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Home Range and Habitat Use by Blunt-nosed Leopard Lizards in the Southern San Joaquin Desert of California

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Abstract.—**We used radiotracking to study the home range and use of space by Blunt-nosed Leopard Lizards (*Gambelia sila*) in the Lokern Natural Area in the San Joaquin Desert of California. The average home-range size of males, based on the fixed kernal local convex hull method, was 6.21 ha in 2003 and 7.62 ha in 2004, which differed significantly from the average size for females, which was 2.85 ha in 2003 and 3.17 ha in 2004. Average home-range size did not differ significantly between years or with the interaction of sex and year. Home ranges of nine lizards with collars were in about the same locations between 2003 and 2004. There were no significant differences in either the percentage or number of home-range overlaps among adjacent pairs. Males moved an average of ~100 m daily, significantly farther than the 65-m average daily movements of females, but there were no significant differences for the average greatest distance moved in 1 day by sex or year, or their interaction. The longest distance moved in a day for a male was 615 m and for a female was 642 m. We found that home ranges of Blunt-nosed Leopard Lizards contained more area of saltbush (*Atriplex* spp.) than expected based on proportion of area, but home-range sizes and distances moved did not differ significantly based on shrub presence.**

Blunt-nosed Leopard Lizards (*Gambelia sila*) are relatively large (115-mm snout–vent length [SVL]) diurnal lizards that are active and swift predators, not prone to stationary or ambush predation (Tollestrup, 1983). This lizard is endemic to the San Joaquin Desert (Montanucci, 1965; Stebbins, 2003; Germano, 2009), which is located in the southern Central Valley of California and covers an area of about 28,500 km^2 (Germano et al., 2011). *Gambelia sila* occur throughout the desert. Largely because of land conversion to agricultural, urban, and industrial (mostly oil) activities covering ca. 59% of the area (Germano et al., 2011), suitable lizard habitats have become smaller and fragmented, resulting in lizards becoming rare and being listed federally as an endangered species in 1967 (U.S. Fish and Wildlife Service, 1967) and listed by California in 1971 (California Department of Fish and Wildlife, 2015). Because these lizards are endangered, considerable effort is focused on protecting both individuals and large areas of lizard habitat (U.S. Fish and Wildlife Service, 1998). Little basic ecological information is available, however, to help develop and implement meaningful management actions. These types of data are important for proper conservation of many species (Bury, 2006; Staab et al., 2015).

Aspects of lizard natural history may be relevant for management of *G. sila* and other diurnal lizards that are wide ranging (Verwaijen and Van Damme, 2008; Schorr et al., 2011). For example, *G. sila* is inactive during the winter months of November through early March; they produce 1–4 clutches per year and each clutch has 2–5 eggs (Montanucci, 1965, 1967; Tollestrup, 1982; Germano and Williams, 2005). These lizards are sexually dimorphic, with the largest (upper 10% of samples) adult females averaging about 113-mm SVL and adult males 116-mm SVL (Germano and Williams, 2005). Based on first egg production, females reach sexual maturity at about 90-mm SVL; based on the appearance of breeding colors, males also mature at about 90-mm SVL (Tollestrup, 1982; Germano and Williams, 2005).

Although the home-range size and use of space by *G. sila* has been addressed in two studies (Tollestrup, 1983; Warrick et al., 1998), we think those estimates were likely influenced by the methods used, such as how home-range estimates were obtained, sample size, duration of study, and materials used to collar lizards (see Discussion), and resulted in underestimated home-range sizes. In addition, although *G. sila* are found in greater abundance in open habitat with little shrub cover (Montanucci, 1965; Warrick et al., 1998), habitat with some cover of saltbush (*Atriplex* spp.) might be beneficial in avoiding predation, thermoregulation, and supporting a higher diversity and abundance of food items. If habitat with some saltbush is beneficial, and if home-range size is resource based (Schoepf et al., 2015), then home ranges of *G. sila* may be smaller and lizards may move less per day in these areas compared to areas with no saltbush. This type of information on habitat condition and use is important in developing meaningful management actions, such as habitat protection and restoration, reintroductions, and translocations for this as well as other species (Dodd and Seigel, 1991). Our research objective was to determine the characteristics of *G. sila* home ranges and habitat use with the relatively impartial method of radiotracking (Kenward, 2001), so that the resulting information could be used to develop more meaningful species and habitat management practices for this and other lizards with similar life-history traits.

