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GREATER ROADRUNNER (*GEOCOCCYX CALIFORNIANUS*) HOME RANGE AND HABITAT SELECTION IN WEST TEXAS

Andrea E. Montalvo^{1,2}, Dean Ransom Jr.¹, and Roel R. Lopez¹

ABSTRACT.—We studied Greater Roadrunner (*Geococcyx californianus*) habitat use during spring and summer 2011 on the Rolling Plains Quail Research Ranch in the Red Rolling Plains of west Texas. We captured 9 roadrunners (1 male, 8 females) and fitted each with a 10-g backpack-style radio-transmitter. We relocated roadrunners 2–4 times per week from February to August. Roadrunners used a mean minimum convex polygon home range of 43.0 ha, a 50% core range of 11.9 ha, and 33% overlap between adjacent home ranges. Home ranges were approximately half the size of those reported in a recent study of roadrunners in north Texas. Habitat selection ratios showed that roadrunners selected for ridge and grassland vegetation types and avoided bare ground and flatland vegetation types at both first- and second- but not third-order levels of selection. Similar results were documented for roadrunners in north Texas.

RESUMEN.—Estudiamos el uso de hábitat del corre caminos (*Geococcyx californianus*) en el Rolling Plains Quail Research Ranch situado en los Planos Rolling en el oeste de Texas durante la primavera y verano de 2011. Capturáramos 9 pájaros (un varón y 8 hembras) y a cada uno colocamos una radio de transmisión (estilo mochila) de 10 gramos. Los corre caminos fueron relocalizados 2–4 veces por semana desde febrero a agosto. Corre caminos usaron un convexo promedio mínimo polígono de área domiciliar de 43.0 ha, una área principal de 50% y 11.9 ha y una 33% entre las dos áreas de domicilio. Las áreas domiciliarias eran aproximadamente la mitad del tamaño de los reportados en un estudio semejante en el norte de Texas. La variación entre la área domiciliar era grande y resulto en gran parte por las diferencias en el porcentaje de terreno nudo. Selección de habitación mostro una selección para elevación y pradera tipos de vegetación, y evitando terreno nudo y plano en la primera y segunda orden pero no en la tercera. Resultados similares fueron documentados para corre caminos en el norte de Texas.

The Greater Roadrunner (*Geococcyx californianus*, hereafter roadrunner) is a common widely occurring, ground-dwelling, predatory bird in the semiarid desert rangelands of the southwestern USA. The species' geographic range extends northeastward to Louisiana, Arkansas, southern Kansas, and southeastern Missouri (Hughes 1996, Maxon 2005). Such a large geographic distribution encompasses a great diversity of vegetation types, though roadrunner habitat typically consists of areas containing no more than 50% brush of approximately 2–3 m in height (Folse 1974). Roadrunners begin pairing up for nesting season as early as February and begin their first clutch as early as April, with a second as late as September. Nests are built in small mottes of shrubs that are approximately 1–3 m from the ground. Young fledge as quickly as 12–14 days later (Folse 1974).

The ecology of roadrunners, including home-range requirements, is not well documented. Existing literature is somewhat dated and

observational in nature (Bryant 1916, Calder and Schmidt-Nielsen 1967, Folse 1974) and the reported results are highly variable likely because of differences in local resource availability, geography, rainfall, soil type, and land use (Ford 1983). Recently, Kelley et al. (2011) utilized radiotelemetry to obtain estimates of survival, home range, and habitat selection of roadrunners in a fragmented agricultural landscape. This method offered greater resolution than previous estimates obtained by observational methods, given the ability to locate roadrunners despite their secretive and elusive nature (Bolger et al. 1991, Maxon 2005).

Our objectives were to better understand roadrunner home-range size, home-range overlap, and habitat selection during the nesting season and to compare our results to existing data reported in the scientific literature. To do this, we calculated home ranges (minimum convex polygon and kernel distribution), percent home-range overlap, and habitat selection ratios for a roadrunner population in west Texas.

