HABITAT USE AND HOME RANGE OF LONG-NOSED LEOPARD LIZARDS (*GAMBELIA WISLIZENII*) IN CANYONS OF THE ANCIENTS NATIONAL MONUMENT, COLORADO

ROBERT A. SCHORR[1,3], BRAD A. LAMBERT[1], AND ERIC FREELS[2]

[1]*Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado 80523, USA*
[2]*Dolores Public Lands Office, San Juan Public Lands, 100 North Sixth Street, Box 210, Dolores, Colorado 81323, USA*
[3]Corresponding author, e-mail: *robert.schorr@colostate.edu*

Abstract.—**An understanding of species' habitat requirements is needed for effective land management decisions, but for many North American reptiles, habitat use information is lacking.** *Gambelia wislizenii* **(Long-nosed Leopard Lizard) is a predatory lizard of most North American deserts, and, although common in the interior of its range, appears to be declining at some peripheral populations. To understand habitat use and movement patterns, we used telemetry and two habitat comparison methods to study a** *G. wislizenii* **population at the eastern boundary of the range.** *Gambelia wislizenii* **home ranges at Canyons of the Ancients National Monument, Colorado, are the largest recorded. Habitat analysis using microsite-attribute comparisons and compositional analysis documented second-order habitat preference for Big Sagebrush- or Utah Juniper-dominated landscapes.** *Gambelia wislizenii* **were found in areas with moderate shrub and forb cover with much bare ground, but were not found in areas dominated with grass cover. Incorporating management strategies that limit grass encroachment and maintain bare ground cover with moderate tree and shrub cover may help sustain** *G. wislizenii* **populations.**

Key Words.—bare ground; Colorado; *Gambelia wislizenii*; grass cover; habitat use; home range; Long-nosed Leopard Lizard; shrub cover

INTRODUCTION

Gambelia wislizenii (Long-nosed Leopard Lizard) is a medium-sized, carnivorous lizard that occurs in the Chihuahuan, Great Basin, Mojave, and Sonoran deserts (Stebbins 2003) and ranges from southern Idaho and southeastern Oregon to northern Mexico, and east to Colorado and Texas (McGuire 1996; Orange et al. 1999). *Gambelia wislizenii* inhabit Greasewood (*Sarcobatus vermiculatus*), sagebrush (*Artemisia* spp.), saltbush (*Atriplex* spp.), and rabbitbrush (*Chrysothamnus* spp.) shrublands, seeming to prefer areas where there is little or no grass cover (McCoy 1967; Baltosser and Best 1990; Steffen and Anderson 2006). Because of its broad range in North American deserts and its affinity for areas devoid of grass cover (Stebbins 2003), *G. wislizenii* is a model species for understanding the impacts of invasive grasses on habitat use.

Habitat changes that limit *G. wislizenii* abundance or distribution may have consequences for other desert species. *Gambelia wislizenii* are higher-order carnivores in southern deserts where they feed primarily on lizards, and have been known to ingest prey nearly as large as themselves (Gracie and Murphy 1986). In northern desert systems, *G. wislizenii* diet consists of more invertebrate prey, including grasshoppers, beetles, and flies (McCoy 1967; Tanner and Krogh 1974; Mitchell 1984). They are sit-and-wait predators that will spend some time actively hunting (Pietruszka 1986) and may subdue active prey, such as small rodents (Pietruszka et al. 1980).

In Colorado, *G. wislizenii* is restricted to the western border of the state (Hammerson 1999). Surveys in Colorado have produced several dozen records from the west-central part of the state (McCoy 1967), but efforts to locate *G. wislizenii* in previously occupied areas of southwest Colorado have been less successful (Hammerson 1999). In Canyons of the Ancients National Monument (Monument), Montezuma County, the few *G. wislizenii* records are from the mesa tops of Cannonball Mesa and the surrounding areas (R. Bruce Bury, unpubl. report; Brad Lambert, unpubl. report).

Because *G. wislizenii* is found in shrubland habitats with minimal grass cover, and these habitat types are declining throughout its range (West 1999), we initiated a habitat use study. The objectives were to understand *G. wislizenii* ecology, movement patterns, and habitat use, and provide management guidance for maintaining habitats for a species that may be declining in abundance and distribution (Nussbaum et al. 1983; Hammerson 1999). Such information can be invaluable for addressing leopard lizard conservation prior to legally-mandated management (U. S. Fish and Wildlife Service 1998).
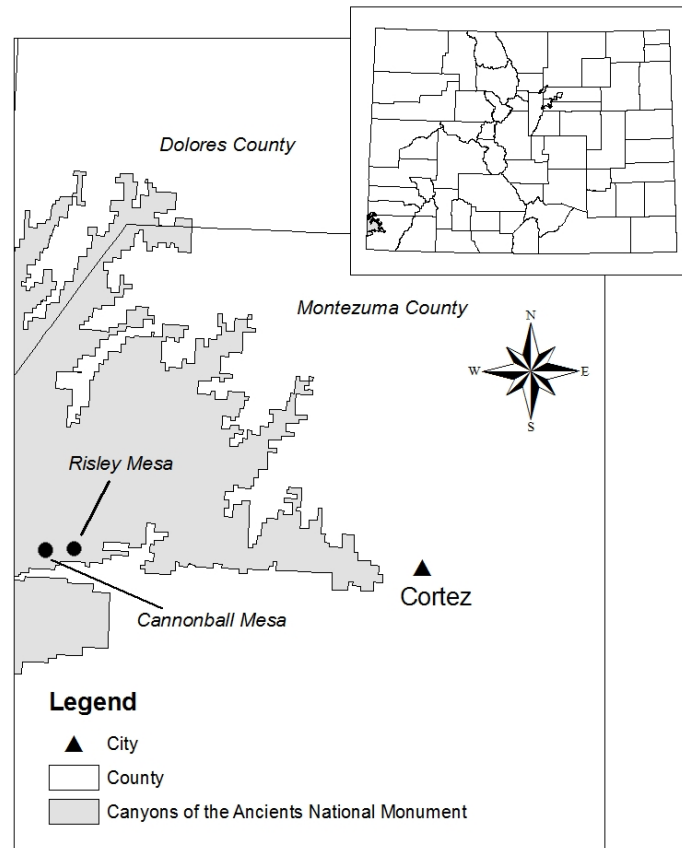
FIGURE 1. Map of Cannonball and Risley mesas on Canyons of the Ancients National Monument in southwestern Colorado, USA. Inset is the State of Colorado and Canyons of the Ancients National Monument in the southwest corner.