Materials and Methods

Study Area.—We studied *G. sila* at the Lokern Natural Area in the southwestern end of the San Joaquin Desert, about 50 km northwest of Bakersfield in Kern County, California (Fig. 1). The site (35°22′24″N 119°36′33″W, 158-m elevation) is a large and broad alluvial fan that is relatively undisturbed at the base of the Elk Hills, although the natural area is surrounded by intensive agriculture, oil fields, and a large landfill. The site is dominated by saltbush, nonnative annual grasses, and native annual forbs and perennial grasses (Germano et al., 2012). Because the natural area is large (5,285 ha), relatively undisturbed, and mostly protected, other ecological studies have been performed there (Cypher et al., 2010; Germano et al., 2012).

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FIG. 1. Location of the home-range study of Blunt-nosed Leopard Lizards (*Gambelia sila*) at the Lokern Study Area (star) in Kern County (shaded) in the southern San Joaquin Desert of California, USA.

Data Collection.—We radiotracked *G. sila* from April until early August in 2003 and 2004. Starting in April each year, we intensively walked the study site during the day and used a pole and noose to catch lizards. Once the lizards were captured, we determined their sex and measured their SVL, total length, and mass. We attached radio transmitters (model BD-2, frequency 164–166 MHz, battery life 16–18 wk, weight 2.0 g; Holohil Systems, Ltd., Carp, Ontario, Canada) to *G. sila* with aluminum beaded chain collars (Harker et al., 1999). We attached the transmitter to the chain by winding several loops of thin brass wire around the transmitter and chain and covering the wire with epoxy glue. The transmitters with collars weighed 2.2 g, which was <7.8% of the weight of the smallest lizards we collared.

We attached collars only to adult *G. sila* and did not radiotag lizards <93 mm SVL or <28 g mass. In 2003 we captured 19 additional *G. sila* in the study area that we did not collar (lack of transmitters), 3 of which were juveniles and likely did not affect overlap estimates (see Discussion). Similarly, in 2004 we captured 20 lizards that went uncollared; 7 of these were too small to collar. We released lizards at their capture site within 24 h of capture. Because of the large heads and forelimbs of *G. sila,* it was virtually impossible for the collars to come off unassisted. We found 20 (12 in 2003, 8 in 2004) intact or chewed collars with functioning transmitters no longer attached to lizards; presumably predators removed the collars. We removed collars in July or August, except for 12 lizards from which the signal completely disappeared, including six transmitters in 2004 that we recovered from lizards that were inside known burrows that appeared to be long-term overwintering sites.

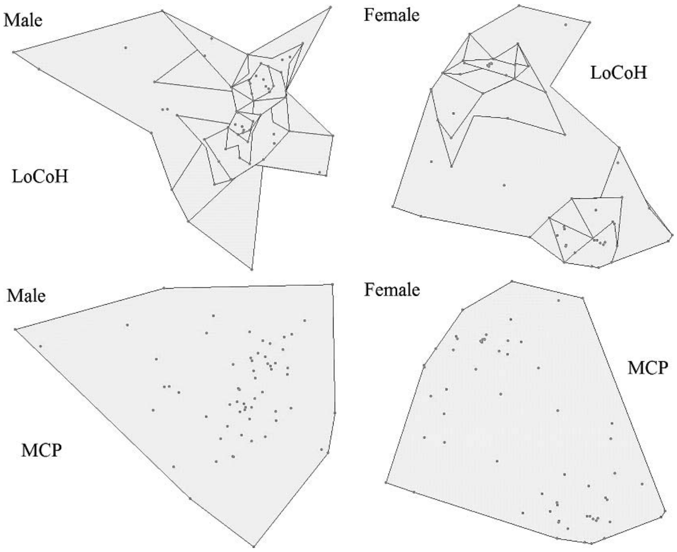

FIG. 2. Comparison of home-range geometry of two individual Blunt-nosed Leopard Lizards (*Gambelia sila*) in 2004 at the Lokern Study Area in the southern San Joaquin Desert of California, USA, with the use of LoCoH (top) and 100% minimum convex polygons (bottom) methods for a male (left) and female (right). The area of the LoCoH home range for this male is 6.76 ha and the MCP area is 9.46 ha. The area of the LoCoH home range for this female is 5.24 ha and the MCP area is 6.12 ha. Internal lines in LoCoH home ranges are boundaries of home ranges based on lower *k* values (see Methods).