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METHODS

Study Area

We collected data from February to August 2011 on the 1902-ha Rolling Plains Quail Research Ranch (RPQRR; 32°02'16"N, 100°32'50"E) in the Rolling Plains ecological region (Gould 1975) of west Texas, approximately 16 km west of Roby, Texas, in Fisher County. The RPQRR contains pockets of mixed grass prairie, Conservation Reserve Program (CRP) fields, food plots, and dense stands of native honey mesquite (*Prosopis glandulosa*), shinnery oak (*Quercus havardii*), and red berry juniper (*Juniperus pinchotii*). An unbroken series of mesa-ridge slopes are prominent topographical features that spanned the entire north–south axis of the RPQRR. These geologic uplifts are characterized by shallow, gravelly, reddish brown soils and quartzitic pebbles over conglomerate rock or sandstone (USGS 1972). Ridge slopes are vegetated by large dense mottes of shrubs, whereas ridgetops support small, sparse patches of shrubs and mixed grasses, largely native Texas wintergrass (*Nassella leucotricha*) and silver bluestem (*Bothriochloa laguroides*).

Land management practices on RPQRR include prescribed burns, mechanical shrub control, and aerial and ground application of herbicide. Land development consists of gravel and dirt roads, barbed wire fences, water troughs, and electrical poles. The surrounding private land uses include natural pastures, CRP fields, and cotton fields left fallow after harvest. During this study, average monthly temperatures registered up to 2 °C higher than normal, and annual precipitation was only 6.4 cm compared to the area's 5-year average of 29.9 cm (NOAA 2011).

Capture Techniques and Triangulation

We used 2 methods to capture roadrunners. The first method was a modified bal-chatri (Berger and Mueller 1959, Lake et al. 2002, Vilella and Hengstenberg 2006) that consisted of a caged mouse (*Mus musculus*) surrounded by monofilament nooses on plywood boards that were nailed into the ground. The modifications addressed the roadrunner's unique ground-level hunting style (Kelley et al. 2011). The second technique was a box trap that had a caged mouse in the back as bait (Vehrencamp and Halpenny 1981, Bub 1991, Kelley et al. 2011). We placed traps on or within 10 m of a

road in the areas where roadrunners were most frequently observed. During handling of each trapped bird, we removed approximately 10 downy feathers for sex verification through PCR DNA analysis (Santamaria et al. 2010). We next fitted the bird with a 10-g backpack-style radio-transmitter, which weighed approximately 3% of the bird's body weight, and then immediately released the bird at the capture site.

We relocated roadrunners 2–4 times per week via triangulation of compass bearings from 3–5 positions. We calculated locations using the program LOCATE III (Pacer Computer Software, Tatamagouche, Canada), utilizing the maximum likelihood estimator and estimated standard deviation settings. We used a threshold location error ellipse of <1 ha to ensure the strength of the triangulation (Saltz and Alkon 1985) and thereby decrease the likelihood of type II error when determining habitat selection (White and Garrott 1986, Nams 1989, Saltz 1994). If a marked roadrunner was observed, we recorded the location with a handheld GPS and included the resulting coordinates in the home-range estimation.

Home-Range and Overlap Calculations

We calculated 95% minimum convex polygons (MCP) with the program Home Range Tools for ArcGIS (Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystems, Thunder Bay, Canada) and used the fixed mean selection style when individuals had ≥ 10 relocations. We also used Home Range Tools to calculate the kernel density estimator's (KDE) 95% home range and 50% core utilization distribution isopleths for those birds with ≥ 30 locations (Rodgers et al. 2007, Kelley et al. 2011). Calculation settings included a fixed-kernel estimator and least-squares cross-validation to estimate the smoothing parameter. We calculated kernel density estimator home range for those animals with <30 locations, despite that number of locations being fewer than the suggested sample number (Rodgers et al. 2007, Kelley et al. 2011) for comparison with the previously calculated home-range estimates.

