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POPULATION STATUS AND HABITAT AFFINITIES OF THE BLAINVILLE'S HORNED LIZARD (*PHRYNOSOMA BLAINVILLII*) AT A SITE IN THE NORTHERN SAN JOAQUIN VALLEY, CALIFORNIA, USA

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Abstract.—**North American horned lizards (genus *Phrynosoma*) are in decline throughout their ranges, primarily as a result of human activities. This study documents baseline information for a population of Blainville's Horned Lizards (*Phrynosoma blainvillii*) on a federal wildlife refuge in the San Joaquin Valley of California, USA. Transects at six localities within the refuge were sampled on 16 dates over fall 2009 and spring 2010, and I encountered 145 individual lizards. I used mark-recapture data to calculate a Jolly-Seber estimate of population size of 566 (408–749) lizards (235.9 lizards/ha) in the combined surveyed areas, or 554 (400–735) lizards (277.1 lizards/ha) when the single transect that yielded only two lizards was excluded. Although the juvenile sex ratio was skewed to males, the adults showed a 1:1 ratio of males and females. Adult females were larger than males by 5.3 mm, on average. Significantly more lizard captures were made in the spring compared to the fall sampling dates, and significantly more lizards were found on transects with sandy loams and loamy sands and a combination of open space and vegetative cover. My data suggest a robust age-structured population. The refuge is currently managed for use by migrating waterfowl, and both grazing and prescribed burns have been utilized to control non-native grasses. I urge continued monitoring of the Blainville's Horned Lizard population and use of appropriate vegetation control to maintain open spaces and native vegetation for use by these lizards.**

Key Words.—Blainville's Horned Lizard; conservation; management; *Phrynosoma blainvillii*; population status

INTRODUCTION

North American horned lizards (*Phrynosoma* spp.) have been reported to be in decline throughout their ranges (Turner and Medica 1982; Price 1990; Beauchamp et al. 1998). Documented factors contributing to these declines are varied, but the majority relate to human activity. Development of natural lands for urbanization has resulted in fragmentation and loss of suitable habitat (Beauchamp et al. 1998; Germaine and Wakeling 2001; Mulcahy et al. 2006; Barrows et al. 2008), direct mortality on roads (Turner and Medica 1982; Donaldson et al. 1994), and depredation by domesticated animals (Hayes and Guyer 1981; Audsley et al. 2006). Agriculture has had an impact through the displacement of suitable habitat (Fair and Henke 1997) and habitat degradation from both livestock grazing (Lovich and Bainbridge 1999; Galina-Tessaro et al. 2002) and pesticide use (Price 1990; Donaldson et al. 1994). Furthermore, human disturbance has also contributed to the success of non-native ants, including the Argentine Ant (*Linepithema humile*) and the Red Imported Fire Ant (*Solenopsis invicta*), both of which displace native harvester ants (e.g., *Pogonomyrmex* and *Messor*) that comprise the preferred diet of horned lizards (Turner and Medica 1982; Suarez et al. 1998, 2000; Suarez and Case 2002; Sherbrooke 2003), and the latter which directly attacks and consumes both eggs and neonate lizards (Sherbrooke 2003). Natural predators of horned lizards (e.g., Greater Roadrunner, *Geococcyx californianus*) also show enhanced presence near human developments, increasing their impact on lizard populations (Audsley et al. 2006). Off-road vehicle use contributes to degradation of habitat through soil compaction and reduction of vegetation (Lovich and Bainbridge 1999) and may result in direct mortality of subterranean lizards (Stebbins 1995). Direct mortality through collection for both the pet and curio trades (Klauber 1939) has also contributed to the decline of these species (Jennings 1987; Jennings and Hayes 1994).

Recently, Leaché et al. (2009) separated the *Phrynosoma coronatum* complex into three species: *P. coronatum*, *P. cerroense*, and *P. blainvillii*. This paper focuses on *P. blainvillii*, Blainville's Horned Lizard, which is distributed from Northern Baja California through Northern California (Leaché et al. 2009) in arid climates at localities with sandy soils. For all citations of studies on *P. coronatum* in the range that now comprises *P. blainvillii*, these lizards will simply be referred to as Blainville's Horned Lizard.

Blainville's Horned Lizard, listed as *P. coronatum blainvillii*, is a California Species of Special Concern (California Department of Fish and Game. 2009. Available from http://www.dfg.ca.gov/wildlife/nongame/ssc/amphibian-reptile.html. [Accessed 12 November 2009]). There is evidence of a decrease in

numbers of populations and in the overall the geographic distribution for the species (Jennings and Hayes 1994; Hollingsworth and Hammerson 2007). While the Blainville's Horned Lizard has broader diet (Suarez and Case 2002) and habitat tolerances (Sherbrooke 2003) than many other horned lizard species, loss of habitat due to human activity (Jennings and Hayes 1994), the prevalence of non-native ants (*Linepithema humile*; Suarez et al. 1998; Suarez et al. 2000; Fisher et al. 2002; Suarez and Case 2002), and direct collection (Klauber 1939; Jennings 1987; Jennings and Hayes 1994) have been major contributors to its diminishing numbers (Fisher et al. 2002; Hollingsworth and Hammerson 2007).