MATERIALS AND METHODS

Study site.—We studied *G. wislizenii* on Cannonball and Risley mesas within the Monument (Fig. 1), which is managed by the Bureau of Land Management (BLM). Declared a national monument in 2000, the 66,370 ha area provides habitat for much herpetofaunal diversity, and this diversity motivated the BLM to establish the McElmo Rare Snake and Lizard Area in Bridge Canyon of the Monument in 1976. Pinyon Pine (*Pinus edulis*) with intermixed Big Sagebrush (*Artemisia tridentata*), saltbush, Skunkbush (*Rhus trilobata*), and Utah Juniper (*Sabina osteosperma*) dominate the mesas on the Monument (Fig. 2). Vegetation along the lowland drainages is a complex of Greasewood, saltbush, Skunkbush, and rabbitbrush, with mesic areas supporting Cottonwood (*Populus angustifolia*), willow (*Salix* spp.), and Tamarisk (*Tamarix ramosissima*).

Telemetry and home range estimation.—In late June of 2006 and 2008, a crew of 4–9 biologists walked the mesas to locate, capture, and attach transmitters to *G.*

wislizenii. Biologists searched between 0800 and 1200 to match lizard activity patterns (McCoy 1967; Parker and Pianka 1976). After capture, we recorded sex and took measurements of snout-to-vent length (SVL), tail length, and mass. We placed a 1.1-g transmitter with a battery life of approximately 4–5 weeks (Holohil Limited Ltd., Carp, Ontario, Canada) over the pelvic girdle of the lizard and attached the transmitter using elastic cord (Knapp and Owens 2005). Transmitter masses ranged from 1.8–6.5% of the lizards' body masses and fell within the tested weight loads of other lizards (Knapp and Owens 2005; Knapp and Abarca 2009). Individuals > 90 mm SVL and showing orange coloration on the sides and under the tail were considered females. Individuals > 80 mm SVL, not showing orange coloration, and having enlarged postanal scales were categorized as males (Parker and Pianka 1976; Mitchell 1984; Hammerson 1999). We located lizards 2–5 times a week (mean = 3.2 locations/7 d) from 19 June to 1 August 2006, and 23 June to 30 July 2008 to match peak *G. wislizenii* seasonal activity (McCoy 1967) and increase capture success. *Gambelia wislizenii*

FIGURE 2. *Gambelia wislizenii* habitat (foreground) on Cannonball Mesa (left) and the area adjacent to and north of *Gambelia wislizenii* habitat on Cannonball Mesa (right). (Photographed by Robert Schorr).

emerge from hibernation as early as April and May in the southern regions of their range (Baltosser and Best 1990), but in Colorado do not emerge until mid-May (McCoy 1967; Hammerson 1999).

We estimated individual home ranges and an aggregated (all individuals) home range using minimum convex polygons (MCP) and kernel estimators (KHR; Seaman and Powell 1996). We used HRT: Home Range Tools for ArcGIS (Rodgers et al. 2007) in a geographic information system (ArcGIS 9.3.1, Environmental Systems Research Institute, Redlands, California, USA) for estimation and visualization of home range and movement patterns. For individual lizard KHR estimates, we used fixed kernels with least squares cross validation. Kernel home range estimators can be advantageous because they are probability-based and give information about the relative use of an area (Seaman and Powell 1996). However, kernel estimators have undergone much criticism because of the subjectivity of smoothing parameter choice and its impact on estimates and the decreased accuracy with small number of observations per individual (Seaman et al. 1999; Laver and Kelly 2008). Seaman et al. (1999) recommended obtaining $\geq$ 30 observations, and preferably $\geq$ 50 observations per animal, but these sample sizes should be used as guidelines and not cut-off values (Laver and Kelly 2008). To understand whether the number of telemetry locations was sufficient to estimate MCP or 90% KHR, we conducted asymptote analysis using ABODE software (Laver 2005; Laver and Kelly 2008). Because observations of *G. wislizenii* were not evenly spaced, we conducted asymptote analysis in which the addition of new points for home range estimation was done randomly (Laver 2005). However, objective guidelines for determining when a stable asymptote is reached for KHR estimation have not been established (Laver and Kelly 2008).

Habitat use.—We assessed habitat use at various scales using a hierarchical approach of habitat selection (Johnson 1980). We compared second-order selection (home range within study area) and third-order selection (habitat patches within home range) using compositional analysis outlined by Aebischer et al. (1993). The sampling units for compositional analysis were the individuals' MCPs. We based habitat types on the dominant vegetation groupings (DOM_VEG_1) in the Canyons of the Ancients National Monument Vegetation Database (2003; Dolores Public Lands Office, Dolores, Colorado, USA). Range ecologists at the Dolores Public Lands Office interpreted vegetation types using 1:24,000 stereographic true-color aerial photograph pairs, then verified vegetation types by assessing ground cover and shrub cover along 30-m transects. For assessment of landscape vegetation cover in second-order habitat use, we defined the study area as the area encompassed by a 100-m buffer around the aggregated MCP. The study area on Cannonball Mesa has five habitat types: Cheatgrass/filaree (*Bromus tectorum*/*Erodium* spp.); Utah Juniper/Pinyon Pine; Big Sagebrush/Cheatgrass; Cheatgrass/Alkali Sacaton (*Sporobolus airoides*)/filaree; and Utah Juniper/rabbitbrush. The habitat types within the Risley Mesa study area are Utah Juniper/Pinyon Pine, Utah Juniper/Mountain Mahogany (*Cercocarpus montanus*), Alkali Sacaton/Cheatgrasss, Cheatgrass/Galleta Grass (*Hilaria jamesii*), and Cheatgrass/filaree.