We used H-Adcock two-element or Yagi three-element receiving antennae with Model R-1000 receivers (Communications Specialists, Inc., Orange, CA) to radiolocate collared lizards by the homing method (Kenward, 2001). We recorded GPS locations with a Dell Axim Pocket PC fitted with a World Navigator Teletype GPS receiver with differential and real-time correction with ±5-m resolution. We located lizards every 1–5 d with the aim to gather 40–50 locations for each individual (Stone and Baird, 2002), but some lizards were preyed upon, or the signal was lost (see above), before we could collect the intended number of locations. We did not use data from individuals with fewer than 25 locations.

Data Analysis.—We calculated home-range size of male and female *G. sila* with the use of two methods: the minimum convex polygon (MCP) technique (Home Range Extension in ArcView 3.2, ESRI, Redlands, CA) and the fixed kernal local convex hull (LoCoH), or kernal nearest-neighbor convex hull method (Getz and Wilmers, 2004; Getz et al., 2007; http://locoh.cnr.berkeley.edu/). The MCP allowed us to compare home ranges with published data (see Discussion), and to calculate other useful metrics with this software (see below). We used the LoCoH method because it more accurately reflects where lizards spend time in their habitat (Fig. 2; see Kenward et al., 2014). We were very familiar with the study site, so we subjectively determined which estimate of LoCoH home range best represented habitat actually used by each lizard by inspecting several different home-range areas for each lizard that were produced by varying the *k* values (size of the hulls or kernals used in calculating the home range). We concluded that best results were obtained by using the smallest *k* value that resulted in a home range with no open gaps or islands within a perimeter of each home range, because of a lack of identifiable habitat features that would result in these home-range "holes" (Fig. 2). After square-root transformation, home-range size data were normal and homoscedastic. We compared square-root transformations of home-range sizes with

TABLE 1. Sample size (n), mean, standard error (SE), and range of LoCoH and 100% minimum convex polygon (MCP) home-range sizes (ha) of male and female Blunt-nosed Leopard Lizards (*Gambelia sila*) in 2003 and 2004 at the Lokern study site in the southern San Joaquin Desert of California, USA.

	LoCoH				MCP			
Year/sex	n	Mean	SE	Range	n	Mean	SE	Range
2003								
Male	13	6.21	1.03	0.70–13.7	13	7.93	1.37	0.93–20.2
Female	12	2.85	0.68	0.94–9.22	12	4.48	0.88	1.65-13.1
2004								
Male	17	7.62	1.51	2.02–29.5	17	9.36	1.63	2.48–31.3
Female	14	3.17	0.71	0.62–8.50	14	5.75	2.11	0.63–31.5

the use of two-way ANOVA by sex, year, and their interaction (sex × year). For all tests, $\alpha = 0.05$; averages are expressed as mean ±SE.

We used the Home Range Extension in ArcView 3.2 to calculate the percentage overlap and number of overlaps of the 100% MCP home ranges of males with males (M/M), females with females (F/F), and males with females (M/F). We calculated both the high and low percentage overlaps among home-range pairs that were related to the different sizes of each home range (if the two ranges were exactly the same size, there would be no difference in the high and low overlaps). We included only home ranges that did not overlap other home ranges (zero overlap) if the distance of the home range was close (the size of one mean home range) to an adjacent home range. This eliminated a few home ranges that were isolated from groups of home ranges.

After square-root transformation of overlap data to meet parametric assumptions, we used a two-way ANOVA to compare high and low percentage overlaps by three sex groups (M/M, F/F, M/F), and by year and group × year interaction. Because we could not meet the assumptions of parametric testing with the number of overlaps across years, we separated the groups by year and used a one-way ANOVA on 2003 data and a Kruskal-Wallis test for 2004 data that transformations did not correct.

To determine distances that *G. sila* moved between consecutive daily locations (ignoring distances from locations taken >1 d apart), we used the ArcView "Path With Distance and Bearing" Extension, v. 3.2b. Data for average distance moved were normal, but greatest distance data were not, so we normalized the greatest distance data with square-root transformations. We then compared average and greatest distances moved by males and females with two-way ANOVA by sex, year, and their interaction.