We calculated an overlap index for MCPs because the MCP is more inclusive and does not traditionally limit individuals because of an insufficient number of relocations (Seaman et al. 1999). We used the intersect tool in ArcMap 9.3 (Environmental Systems Resource Institute, Redlands, CA) to find the overlapping

areas of home-range MCPs, and the overlap index was then calculated using the formula

$$OI = [(n_1 + n_2) / (N_1 + N_2)] \times 100.$$

Here n_1 and n_2 are the number of the adjacent individuals' locations within the overlap polygon, and N_1 and N_2 corresponded to the total number of locations for the 2 roadrunners used in the calculation of the home-range overlap (Chamberlain and Leopold 2002, Brunjes et al. 2009, Kelley et al. 2011). We did not include overlap indices with a value of zero, and we split the calculations into 2 groups: one index that included all overlapping polygons regardless of time and one index of only concurrently used overlapping polygons.

Vegetation Types and Selection Ratios

We determined roadrunner land use with resource selection ratios (e.g., selection functions; Manly et al. 2000). Researchers have found selection ratios more helpful than hypothesis testing (Lopez et al. 2004, McCleery et al. 2007, Kelley et al. 2011) given the *a priori* knowledge of nonrandom use (Cherry 1998, Johnson 1999). We calculated resource selection ratios with the formula

$$S = ([U + 0.001] / [A + 0.001]),$$

where U and A correspond to observed use and availability (McCleery et al. 2007) and 0.001 is used to ensure nonzero numbers (Bingham and Brennan 2004). Observed use was the number of locations for each vegetation type. Availability was the number of locations for each roadrunner multiplied by the proportion of each vegetation type within the study site boundary (Aebischer et al. 1993).

We looked at first- (landscape), second- (home range), and third-order (point locations) spatial scales of resource selection ratios (Johnson 1980). We calculated first-order selection ratios by comparing the proportion of locations in each vegetation type to the proportion of each vegetation type in the study area. We calculated second-order selection ratios by dividing the proportion of each vegetation type in each home range by the proportion of each vegetation type for the study area. Finally, we found third-order selection ratios by comparing the proportion of locations in each vegetation type to those present in their individual

95% MCP home-range estimate. We described selection ratios with means and 95% confidence intervals. Selection ratios (S) equal to 1.0 indicated resource use proportional to availability. A selection ratio whose confidence interval was >1.0 was interpreted as vegetation type selection, whereas a selection ratio <1.0 indicated avoidance (Manly et al. 2000).

We used ArcMap to determine the proportion of each vegetation type in the study area. We used one vegetation map (TNRIS 2010) and one topographic map (USGS 1972) for this analysis, and created a total of 6 land variables (4 vegetative and 2 topographic). We created the vegetation map using ArcMap's unsupervised image classification. This method resulted in 4 vegetation types described as shrubs, dense grass, sparse grass, and bare ground/rock. We determined that 4 vegetation types were most appropriate because the resulting map lacked redundancies and had the clearest delineations. Independent of the vegetative classes, the topographic map split the study area into flats and ridge. The ridge category included the ridgetop, incline, and a 25-m buffer along the ridge base.

Statistical Analysis

We followed the methodology used by Kelley et al. (2011) for statistical tests involving home-range estimates and overlap index. Our MCP home-range estimates were associated with a large variance. In an effort to explain this variation, we first looked at the vertical area of ridge slopes not calculated in conventional home-range estimates (Stone et al. 1997, Castleberry et al. 2001, Campbell et al. 2004, Greenberg and McClintock 2008). To do this, a topographic map (USGS 1972) was clipped in ArcMap with the individual 95% MCP home-range polygons, and the 2D area and 3D surface area were determined. The average percent increase was calculated in the comparison of the 2D and 3D raster areas.

RESULTS

We caught 9 roadrunners (1 male, 8 females) and relocated them a total of 437 times with acceptable accuracy. We suspect that the 4 roadrunners that died (Table 1) during the study were killed by predators. The average error polygon was 0.64 ha (CI 0.24, 1.05). Mean MCP and KDE home ranges were 43.0 ha (CI 20.1, 65.1) and 55.1 ha (CI -6.3, 116.5),

TABLE 1. Individual Greater Roadrunner home-range data including the sex, dates encompassing relocations, number of relocations, and home-range estimates (ha) comprising the 95% MCP home-range estimate, 95% KDE home-range estimate, and 50% core KDE from the birds in Fisher County, Texas.