We measured microhabitat characteristics at the location of first observation of each lizard and at each telemetry location. Within a 3-m radius (28 m^2) plot centered at a lizard location, we counted rodent burrows

and estimated species-specific vegetation cover into percentage categories (0%, 1–20%, 21–40%, 41–60%, 61–80%, 81–100%). At each lizard location, and at 1.5 m in each cardinal direction, we estimated ground cover of grass, forb, cactus, litter, rock, loose soil, and cryptogamic crust within a 1-m^2 plot. We measured distance to nearest tree (> 5 cm diameter at breast height), exposed large rock (rock > 0.5 m in any dimension with overhanging edges that might provide cover), shrub, and water from each lizard location. We combined measurements > 50 m from the center point of the sampling area into a "> 50 m" category. We measured ambient temperature, soil surface temperature, and sub-surface temperature (3 cm below soil surface) at each lizard location. We assessed sun exposure of each lizard location using three categories: full sun, partial sun, or full shade.

Because animals may select habitat based on a variety of spatial scales, in 2006 we assessed *G. wislizenii* microhabitat selection using a site-attribute design that compares known use locations to random sites (Garshelis 2000). We considered the 90% KHR the primary habitat used by an individual because kernel home range methods provide information about the intensity of use (Seaman and Powell 1996). We considered area outside the 90% KHR, but within the individual's MCP areas not actively used by the lizards (termed "non-core" habitat hereafter). Non-core habitat was our best estimate of areas within the animal's home range that were not known to be used by the lizards. We generated 30 random points in the non-core habitat area and conducted habitat sampling identical to that described for each telemetry location at 19 of these locations. The discrepancy between the number of random points generated and the number sampled was caused by inaccessibility of some random points and misclassification of some random points. We considered unused habitat to be the area delimited by a 100-m buffer around the aggregated MCP boundary habitat that was not used by any lizards during the study. We generated 30 random points for the unused habitat and conducted habitat sampling as described above at 32 locations. The addition of two unused habitat locations was caused by shifts in *G. wislizenii* movement and reclassification of these points as unused habitat. Because of changes in technician availability in 2008, we did not conduct site-attribute comparisons among habitat categories on Risley Mesa.

Statistical analysis.—We conducted compositional analysis following Aebischer et al. (1993) using the randomization test (1000 iterations, α = 0.05) in Adehabitat Package for R software (Calenge 2006). Compositional analysis compares the log ratios of each individual's habitat use composition with the log ratios of the respective habitat availability composition. If the

habitat is used randomly then the log ratios are approximately equal. Differences in habitat use and availability are compared using a generalized likelihood statistic (Λ) and the ratio of the residual sum-of-squares and cross-product matrix to the raw sums of squares and cross products matrix of log ratios. Then -*N* ln Λ approximates a χ^2 statistic with *d*-l (*d* = number of habitat categories) degrees of freedom. For the 2006 data, we calculated a matrix of use and availability differences for each lizard and a mean and standard error (SE) for each comparison over all animals. If non-random habitat use exists (*P* < 0.05 for χ^2 statistic), departures from random are identified using ratios of mean and standard error comparable to a *t* value. When a lizard's proportional use of a habitat was 0%, we used 0.01% for that habitat (Aebischer et al. 1993).

Because of the broad variability in distances to nearest rock and the difficulty of accurate long-distance measurements, we lumped the data into six distance categories: A (0–5 m); B (6–10 m); C (11–20 m); D (21–30 m); E (31–50 m); and F (> 50 m). Plant cover classes and distance-to-rock categories were ordinal data sets that we compared using PROC GENMOD in SAS v9.1 (SAS Institute Inc., Cary, North Carolina, USA). PROC GENMOD generated odds ratios that we considered significant at *P* < 0.05. We compared percentage ground cover among habitat classes, mean distance to nearest shrub and nearest tree, and number of burrows within a plot using PROC GLM in SAS v9.1. Prior to analysis we transformed percentages using arcsine-square root (Sokal and Rohlf 1995). For multiple mean comparisons, we used Tukey's Studentized Range Tests to control for Type I experiment-wise error rate (*P* < 0.05).

RESULTS

Telemetry, movement, and home range.—In 2006, we placed transmitters on three reproductive females, three adult males, and one juvenile *G. wislizenii* at Cannonball Mesa, but the juvenile escaped before being weighed. In 2008, we placed transmitters on three reproductive females, six males, and a juvenile male at Risley Mesa. We captured the juvenile male late in the active season and located it eight times prior to removing the transmitter. *Gambelia wislizenii* ranged in mass from 17–63 g (mean = 35 ± 4 g SE). Males averaged 26 g (± 4 g SE), 93 mm (± 5 mm SE) SVL, and 184 mm (± 9 mm SE) tail length. Females showed typical sexual dimorphism (Lappin and Swinney 1999) and were larger than males (*P* ≤ 0.06), averaging 46 g (± 4 g SE), 108 mm (± 2 mm SE) SVL, and 232 mm (± 9 mm SE) tail length (Table 1).

We located most lizards 21–24 times, but two individuals were resighted < 13 times and were not used in home range estimation. All gravid females appeared

TABLE 1. Age, sex, mass, snout-vent length (SVL), number of telemetry locations (N), tail length, minimum convex polygon (MCP), and 90% KHR of *Gambelia wislizenii* on Cannonball Mesa in 2006 and Risley Mesa in 2008, Montezuma County, Colorado. *Indicates comparison did not include individuals observed insufficiently to produce home range estimates.

