canopy cover of 67.2% (± 16.2). Mean maximum heights at which ≥50% of the visibility board was obstructed was 24.8 cm (± 13.7) for all flush sites.

DISCUSSION

We found that vegetation richness and cover affected habitat selection of Montezuma quail within Madrean evergreen woodlands, during the brood season. Flush site characteristics were different from random plots for half of the habitat variables we measured. Our specific findings during brood season were similar to earlier general descriptions of year-round habitat use patterns (Leopold and McCabe 1957, Bishop 1964, Brown 1978, Stromberg 1990).

The most marked difference between flush sites and random plots was in the amount of visual obstruction and cover. Most perennial bunch grasses that provide cover for Montezuma quail are summer growing species, and are at their greatest densities and heights during brood season (Stromberg 1990). Despite increased availability of grass cover during brood season throughout the study area, flush sites had greater percent canopy cover of grass and greater visual obstruction than randomly available. Possible explanations for this selection include predator avoidance and feeding strategies.

Montezuma quail are typically associated with dense grass cover (Leopold and McCabe 1957, Bishop 1964, Brown 1978, Brown 1982). However, some studies have found that Montezuma quail habitat selection is less affected by grass cover in ungrazed areas (Albers and Gelbach 1990, Stromberg 1990). Stromberg (1990) found that Montezuma quail on TRR used areas with less understory cover than randomly selected sites. Although flush sites at CNF had less grass canopy cover than at TRR, amount of visual obstruction at flush site centers was consistent between grazed and ungrazed areas. Thus, Montezuma quail were still able to find suitable cover in areas with moderate grazing pressure. This evidence tends to support Stromberg's (1990) contention that protection from grazing increased availability of cover beyond requirements of the species.

Raptor depredation is the greatest source of natural mortality for Montezuma quail (Bishop 1964, Stromberg 1990). The primary predator avoidance strategy of Montezuma quail is to remain motionless, relying on cryptic coloration to avoid detection (Leopold and McCabe 1957). This behavior can only be effective when there is sufficient cover to hide birds. Brown (1982) found that Montezuma quail were absent from otherwise suitable habitat where available grass biomass had been reduced by more than 55% of annual production. He speculated that reduced cover exposed birds to increased threat of predation and made these areas uninhabitable.

Table 2. Means (± SD) of important habitat variables at Montezuma quail flush sites collected on The Research Ranch (TRR, n = 29) and Coronado National Forest (CNF, n = 31) study area subunits in the foothills of the Huachuca and Santa Rita mountains, southeastern Arizona, Aug–Oct 1998 and 1999.

Variable	TRR	CNF	P^a
Grass species richness	5.3 ± 1.4	5.7 ± 1.4	0.214
Forb species richness	6.1 ± 1.3	6.7 ± 3.0	0.325
Distance to nearest tree (m)	10.3 ± 11.3	5.0 ± 4.4	0.024
Percent grass canopy cover	73.3 ± 10.8	61.4 ± 18.4	0.003
Percent tree canopy cover	21.1 ± 14.3	41.8 ± 20.1	<0.001
Maximum 50% obstruction (cm)[b]	26.2 ± 12.4	23.5 ± 15.0	0.456

[a] Differences determined by 2 sample t-tests.
[b] Average maximum height at which the visual obstruction ≥50%.

We found that flush sites in grazed areas had higher tree canopy and lower grass canopy than in ungrazed areas. We might speculate that Montezuma quail are compensating for reduced grass cover availability in grazed areas by selecting sites with more tree cover. However, since differences in grass and tree canopy cover between study area subunits were consistent for random plots as well as flush sites, we feel that these habitat use patterns simply reflected availability.

We found that visual obstruction was important at each height level ≤50 cm. However, differences in visual obstruction between flush and random points decreased with increasing height and would probably be insignificant at levels reaching maximum heights of native bunch grasses. Based on average grass canopy and visual obstruction at flush sites, optimum brood season Montezuma quail habitat should contain 50–85% grass canopy in a mosaic of heights between 10 and 40 cm. Minimum average grass heights should be >25 cm to adequately protect broods and adults from ground predators. Higher grass cover may be necessary to reduce the threat of aerial predators.

Although grass species richness was greater at flush site than random plots, this may be a function of grass densities, as areas with higher grass densities often have increased diversity (Brady et al. 1989). This may also be related to diet. Bishop and Hungerford (1965) found that insects composed nearly 50% of the volume of Montezuma quail crops during brood season. Areas with greater vegetational diversity would likely have greater insect diversity and density. This may be especially important for young chicks, which are more dependent upon insects than are adults (Bishop and Hungerford 1965).

Vegetation at flush sites was typical of that found on more mesic north-facing slopes of our study area. Most accounts of Montezuma quail consider oak trees to be indicators of their habitat (Leopold and McCabe 1957, Bishop 1964, Brown 1978, Stromberg 1990). However, Bishop and Hungerford (1965) found that mast from various species of oaks were important in Montezuma quail diets only during spring. Montezuma quail populations also exist in mesquite grassland habitats that contain few oaks. Selection for proximity to trees and greater tree canopy, therefore, may be more related to microclimate conditions or predator avoidance rather than to mast availability.

Forb richness was greater at flush sites than random plots. This is probably a function of dietary requirements of Montezuma quail. Holdermann and Holdermann (1997) found that Montezuma quail in New Mexico were associated with yellow nutsedge (*Cyperus esculentes*) and Gray's woodsorrel (*Oxalis grayi*), and that these plants were associated with relatively mesic deep loamy soils, where forb diversity was high. Yellow nutsedge and Gray's woodsorrel composed a substantial portion of Montezuma quail diets in Arizona (Bishop and Hungerford 1965), and their habitat selection may be largely affected by habitat requirements of these plants.

In summary, habitat selection of Montezuma quail is likely affected by dietary and security requirements. Brown (1982) found heavily grazed areas devoid of birds, presumably due to lack of cover, although those areas had higher food availability for Montezuma quail. We found that visual obstruction was important relative to habitat selection, yet other factors, such as proximity to trees, tree canopy, and vegetational diversity may be more related to microclimate and diet. Although our study did not look at relative densities or productivity of populations in different habitats, habitat quality typically influences population viability. Future Montezuma quail research should focus on relative bird densities and nesting success under different habitat conditions, especially with respect to availability of cover and specific food resources.

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