Because some shrub cover may be beneficial to *G. sila* (Warrick et al., 1998), we analyzed lizard use of shrub-dominated areas at our site in several ways. In one comparison, we conducted a preference analysis for lizards found in 2003 and 2004 in an area of the site with narrow bands of saltbush in two washes. We tested for preference with the use of the chi-square equation from Manly et al. (1993) as described in Rogers and White (2007). In this section of the site in 2003, home ranges of all 20 *G. sila* overlapped with saltbush in the washes (range: 0.4–73.5%; mean = 19.7%), and in 2004, 15 of 17 *G. sila* overlapped areas of saltbush (range: 8.1–42.4%; mean = 18.0%). We used the Dell Axim GPS receiver to construct a polygon of the saltbush in the washes and used the area as the available shrub habitat. To determine the area of open habitat available to the lizards, we used the 100% MCP polygon area of all locations of lizards with collars that we used for home-range calculations. Following Rogers and White (2007), selection by lizards for shrub-dominated habitat is demonstrated if the chi-square is sufficiently large compared to a chi-square with $n\ (I - 1)$ df, where n is the number of lizard home ranges used in the equation and I is the number of habitats tested; in our case, two.

We also compared habitat use by comparing home-range sizes and average daily distances moved of males and females in three areas with different habitats: One area was dominated by shrubs, another with few shrubs, and the third with shrub cover restricted to two washes (see above). We only used data for 2004 because no lizards were tagged in shrub-dominated habitat in 2003. The only lizards with home ranges that did not contain shrubs were four males. Transformations did not normalize the size or distance data for the habitat comparisons, so we used Kruskal-Wallis followed by Mann-Whitney tests of pairwise comparisons (P values adjusted with the use of the method of Legendre and Legendre, 1998), to compare the sizes of home ranges and average distances moved of males and females in areas dominated by shrubs, few shrubs, and shrubs restricted to washes. We treated each combination of the two factors as a separate group and analyzed all five groups (there were no females in areas devoid of shrubs) in single separate analyses for home-range size and distance moved.

RESULTS

For each of 32 *G. sila* radiocollared in 2003, we obtained 25 or more locations to calculate home ranges for 13 males and 12 females (Table 1). In 2004, we radiocollared 33 *G. sila* and obtained enough locations for 17 males and 14 females. We located lizards an average of 38.4 ± 1.46 times (range = 25–50) in 2003 and 48.8 ± 1.96 times (25–62) in 2004. We radiocollared the same four male and five female lizards in both 2003 and 2004, and the area of home ranges from one year to the next overlapped by an average of 76.1 ± 6.25% (49.2–91.5%).

The mean LoCoH home-range size of males in 2003 was over twice as large as that of females and almost 2.4 times larger than females in 2004 (Table 1). These differences by sex were significant ($F_{1,52} = 16.53$, $P < 0.001$), but year differences were not significant ($F_{1,52} = 0.520$, $P = 0.474$), and there was no significant interaction of sex and year ($F_{1,52} = 0.230$, $P = 0.630$). The results of home-range comparisons by sex and year for MCP estimates were similar to those for LoCoH (Table 1), with male home ranges being significantly larger than those of females ($F_{1,52} = 7.47$, $P = 0.009$), no difference by year ($F_{1,52} = 0.200$, $P = 0.658$), and no sex × year interaction ($F_{1,52} = 0.100$, $P = 0.754$).

The mean percentage of the home-range overlap between adjacent individuals was 12.7–42.4% across all group comparisons (Table 2), but there were no significant differences by sex ($F_{2,119} = 1.05$, $P = 0.355$), year ($F_{1,119} = 0.900$, $P = 0.344$), or interaction ($F_{2,119} = 0.050$, $P = 0.955$) for the lower-percentage overlaps. Similarly, there were no significant differences by sex ($F_{2,118} = 0.650$, $P = 0.522$), year ($F_{1,118} = 1.50$, $P = 0.223$), or interaction ($F_{2,118} = 1.45$, $P = 0.238$) for the higher-percentage overlaps. The number of adjacent lizards overlapping each other ranged from zero to eight (Table 2), but there were no significant differences in the number of overlaps for either 2003 ($F_{3,46} = 1.57$, $P = 0.210$) or 2004 ($H = 2.56$, df = 3, $P = 0.464$).

TABLE 2. Sample size (*n*), mean, standard error (SE), and range of the low and high (see methods) percentage overlap and the number (No.) of overlaps based on the minimum convex polygon home ranges of Blunt-nosed Leopard Lizards (*Gambelia sila*) in 2003 and 2004 at the Lokern study site in the southern San Joaquin Desert of California. Comparisons are for males (M) and females (F), and for the number of overlaps, M–F is the number of home ranges of females that overlap an individual male and F–M is the reverse.