Year	Age	Sex	Mass (g)	SVL (mm)	Tail (mm)	N	MCP (ha)	90% KHR (ha)
2006	A	M	55	120	230	24	10.2	19.2
2006	A	M	17	86	192	23	8.4	26.0
2006	A	M	27	105	158	23	2.5	12.2
2006	A	F	46	117	231	23	27.4	52.1
2006	A	F	63	110	240	22	3.7	12.2
2006	A	F	56	110	270	24	41.6	55.2
2006	J	*NA*	*NA*	80	160	*NA*	*NA*	*NA*
Mean$_{2006}$			44	108	220	23	15.6	29.5
SE$_{2006}$			8	6	17	0.3	7.0	8.7
2008	A	M	25	82	190	23	1.6	2.3
2008	J	M	18	78	147	21	3.3	2.2
2008	A	M	25	93	185	22	2.9	5.2
2008	A	M	25	98	196	22	6.5	10.0
2008	J	M	19	80	173	8	*NA*	*NA*
2008	A	F	37	102	218	21	9.8	7.8
2008	A	F	39	101	204	22	3.3	1.0
2008	A	F	37	105	230	12	*NA*	*NA*
Mean$_{2008}$			28	92	193	19	4.6	4.8
SE$_{2008}$			3	4	9	2	1.2	1.5
Sex	male	Mean	26	93	184	23	5.1	11.0
		SE	4	5	9	0.4	1.3	3.4
	female	Mean	46	108	232	21	17.2	25.7
		SE	4	2	9	2	6.9	10.6
	Sex comparison	*P*-value	0.02	0.06	0.01	0.79*	0.18*	0.30*
All		Mean	35	99	205	21	10.1	17.1
		SE	4	4	9	1	3.5	5.4

slack-bodied between 29 June and 12 July suggesting they laid their eggs during this time. After tracking for approximately five weeks, we captured the lizards and removed the transmitters. Several lizards displayed slight chafing at the site of transmitter attachment. In early August 2006, one lizard was not found in the study area. It is unknown if this individual was removed by a predator, dispersed from the area, or if the transmitter battery expired.

Mean 90% KHR for *G. wislizenii* was 17.1 ha (± 5.4 ha SE) with a range of 1.0–55.2 ha, and mean MCP was 10.1 ha (± 3.5 ha SE) with a range of 1.6–41.6 ha (Table 1). Male and female home ranges were not significantly different (*P* = 0.18–0.30). Mean 90% KHR for Risley Mesa (4.8 ha) were smaller than those for Cannonball Mesa (29.5 ha; *P* = 0.03). Furthest distance moved during tracking was 1.5 km by an adult female in 2006 and 2.8 km by a juvenile male in 2008. In eight days the female moved approximately 1.0 km, while the male traveled approximately 2.7 km in 14 days. Mean total distance moved (distance between furthest locations) by *G. wislizenii* was 739 m (± 175 m SE; range = 205–2680 m).

For the 12 lizards with home range estimates, nine reached a stabilized asymptote in which there was no change in MCP size. For the nine lizards that reached a stable asymptote, MCP estimates were within 2% of the final estimate after 17 observations (± 0.6 SE). None of the 12 lizard KHR estimates reached a stabilized estimate in which three consecutive estimates changed less than 1% from the previous estimate (Odum and Kuenzler 1955). Eight of the 12 lizards had three consecutive estimates that were ≤ 5% different than the previous KHR estimate. By the 14th observation (± 0.7 SE) all lizard had KHR estimates that were within 5% of the final 90% KHR estimate, and all but one lizard had a stabilized (stopped increasing or decreasing) estimate. This does not mean that each home range estimate reached an asymptote, because it is unknown how KHR estimates would change with additional observations. However, it does suggest that for most of the *G. wislizenii*, the number of observations was sufficient to identify MCP and 90% KHR estimates. For some lizards that did not show a stabilizing home range estimate, the estimates provided here are only minimum values.
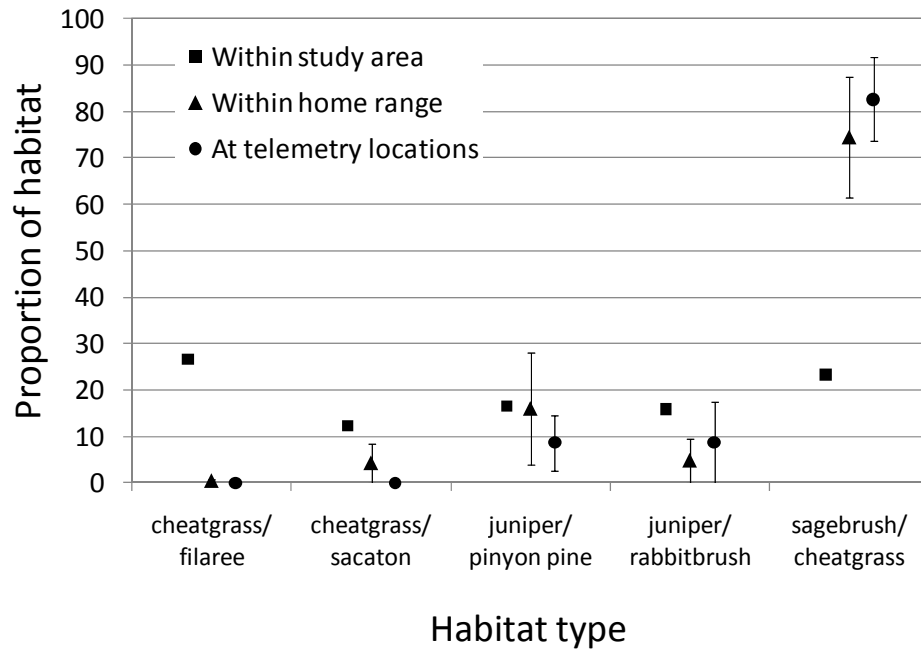
FIGURE 3. Mean (± SE) proportion of habitat type in study area, within home range, and at telemetry locations for *Gambelia wislizenii* on Cannonball Mesa in 2006, Montezuma County, Colorado.

We observed *G. wislizenii* most frequently in areas with partial shade (44%; n = 105) and least frequently in areas with full shade (22%, n = 52). Mean soil surface temperatures at lizard locations in full sun, part-sun, and shade were 37.2 ºC (± 0.5º C SE), 37.5º C (± 0.5º C SE), and 34.6º C (± 0.7º C SE), respectively. At lizard locations with part-sun and full sun exposures, sub-surface soil temperatures averaged 3.4º C lower than soil surface temperatures. Mean ambient temperature during tracking was 33.4º C (± 0.3º C SE).