ID	Sex	Dates	<i>n</i>	95% MCP	95% KDE	50% KDE
I	F	15 Feb–5 Aug	56	111.82	119.47	26.12
II	F	21 Mar–6 May (Died)	22	33.26	117.24 ^a	25.40 ^a
III	M	8 Feb–22 Apr (Died)	29	45.71	85.17 ^a	21.63 ^a
IV	F	31 May–3 Aug	76	43.81	19.22	3.95
V	F	18 Feb–18 Apr (Died)	21	33.75	132.71 ^a	32.36 ^a
VI	F	7 Feb–9 Mar (Died)	10	54.18	277.91 ^a	64.14 ^a
VII	F	21 Mar–8 Aug	109	18.53	27.13	5.43
VIII	F	3 May–10 Aug	94	32.14	54.52	12.65
IX	F	4 Mar–20 Apr	20	13.87	28.30 ^a	6.65 ^a

^aKernel estimates calculated using fewer than the recommended 30 locations

TABLE 2. The 6 vegetation types on the study site, including mean first-, second-, and third-order resource selection ratios (SR), 95% confidence interval (CI), and the outcome for Greater Roadrunners in Fisher County, Texas.

Order/ vegetation type	Mean SR	95% CI	Outcome
First-order			
Shrubs	0.77	0.44, 1.11	Proportional
Dense grass	2.95	1.70, 4.20	Selected
Sparse grass	2.25	1.76, 2.74	Selected
Bare ground	0.15	0.07, 0.23	Avoided
Flats	0.45	0.20, 0.69	Avoided
Ridge	3.03	1.49, 4.57	Selected
Second-order			
Shrubs	0.78	0.44, 1.12	Proportional
Dense grass	3.11	2.55, 3.67	Selected
Sparse grass	2.45	1.96, 2.95	Selected
Bare ground	0.25	0.16, 0.33	Avoided
Flats	0.53	0.21, 0.85	Avoided
Ridge	3.18	1.71, 4.64	Selected
Third-order			
Shrubs	1.13	0.74, 1.52	Proportional
Dense grass	1.05	0.61, 1.50	Proportional
Sparse grass	1.06	0.82, 1.30	Proportional
Bare ground	0.85	0.15, 1.56	Proportional
Flats	1.19	0.42, 1.96	Proportional
Ridge	0.90	0.53, 1.26	Proportional

respectively. The mean traditional KDE 50% core estimate (≥ 30 relocations) was 22.0 ha (CI = 7.6, 36.5), and the mean pooled KDE measured 95.7 ha (CI 33.5, 158.0; Table 1). None of the above home-range estimates, including MCP and both KDE home ranges, were significantly different ($F = 1.92$, $df = 2$, $P = 0.17$). The average overlap index for the pooled overlap polygons was 33.0% (CI 20.2%, 45.9%), whereas the average overlap index for polygons of only concurrently used home ranges was 34.9% (CI 16.5%, 53.4%). These 2 overlap indices were not significantly different ($t = -0.577$, $df = 1$, $P = 0.59$).

The study site had 27% shrubs, 8% dense grass, 18% sparse grass, and 11% bare ground. Topographically, 82% of the site was classified as flats and 18% was ridge. Resource selection ratios at the first-order landscape level and second-order home-range level were identical; roadrunners selected for mesa-ridge, sparse grass, and dense grass and avoided bare ground and areas of flat topography (Table 2). The third-order, point-location level indicated that roadrunners used all vegetation types proportional to their availability within individual home ranges (Table 2). MCP 3D area calculations increased the average surface area to 45.7 ha (CI 23.7, 67.7), showing an overall 6% increase but only a 0.3% reduction in the mean's variance. A t test showed no significant difference between the 2D and 3D estimates ($t = 0.778$, $P = 0.25$).