	2003				2004			
Group	*n*	Mean	SE	Range	*n*	Mean	SE	Range
Low % overlap								
M–M	13	17.9	3.94	0.14–50.0	13	21.3	3.78	1.82–43.6
F–F	19	12.7	2.26	0.41–33.8	11	15.7	3.61	2.96–43.1
M–F	42	17.7	2.25	1.00–71.7	27	21.0	3.30	0.11–57.2
High % overlap								
M–M	13	40.8	6.11	0.14–78.5	13	38.2	6.11	4.48–84.6
F–F	19	23.1	4.99	0.76–90.3	11	42.4	6.99	8.68–82.8
M–F	42	39.0	4.28	1.54–100	27	40.1	5.79	0.18–100
No. overlaps								
M–M	13	2.0	0.45	0–5	18	1.4	0.28	0–4
F–F	12	3.1	0.61	0–8	13	1.7	0.26	0–3
M–F	13	3.2	0.54	0–6	18	1.5	0.33	0–5
F–M	12	3.5	0.51	1–7	13	2.1	0.29	1–4

On average, male *G. sila* moved about 100 m from one day to the next, whereas females moved about 65 m (Table 3). These differences were significant ($F_{1,52} = 22.5$, $P < 0.001$), but year ($F_{1,52} = 0.490$, $P = 0.487$) or sex × year interaction ($F_{1,52} = 0.480$, $P = 0.490$) were not significant. The mean greatest distance moved varied by sex and year, but were not significantly different by sex ($F_{1,52} = 1.37$, $P = 0.248$), year ($F_{1,52} = 0.180$, $P = 0.675$), or interaction ($F_{1,52} = 3.06$, $P = 0.086$). The longest 1-day move for a male was twice the average greatest distance moved and for females was almost three times the average (Table 3).

In both 2003 and 2004, *G. sila* showed preference for the saltbush habitat in the two washes (2003: $\chi^2 = 92.23$, df = 20, $P < 0.001$; 2004: $\chi^2 = 85.37$, df = 17, $P < 0.001$). There was an increasing trend, however, in the size of home ranges from habitats dominated by shrubs to that with shrubs restricted to washes to that with few shrubs (Table 4), and this trend was significant ($H = 7.99$, df = 3, $P = 0.046$). With adjusted *P* values because of multiple comparisons, however, no pairwise comparisons were significant. The average distance moved by lizards differed by sex and amount of shrub cover (Table 4), which were significantly different ($H = 16.40$, df = 4, $P = 0.003$). These differences also were based on sex differences, with males in the shrub-dominated area moving significantly more than females in shrubs in washes ($W = 87.0$, $P = 0.043$ adjusted).

TABLE 3. Sample size (*n*), mean, standard error (SE), and range of the average and greatest distance moved (m) between consecutive days by Blunt-nosed Leopard Lizards (*Gambelia sila*) in 2003 and 2004 at the Lokern study site in the southern San Joaquin Desert of California.

	2003				2004			
Type/sex	*n*	Mean	SE	Range	*n*	Mean	SE	Range
Average								
Male	14	97.4	9.50	34.1–168.1	17	108.4	7.24	58.6–150.3
Female	12	65.5	6.46	33.4–102.4	14	65.5	7.47	33.3–129.1
Greatest								
Male	14	271.5	26.8	105–521	17	316.1	29.9	182–615
Female	12	295.0	39.1	135–545	14	230.8	36.8	97.0–642

TABLE 4. Sample size (*n*), mean, standard error (SE), and range of the size of LoCoH home ranges (ha) and average distance moved (m) of Blunt-nosed Leopard Lizards (*Gambelia sila*) in which home ranges were in a shrub-dominated area (SDA), an area with shrubs in washes (SW), or an area devoid of shrubs at the Lokern study site in the southern San Joaquin Desert of California.