Habitat use.—Compositional analysis in 2006 suggests lizards used habitat non-randomly within the study area ($\Lambda = 5.7 \times 10^9$, df = 4, $P = 0.06$). Second-order habitat use preference was for Big-Sagebrush/Cheatgrass over all other habitat types (Fig. 3). Third-order habitat analysis showed random habitat use ($\Lambda = 1.4 \times 10^{15}$, df = 4, $P = 0.5$) within the home range (Fig. 3). In 2008, *G. wislizenii* had a second-order use preference for Utah Juniper/Mountain Mahogany habitats ($\Lambda = 0.002$, df = 4, $P = 0.009$), but showed no third-order habitat preference ($\Lambda = 0.50$, df = 4, $P = 1.0$; Fig. 4). Based on four reference plots of the DOM_VEG_1 spatial layer, the Big Sagebrush/Cheatgrass habitat type on Cannonball Mesa averaged 8.8% (± 3.4% SE) Cheatgrass cover, 11.2% (± 4.3% SE) total grass cover, and 11.0% (± 4.2% SE) shrub cover. On the seven reference plots for Cheatgrass-dominated habitat types, Cheatgrass cover averaged 28.8% (± 3.8%

SE), total grass cover averaged 34.2% (± 3.5%), and shrub cover averaged 3.7% (± 1.4% SE).

Typical ground cover at lizard locations (core habitat) was much bare ground (>50%), moderate cover of litter, rock, cryptogamic soils, and forbs, with minimal grass and cactus cover (Table 2). Lizards commonly were near shrubs and trees, but infrequently near large rocks that could provide cover (Table 2). Site-attribute comparisons showed that core areas had less grass cover than non-core or unused habitats (Table 3). Core areas had greater cover of cryptogamic soils and forbs than unused areas (Table 3). Also, core habitat had more rock cover than non-core habitats (Table 3). In 2006, mean number of burrows at lizard locations was 1.4 (±

TABLE 2. Mean percentage ground cover (± SE), burrow abundance (± SE), and distance to feature (± SE) at *Gambelia wislizenii* locations (n = 234) on Cannonball and Risley mesas, Montezuma County, Colorado, in 2006 and 2008.

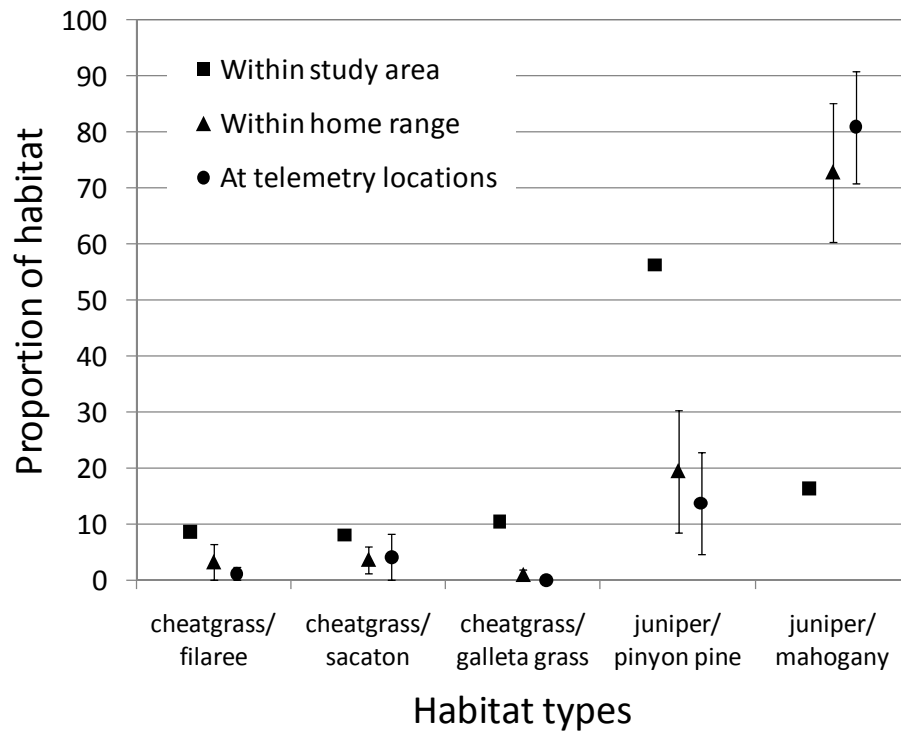| Habitat Feature	Amount (%)
Cactus	0.2 (0.1)
Cryptogamic Soil	9.9 (1.7)
Forb	16.3 (0.8)
Grass	1.4 (0.3)
Litter	23.8 (1.8)
Loose Soil	46.0 (2.4)
Rock	16.8 (2.1)
Number of burrows	1.4 (0.09)
Distance to tree (m)	6.9 (0.2)
Distance to shrub (m)	2.0 (0.1)

317

FIGURE 4. Mean (± SE) proportion of habitat type in study area, within home range, and at telemetry locations for *Gambelia wislizenii* on Risley Mesa in 2008, Montezuma County, Colorado.

0.09 SE; Table 2), but core habitats had fewer burrows than non-core habitats (Table 3).

We encountered 10 plant species at core, non-core, and unused sampling plots. Only saltbush, sagebrush, Cheatgrass, Mormon Tea (*Ephedra torreyana*), Galleta Grass, and Utah Juniper were encountered frequently enough to warrant statistical analysis. Compared to non-core habitat and unused habitats, core habitat had less saltbush, Cheatgrass, and Galleta Grass cover (Table 4) and more Big Sagebrush, Utah Juniper and Mormon Tea cover (Table 4). At core habitat locations, trees were

closer than in non-core and unused habitats, but there were no differences in the proximity of shrubs among habitat types (Table 5). The paucity of records where distance was ≤ 50 m from a rock feature and water feature precluded comparisons of these habitat components.

DISCUSSION

Home ranges of *G. wislizenii* on the Monument are highly variable, but larger than *G. wislizenii* home range

TABLE 3. Mean percentage ground cover (± SE) and burrow abundance (± SE) of core, non-core, and unused habitat for *Gambelia wislizenii* on Cannonball Mesa, Montezuma County, Colorado, in 2006. Means with different letters within a row represent differences with significance of *P* < 0.05. *Sample size reflects total habitat samples from six *G. wislizenii*.