DISCUSSION

Our home-range estimates were similar to those reported by early observational studies in south Texas (Folse 1974), Arizona (Calder 1965), and southern California (Bryant 1916). These reports ranged from 28 to 50 ha but were approximately half the size of the areas reported by Kelley et al.'s (2011) telemetry study in north central Texas. Some of the difference in home-range size may be a function of resource availability so that home ranges increase as the abundance and availability of resources declines (Ford 1983). In effect, our home-range estimates may be smaller than those of Kelley et al. (2011) because the more contiguous habitat of our site provided more resources per unit area than the highly patchy habitat in their study site in north central Texas.

The large variance in our estimates of home-range size is likely due to small sample size of

birds. Roadrunners are difficult to capture in large numbers over a short period of time because of low population densities (Hughes 1996, Maxon 2005). Kelley et al. (2011) were able to monitor 34 roadrunners but required 4 years to acquire that sample size. Roadrunners have been poorly studied to date, and thus capture methodology has not been developed or refined beyond the basic bal-chatri or walk-in trap (Vehrencamp and Halpenny 1981). Folse and Arnold (1978) used mist nets set across dirt ranch roads to capture roadrunners in south Texas, but this method also required a sizable time commitment per bird trapped.

Our estimates of home-range overlap (33%) were similar to the estimates of Kelley et al. (2011; 38%), and we never witnessed any of the territorial behavior seen by others (Folse and Arnold 1978, Meinzer 1993, Maxon 2005). The studies in which territorial behavior was observed were based on observational resightings (Folse and Arnold 1978, Meinzer 1993), making delineation of territory boundaries difficult to determine. At our study site, an increased overlap and lack of territoriality could have been occurring because of an abundance of resources not requiring defense or unavoidable overlap as a result of the clumped distribution of home ranges centralized on the site's ridges. Additionally, the far-reaching borders of the roadrunner's large home range might have made defense impractical or limited to a smaller core area (i.e., around a nest or roosting site).

Our results on hierarchical resource selection were also similar to those of Kelley et al. (2011) in that roadrunners showed both selection and avoidance of vegetation types only at coarse-grained scales (landscape and home-range scale), suggesting that necessary resources were uniformly available within roadrunner home ranges (Wiens 1976). This scale is significant because common land management practices manipulate resources at these 2 scales (e.g., brush control, prescribed fire). The roadrunner's avoidance of bare ground was likely a strategy to minimize exposure to sight-based predators, such as hawks, coyotes (*Canis latrans*), and bobcats (*Lynx rufus*; Maxon 2005). Roadrunners in our study selected for grassland coverage and proportional use of shrub coverage. Grass and shrub coverage on semiarid landscapes such as ours would also provide cover for much of the roadrunner's primary prey, such as reptiles, small mammals, and arthropods

(Bryant 1916, Meinzer 1993, Maxon 2005). Tall grass also offered some security from detection by predators.

Ridge vegetation type was particularly important. We observed the ridge's dense shrub patches being used for roosting sites and escape cover. Summits were also used to search for prey (small lizards and snakes) sunning on rocks or mammals burrowing around shrubs and in the ridge crevices (Bryant 1916, Meinzer 1993, Maxon 2005). Further, the ridge vegetation type allowed for exposure to prevailing winds, which, along with the shrub cover on ridge slopes, likely helped mediate seasonal temperature extremes. The ridges also offered additional area in their slopes. Calculations of the additional area were consistent with previous studies that found home-range estimates ranging from 3% to 14% larger than 2D, planimetric home-range estimates (Stone et al. 1997, Castleberry et al. 2001, Campbell et al. 2004, Greenberg and McClintock 2008). The additional area was consistent across the individual home-range estimates, so there was no significant decrease in the variance.

Though RPQRR may be floristically and topographically representative of the southern Rolling Plains, we cannot extend inferences to the ecological region at large based on one study site. Our data is relevant to female roadrunners on the RPQRR. The large variation in home-range size is likely a result of our small sample of female roadrunners and is best addressed with a long-term approach (Kelley et al. 2011).

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