	Male				Female			
Shrub	*n*	Mean	SE	Range	*n*	Mean	SE	Range
Size								
SDA	7	7.02	0.70	3.73–8.77	5	4.80	1.08	1.44–8.04
SW	6	8.05	4.34	2.02–29.5	9	2.26	0.82	0.62–8.50
None	4	8.05	1.63	3.97–11.3	0	–	–	–
Distance								
SDA	7	121.7	8.11	97.6–150.3	5	80.0	9.15	45.9–97.9
SW	6	86.93	12.9	58.6–132.4	9	57.5	9.76	33.3–129.1
None	4	117.5	13.5	84.0–146.0	0	–	–	–

DISCUSSION

Influence of Methods on Results.—How *G. sila* use space is an important aspect of developing and implementing successful management actions for this endangered species. We think our spatial results for this species are more robust than the two previous studies (Tollestrup, 1983; Warrick et al., 1998). We also think the methods and results of our study are important in terms of developing management actions, including for other species of vagile and diurnal lizards.

Our results are superior to the previous studies because technology and the science of home-range analysis has become more rigorous than it was 30 y ago. Tollestrup (1983) relied on visual observations of marked *G. sila* that resulted in very useful insights into behavior and social structure, but it is not clear if the movement patterns of the observer influenced the size and shape of the home-range estimates. Radiotracking, as used by Warrick et al. (1998), largely eliminated potential sampling bias, but we are concerned that weight (9 g) and size of the radiocollars and the short life of the batteries they used (15 d), may have influenced the results. Because we also suspect the plastic cable-tie collars used by Warrick et al. (1998) may have influenced the behavior of the tagged lizards, we used beaded chain collars (Harker et al. 1999). The chains were lightweight, easily adjusted to the neck of *G. sila*, and did not chafe the skin of the animal, even after 23 mo on one animal that was not recovered until after the study concluded. We recommend the use of beaded chain to attach transmitters to any lizard with a similar neck configuration.

In neither of the previous studies of *G. sila* (Tollestrup, 1983; Warrick et al., 1998) is it clear if all the individuals within the study sites were tagged. This raises concerns about the validity of overlap results, especially as it relates to trying to understand the social structure of *G. sila* better (Tollestrup, 1983). Unfortunately, our study suffered from the same problem. Overlaps also are influenced by the method of estimating home-range size and hence, for comparative purposes, we calculated overlap based only on 100% MCP home ranges.

The number of animals radiotracked and the study period, among other variables, likely will impact the resulting home-range estimates (Kenward, 2001). Both of the previous studies of *G. sila* home ranges (Tollestrup, 1983; Warrick et al., 1998) were based on comparatively few tagged individuals over short periods of time, which we think resulted in underestimating home ranges (see below). Because of the importance of understanding how much space *G. sila* uses during their entire period of activity, as well as their site fidelity between seasons, we think our home-range estimates will be more useful in understanding their space needs, and then implementing habitat and species conservation plans.

Home-Range Areas.—Male *G. sila* had significantly larger home ranges than females, averaging more than twice the size of a female's home range. This was expected because territorial males defend areas to have access to one or more females (Montanucci, 1965; Tollestrup, 1983). Despite average differences, there were females with above-average LoCoH home ranges of 9.2 ha in 2003, and 8.0 and 8.5 ha in 2004, although 80% of female home ranges were <5.0 ha. One male had a LoCoH home-range size of 29.5 ha in 2004, and another 13.7 ha in 2003, but 86.7% of male home ranges were <9.0 ha. We do not know why a few lizards had these large home ranges. There were no obvious habitat reasons for such large sizes and all lizards we tracked were adults between 104 and 110 mm SVL. Home-range size (as well as overlap, see below) may be related to the density of lizards and their sex ratios at any time, but unfortunately, we were unable to radiotag all the lizards in our study area due to the shortage of radio transmitters.

Pixley National Wildlife Refuge, located about 60 km northeast of our study area, contains mainly annual grassland interspersed with strips of seepweed (*Suaeda nigra*) shrubs. Based on visual searches during a 30-d period at this site, Tollestrup (1983) estimated the average MCP size of home ranges of males ($n = 10$) in 1976 as 0.21 ha and that of females ($n = 7$) as 0.10 ha. Importantly, these home-range estimates were based on only 5–20 locations. These estimates are remarkably smaller than ours, probably for the various factors discussed above. Warrick et al. (1998) used radiocollared lizards to estimate home-range sizes in the Buena Vista Valley, about 15 km southeast of our study area. The site is similar to our site, with nonnative grasses and forbs and sparse shrub cover. They radiotracked at one site in 1982 and at another site in 1984, and estimated the average MCP home-range size of males ($n = 11$) as 4.24 ha and that of females ($n = 5$) as 2.02 ha. These data were based on 16 to 79 ($\text{mean}_{\text{males}} = 36.7$, $\text{mean}_{\text{females}} = 34.0$) locations per lizard during study periods of 73 and 85 d. In comparison, our MCP estimate of the average size of a male home range was 8.61 ha (average of 2003 and 2004), which is significantly larger than that estimated by Warrick et al. (1998; one-sample $t_{30} = 4.12$, $P < 0.001$). Similarly, our estimate of average female home ranges was 5.18 ha (average of 2003 and 2004), also significantly larger (one-sample $t_{24} = 2.55$, $P = 0.018$) than that of Warrick et al. (1998). These differences likely are caused by the biases discussed above.