	Core Habitat* (n = 92)	Non-core Habitat (n = 19)	Unused Habitat (n = 32)
Cactus	< 0.01	-	< 0.01
Cryptogamic Soil	10.9 (1.6) a	8.6 (3.1)	5.1 (0.01) b
Forb	16.4 (1.2) a	16.3 (2.8) a	7.1 (1.4) b
Grass	1.5 (0.01) a	9.7 (1.9) b	12.4 (2.5) c
Litter	19.6 (1.6)	28.5 (4.3)	16.7 (3.0)
Loose Soil	52.0 (2.5)	56.8 (5.0)	51.1 (4.5)
Rock	16.3 (2.1) a	6.6 (3.8) b	20.1 (4.5) a
Number of burrows	1.5 (0.2) a	3.5 (0.6) b	1.8 (0.5) a

TABLE 4. Odds of *Gambelia wislizenii* core habitat having more or less cover than non-core and unused habitats on Cannonball Mesa, Montezuma County, Colorado. All contrast are significant at P < 0.05.

Plant species with less cover in core areas	Odds of plant species having greater cover in non-core area	Odds of plant species having greater cover in unused areas
Atriplex spp. (saltbush)	2:1	6:1
Bromus tectorum (Cheatgrass)	10:1	22:1
Hilaria spp. (Galleta Grass)	19:1	13:1
Plant species with more cover in core areas	**Odds of plant species having less cover in non-core areas**	**Odds of plant species having less cover in unused area**
Artemesia tridentata (Big Sagebrush)	2:1	3:1
Ephedra torreyana (Mormon Tea)	3:1	5:1
Sabina osteosperma (Utah Juniper)	5:1	5:1

estimates from other areas (≤ 2.35 ha, Tanner and Krogh 1974) or from the closely-related Blunt-nosed Leopard Lizard (*G. sila*; ≤ 9 ha, Warrick et al. 1998). Estimates from Risley Mesa are smaller than those observed on Cannonball Mesa, but more closely match other estimates (Tanner and Krogh 1974). The smaller home ranges of lizards from Risley Mesa may be caused by a host of factors, including increased territoriality (more *G. wislizenii*) or increased resource availability and diversity (greater shrub abundance and diversity). A majority of *G. wislizenii* moved < 1 km (maximum linear distance); however, two gravid females had movements > 1 km and these movements may have been prompted by the onset of egg-laying (Parker and Pianka 1976). These females may have been reducing competition for their young (Ryberg et al. 2004; Le Galliard et al. 2005), reducing the probability of cannibalism (McCoy 1967), or searching for appropriate nesting locations (Parker and Pianka 1976; Anguilletta et al. 2009). The juvenile male movement observed on Risley Mesa (2.8 km) is the largest documented for *G. wislizenii* and it may have been caused by an effort to avoid adult males in the vicinity. Although not considered a territorial species (Tollestrup 1983; Lappin and Swinney 1999), this juvenile was never observed

within the home ranges of the nearby adult males. Such long-distance movements may not be abnormal for juvenile males as Parker and Pianka (1976) recorded one moving nearly 1.2 km over 20 days. *Gambelia wislizenii* long-distance movements may have been a product of hunting forays. Although considered a sit-and-wait predator, *G. wislizenii* will stalk prey more frequently early in the active season, traveling more than 200 m in an hour (Pietruszka 1986).

Gambelia wislizenii prefer habitats with moderate shrub and forb cover and minimal grass cover (Baltosser and Best 1990; Steffen and Anderson 2006). The second-order compositional analysis identified shrub- or tree-dominated habitat types as preferred habitats over grass-dominated landscapes. In site-attribute comparisons, grass cover was the cover category that was statistically lower at telemetry locations (core areas), than at non-core areas within *G. wislizenii* home ranges and outside *G. wislizenii* home ranges. Additionally, the probability of having either of the major grass species (Cheatgrass and Galleta Grass) at lizard locations is much less than at non-core and unused areas. The preferred community on Risley Mesa was the Utah Juniper/Mountain Mahogany habitat type and the preferred communities on Cannonball Mesa were the Big Sagebrush/Cheatgrass habitat types. Cheatgrass and total grass cover on the Big Sagebrush/Cheatgrass habitat types was much less than that found on the least-preferred habitat types where Cheatgrass was considered the most abundant vegetation. Given our data, it is unclear if *G. wislizenii* avoid areas with Cheatgrass, or avoid any areas where grass cover is the most abundant cover type. Cheatgrass is an invasive annual grass that can alter landscapes by precluding native species (Billings 1990), increasing the frequency and severity of fire (Brooks et al. 2004), changing soil chemistry (Rimer and Evans 2006), reducing availability of soil moisture

TABLE 5. Mean distance (m) to vegetation feature (± SE) in three *Gambelia wislizenii* habitat groups on Cannonball Mesa, Montezuma County, Colorado. Means with different letters within in a row are significantly different (*P* < 0.05).

	Core Habitat (n = 98)	Non-core Habitat (n = 19)	Unused Habitat (n = 32)
Shrub	2.1 (0.2)	2.7 (0.5)	2.5 (0.3)
Tree	6.9 (0.4) a	15.4 (1.5) b	16.5 (2.2) b

FIGURE 5. Male *Gambelia wislizenii* holding a *Sceloporus graciosus*. The *S. graciosus* is alive and the tail is separated from the body. (Photographed by Paul Morey).

(Melgoza et al. 1990), and converting shrublands and woodlands to grasslands (Chambers et al. 2007; Shinneman and Baker 2009). For desert lizards, Cheatgrass-dominated landscapes can alter movement patterns by limiting lizard mobility (Newbold 2005; Rieder et al. 2010).

Habitat use by *G. wislizenii* likely is influenced by other factors besides grass cover. In particular, *G. wislizenii* prefer areas with moderate shrub or tree cover. Similar to studies in southeastern Oregon (Steffen and Anderson 2006), the compositional analysis on Cannonball Mesa identifies Big Sagebrush as a preferred habitat type for *G. wislizenii*. The three plants with greater odds of being found in areas used by *G. wislizenii* (sagebrush, juniper, and Mormon Tea) were shrubs that have a growth form that provides canopy cover without prohibiting movement along the ground. *Gambelia wislizenii* affinity for moderate shrub and forb cover with sparse grass cover may be due to thermoregulatory requirements, preferences for prime foraging areas, and a need to limit predation risk (Steffen and Anderson 2006). Choosing areas near the base of trees or shrubs, where there is little grass cover, ensures prey species are seen in advance of their approach. Open areas with partial shade may provide access to various soil temperatures for thermoregulation (Parker and Pianka 1976; Steffen and Anderson 2006). Additionally, remaining close to shrubs that provide incomplete cover (e.g., Big Sagebrush, Utah Juniper and Mormon Tea) ensures the checkered dorsal pattern of Leopard Lizards blends well with the shade patterns produced by sparsely-vegetated shrub branches (Montanucci 1976).

Infrequently we saw *G. wislizenii* in the lower branches of Utah Juniper (n = 4) and cliff rose (n = 1). *Gambelia sila* are known to bask in shrubs and roost in limbs overnight (Montanucci 1965). In Nevada, *G. wislizenii* have been found foraging on berries in the branches of Desert-thorn (*Lycium*; Tanner and Krogh 1974), but it is unlikely that *G. wislizenii* climb Utah Juniper trees to feed on the berries that are abundant on the ground. Likely, *G. wislizenii* are basking or depredating insects that feed on Utah Junipers (Hayes et al. 2008). This study did not document insect prey; however, on three occasions *G. wislizenii* were seen consuming lizards, including a Sagebrush Lizard (*Sceloporus graciosus*; Fig. 5).

Gambelia wislizenii on the Monument use habitats that have minimal grass cover with moderate cover of shrubs or trees. Maintaining such a system may involve efforts to limit the expansion of Cheatgrass and other grasses, while maintaining the distribution of native shrubs and trees that may provide thermoregulatory habitats, resting habitats, cover from predators and concealed areas for ambushing prey (Montanucci 1976). Investigations of *G. wislizenii* habitat use and home range prior to and after manipulations of grass cover may clarify the impact dense stands of grass have on *G. wislizenii* populations.

LITERATURE CITED

Aebischer, N.J., P.A. Robertson, and R.E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74:1313–1325.

Anguilletta, Jr., M.J., M.W. Sears, and R.M. Pringle. 2009. Spatial dynamics of nesting behavior: Lizards shift microhabitats to construct nests with beneficial thermal properties. Ecology 90:2933–2939.

Baltosser, W.H., and T.L. Best. 1990. Seasonal occurrence and habitat utilization by lizards in southwestern New Mexico. Southwestern Naturalist 35:377–384.

Billings, W.D. 1990. *Bromus tectorum*, a biotic cause of ecosystem impoverishment in the Great Basin. Pp. 301–322 *In* The Earth in Transition: Patterns and Processes of Biotic Impoverishment. Woodwell, G.M., (Ed.). Cambridge University Press, New York, USA.

Brooks, M.L., C.M. D'Antonio, D.M. Richardson, J.B. Grace, J.E. Keeley, J.M. DiTomaso, R.J. Hobbs, M. Pellant, and D. Pyke. 2004. Effects of invasive alien plants on fire regimes. BioScience 54:677–688.

Calenge, C. 2006. The package "adehabitat" for the R software: A tool for the analysis of space and habitat use by animals. Ecological Modeling 197:516–519.

Chambers, J.C., B.A. Roundy, R.R. Blank, S.E. Meyer, and A. Whittaker. 2007. What makes Great Basin sagebrush ecosystems invasible by *Bromus tectorum*? Ecological Monographs 77:117–145.

Garshelis, D.L. 2000. Delusions in habitat evaluation: measuring use, selection and importance. Pp. 111–164 *In* Research Techniques in Animal Ecology: Controversies and Consequences. Boitaini, L., and T. K. Fuller (Eds.). Columbia University Press, New York, USA.

Gracie, A.E., and R.W. Murphy. 1986. *Gambelia wislizenii* (Leopard Lizard) food. Herpetological Review 17:47.

Hammerson, G.A. 1999. Amphibians and Reptiles in Colorado: A Colorado Field Guide, 2nd Edition. University Press of Colorado, Niwot, Colorado, USA.

Hayes, J.L., P.L. Johnson, A. Eglitis, D.W. Scott, L. Spiegel, C.L. Schmitt, and S.E. Smith. 2008. Response of bark and woodboring beetles to host volatiles and wounding on western juniper. Western Journal of Applied Forestry 23:206–215.

Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluation of resource preference. Ecology 61:65–71.

Knapp, C.R., and A.K. Owens. 2005. An effective new radio transmitter attachment technique for lizards. Herpetological Review 36:264–266.

Knapp, C.R., and J.G. Abarca. 2009. Effects of radio transmitter burdening on locomotor ability and survival of iguana hatchlings. Herpetologica 65:363–372.

Lappin, A.K., and E.J. Swinney. 1999. Sexual dimorphism as it relates to natural history of leopard lizards (Crotaphytidae: *Gambelia*). Copeia 1999:649–660.

Laver, P.N. 2005. Kernel home-range estimation for ArcGIS, using VBA and ArcObjects. Available online at http://www.fishwild.vt.edu/abode/abode.pdf.

Laver, P.N., and M.J. Kelly. 2008. A critical review of home range studies. Journal of Wildlife Management 72:290–298.

Le Galliard, J., R. Ferriere, and J. Clobert. 2005. Effect of patch occupancy on immigration in the common lizard. Journal of Animal Ecology 74:241–249.

McCoy, C.J. 1967. Natural history notes on *Crotaphytus wislizeni* (Reptilia: Iguanidae) in Colorado. American Midland Naturalist 77:138–146.

McGuire, J.A. 1996. Phylogenetic systematics of Crotaphytid lizards. Bulletin of the Carnegie Museum of Natural History 32:1–143.

Melgoza, G., R.S. Nowak, and R.J. Tausch. 1990. Soil water exploitation after fire: Competition between *Bromus tectorum* (Cheatgrass) and two native species. Oecologia 83:7–13.

Mitchell, J.C. 1984. Observations on the ecology and reproduction of the Leopard Lizard, *Gambelia wislizenii* (Iguanidae), in southeastern Arizona. Southwestern Naturalist 29:509–511.

Montanucci, R.R. 1965. Observations on the San Joaquin Leopard Lizard, *Crotaphytus wislizenii silus* Stejneger. Herpetologica 21:270–283.