Home-Range Overlaps and Long-Distance Movements.—The amount of overlap of the home ranges of our males was low (17.9–40.8%), indicative of the territoriality documented mainly by Tollestrup (1983). This overlap was not significantly different from the amount of overlap of females with females or males with females. The values we found were similar to those reported by Tollestrup (1983) and Warrick et al. (1998), even though it is not clear what impact the different field methods had on this metric (see discussion above).

Gambelia sila are predatory lizards, which likely explains the relatively long distances they moved daily. No other studies have reported on the length of average daily movements of *G. sila*, but the average greatest distances moved daily by male lizards in the Buena Vista Valley study was 228.1 (1982) and 384.0 m (1984) and for females it was 180.3 m for combined years (Kato et al., 1987). These values, although not directly comparable to our data, are similar to what we found.

Early studies indicate that dense shrub cover harbors few *G. sila* (Montanucci, 1965), and lizards also avoid dense herbaceous vegetation (Warrick et al., 1998; Germano et al., 2012); however, some cover from *Atriplex* shrubs, concentrations of rodent burrows, and variable topography associated with washes, may be beneficial, especially in avoiding predation (Warrick et al., 1998). Our data suggest that presence of shrubs did not appreciably affect the size of home ranges or the daily distances that lizards moved in these habitats, but we did find that if both open and shrub areas were available to *G. sila*, then more area of a home range than expected included shrub habitat. We caution, however, against concluding that shrub habitats are a necessary component for *G. sila*, because neither home-range size nor distances moved by lizards in different habitats changed in completely open areas, and there are many large areas in the southern San Joaquin Desert, including our study site, that have virtually no shrubs but harbor robust populations of *G. sila*. The presence of burrows of kangaroo rats (*Dipodomys* spp.) likely is sufficient to provide cover for *G. sila*; therefore, restoration of areas to support *G. sila* may not need stands of shrubs, which can greatly reduce the costs of these management efforts. That said, more research into the potential benefits of low to moderate shrub cover is warranted.

Home-range sizes, distances moved, and the influence of shrubs have important management implications. *Gambelia sila* need relatively large areas to sustain even a moderate population. There are many small patches of habitat remaining on the floor of the San Joaquin Valley (Germano et al., 2011), but it may take blocks of ≥500 ha to sustain a population. In fact, a logistic regression of patch size in the valley showed that there was only a 4.1% chance of *G. sila* occurring on a habitat patch ≤100 ha, a 14.3% chance of occurrence at 200 ha, a 56.0% chance at 350 ha, and a 90.7% chance of occurrence at 500 ha (Bailey and Germano, 2015). *Gambelia sila* populations in small patches (e.g., <100 ha), with their long daily movements, probably encounter high-risk areas (e.g., agriculture, roads) more easily, which can lead to their deaths. Only a few years may be required until all lizards become extirpated in small habitat patches that have high amounts of edge, as lizards are killed moving into unsuitable habitat.

We suggest that management actions involving *G. sila* and their habitat take into account their large home ranges and movement distances. Populations probably need at least 500 ha of protected habitat, which ideally should be characterized by open substrates (i.e., minimal exotic annual grasses). Although *G. sila* do construct their own burrows, including areas that harbor populations of burrowing rodents to provide additional shelter for the lizards, as well as a mosaic of features that include washes and patches of native bushes, as discussed above, may be beneficial. Target relocation and translocation sites should be carefully chosen if moving animals is contemplated (IUCN, 1998). Given the large home ranges and long movements of *G. sila*, we suggest allowing ≥2 km from a source population to discourage individuals from homing, and also include ≥1-km buffer zone from roads and unsuitable habitat (including urban areas with domestic cats) that could lead to local population extirpation.

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