Montanucci, R.R. 1976. Dorsal pattern polymorphism and adaptation in *Gambelia wislizenii* (Reptilia, Lacertilia, Iguanidae). Journal of Herpetology 12:73–81.

Newbold, T.A.S. 2005. Desert Horned Lizard (*Phrynosoma platyrhinos*) locomotor performance: the influence of Cheatgrass (*Bromus tectorum*). Southwestern Naturalist 50:17–23.

Nussbaum, R.A., E.D. Brodie, Jr., and R.M. Storm. 1983. Amphibians and Reptiles of the Pacific

Northwest. University of Idaho Press, Moscow, Idaho, USA.

Odum, E.P., and E.J. Kuenzler, Jr. 1955. Measurement of territory and home range size in birds. Auk 72:128–137.

Orange, D.I., B.R. Riddle, and D.C. Nickle. 1999. Phylogeography of a wide-ranging desert lizard, *Gambelia wislizenii* (Crotaphytidae). Copeia 1999:267–273.

Parker, W.S., and E.R. Pianka. 1976. Ecological observations on the Leopard Lizard (*Crotaphytus wislizeni*) in different parts of its range. Herpetologica 32:95–114.

Pietruszka, R.D. 1986. Search tactics of desert lizards: How polarized are they? Animal Behaviour 34:1742–1758.

Pietruszka, R.D., J.A. Wiens, and C.J. Pietruszka. 1980. Leopard Lizard predation on *Perognathus*. Journal of Herpetology 15:249–250.

Rieder, J.P., T.A.S. Newbold, and S.M. Ostoja. 2010. Structural changes in vegetation coincident with annual grass invasion negatively impacts sprint velocity of small vertebrates. Biological Invasions 12:2429–2439.

Rimer, R.L., and R.D. Evans. 2006. Invasion of Downy Brome (*Bromus tectorum* L.) causes rapid changes in the nitrogen cycle. American Midland Naturalist 156:252–258.

Rodgers, A.R., A.P. Carr, H.L. Beyer, L. Smith, and J.G. Kie. 2007. HRT: Home Range Tools for ArcGIS Version 1.1. Ontario Ministry of Natural Resources, Centre for Northern Forest Ecosystem Research, Thunder Bay, Ontario, Canada. 29 p.

Ryberg, K., M. Olsson, E. Wapstra, T. Madsen, S. Anderholm, and B. Ujvari. 2004. Offspring-driven dispersal in female Sand Lizard (*Lacerta agilis*). Journal of Evolutionary Biology 17:1215–1220.

Seaman, D.E., and R.A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. Ecology 77:2075–2085.

Seaman, D.E., J.J. Millspaugh, B.J. Kernohan, G.C. Brundige, K.J. Raedeke, and R.A. Gitzen. 1999. Effects of sample size on kernel home range estimates. Journal of Wildlife Management 63:739-747.

Shinneman, D.J., and W.L. Baker. 2009. Environmental and climatic variables as potential drivers of post-fire cover of Cheatgrass (*Bromus tectorum*) in seeded and unseeded semiarid ecosystems. International Journal of Wildland Fire 18:191–202.

Sokal, R.R., and F.J. Rohlf. 1995. Biometry: The Principles and Practice of Statistics in Biological Research. 3rd Edition. W.H. Freeman and Company, New York, New York, USA.

Stebbins, R.C. 2003. A Field Guide to Western Reptiles and Amphibians. 3rd edition. Houghton Mifflin, Boston, Massachusetts, USA.

Steffen, J.E., and R.A. Anderson. 2006. Abundance of the Long-nosed Leopard Lizard (*Gambelia wislizenii*) is influenced by shrub diversity and cover in southeast Oregon. American Midland Naturalist 156:201–207.

Tanner, W.W., and J.E. Krogh. 1974. Ecology of the Leopard Lizard, *Crotaphytus wislizeni* at the Nevada Test Site, Nye County, Nevada. Herpetologica 30:63–72.

Tollestrup, K. 1983. The social behavior of two species of closely related leopard lizards, *Gambelia silus* and *Gambelia wislizenii*. Zeitschrift für Tierpsychologie 62:307–320.

U.S. Fish and Wildlife Service. 1998. Recovery Plan for Upland Species of the San Joaquin Valley, California. U.S. Fish and Wildlife Service, Portland, Oregon, USA. 340 p.

Warrick, G.D., T.T. Kato, and B.R. Rose. 1998. Microhabitat use and home range characteristics of Blunt-nosed Leopard Lizards. Journal of Herpetology 32:183–191.

West, N.E. 1999. Managing biodiversity of rangelands. Pp. 101–126 *In* Biodiversity in Agroeconomic Systems. Collins, W.W., and C.O. Qualset (Eds.). Boca Raton, Florida, USA.

ROBERT SCHORR is a Research Associate with the Fish, Wildlife, and Conservation Biology Department, Colorado State University, and a Zoologist with the Colorado Natural Heritage Program. His interests are population ecology, habitat use, and conservation of rare vertebrates. Rob has been investigating movement patterns, habitat use, and population ecology of the Preble's Meadow Jumping Mouse (*Zapus hudonius preblei*) since 1997. He earned his B.S. in Biological Sciences from University of California, Davis, and his M.S. in Forest Resources (Wildlife Biology) from the University of Georgia. (Photographed by Colorado Natural Heritage Program)

BRAD LAMBERT is a Research Associate with the Fish, Wildlife, and Conservation Biology Department, Colorado State University, and a Zoologist with the Colorado Natural Heritage Program. His interests are population ecology and conservation of amphibians and reptiles in Colorado, and he has been studying Boreal Toad (*Bufo boreas boreas*) populations in Colorado since 1999. Brad earned his B.S. in Zoology from Colorado State University. (Photographed by Colorado Natural Heritage Program)

ERIC FREELS is a Wildlife Biologist for the Dolores Public Lands Office, Bureau of Land Management, Dolores, Colorado. Eric earned a B.A. in Biology from Southern Wesleyan University in 1998 and his B.S. Wildlife Biology at Colorado State University in 2001. (Photographed by Robert Schorr)