The historic and current distributions of the Blainville's Horned Lizard in the San Joaquin Valley of California are poorly documented. Montanucci (1968) observed this lizard in both Fresno and Merced counties, but did not report a thorough census. A query of the HerpNET data portal (Available at http://www.herpnet.org) on 5 January 2011, searching for all records of *Phrynosoma coronatum* and *Phrynosoma blainvillii* for the eight counties of the San Joaquin Valley (San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulare, Kern), including all 55 participating institutions, yielded only 345 specimen records, collected from 1879 to 2002 (for those with reported collection dates) held in 10 institutions (California Academy of Sciences; Amphibian and Reptile Collection, University of Arizona; Cornell University Museum of Vertebrates; James R. Slater Museum, University of Puget Sound; Museum of Comparative Zoology, Harvard University; Museum of Vertebrate Zoology, University of California, Berkeley; Natural History Museum of Los Angeles County; San Diego Natural History Museum; Smithsonian National Museum of Natural History; University of Kansas Natural History Museum and Biodiversity Research Center). Only 18 of these specimens represent locality records for Merced County, the region represented by this study.

This study presents baseline information for a protected population of Blainville's Horned Lizards in Merced County, California. Blainville's Horned Lizards were repeatedly observed by United States Fish and Wildlife Service (USFWS) employees at the Arena Plains Unit of the Merced National Wildlife Refuge (Rich Albers, pers. comm.). Other than preliminary surveys performed by the author, no previous studies have been made of the population at this location. The primary objective of this study was to document size and structure of the population of Blainville's Horned Lizards on this federal refuge. The secondary objective was to characterize the habitat affinities of the lizards at this locale, providing information critical to management of the property for the continued success of this population.

MATERIALS AND METHODS

Description of study area.—The Arena Plains Unit of the Merced National Wildlife Refuge (NWR) in Merced County, California is located in the San Joaquin Valley of California, between the California Coast Range and the Sierra Nevada (Fig. 1). The 997 ha refuge is managed for use by migrating waterfowl and is

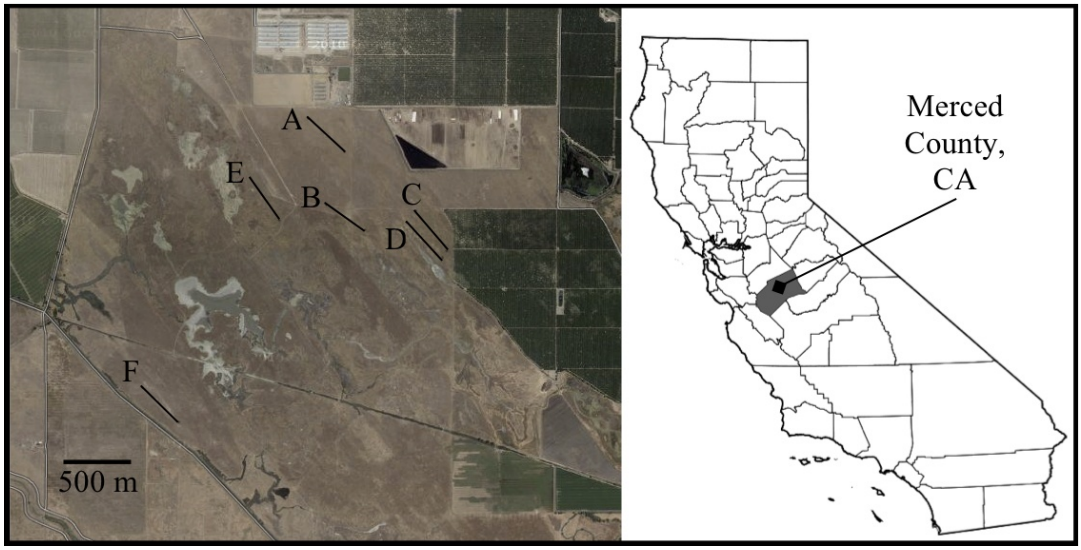

FIGURE 1. Map of the Arena Plains Unit of the Merced National Wildlife Refuge, Merced County, California, USA showing the locations of six survey transects.

characterized by wetlands, vernal pools, and both native and non-native forbs and grasses. Low dune systems are located in the northern and southern parts of the refuge, and mounds made by the burrowing activities of California Ground Squirrels (*Spermophilus beecheyi*) provide additional topographical relief. These elevated features exhibit a mix of native and non-native vegetation (Table 1). Soil types on the Arena Plains include clays, loams, and sands; most of the soils have saline-alkali characteristics (USFWS, unpubl. map).

The Arena Plains Unit of the Merced NWR was obtained by the USFWS in 1992, prior to which time it was operated as a cattle ranch (Silveira 2000). The Arena Plains is closed to the public, and there is very little traffic on the small number of unimproved dirt roads on the refuge. Current management practices include irrigation to maintain wetland habitat through winter and spring, and both periodic controlled burns of isolated areas and grazing by cattle to maintain the upland grassland habitats.

Sampling techniques.—I performed transect sampling at six sites within the refuge (Fig. 1; Table 1). Each strip transect measured 400 X 10 m. I selected a breadth of habitats at the Arena Plains to survey, including areas known to have Blainville's Horned Lizards and adjacent areas in which lizards had not previously been observed. Soils included clay and loamy sands and elevations ranged from 28–32 m above sea level. Vegetation in the lower elevations consisted primarily of non-native grasses; native forbs were abundant on dunes and ground squirrel mounds.

The order in which I surveyed transects on each visit was randomized. Each transect survey involved active searching for lizards for one person-hour. Only those lizards present on the surface were detectable, and detectability extended to approximately 2 m outside the edge of the transect strip. It is possible, given the cryptic coloration of these animals, that some lizards were undetected although present on the surface; any lizards below the substrate would not have been detected by visual searching. To sample every transect on each visit, I surveyed in fall and spring, when Blainville's Horned Lizards exhibit activity on the surface throughout the day (Hager and Brattstrom 1997; Fisher et al. 2002; unpubl. data); I performed surveys between 20 September and 7 November 2009 (fall) and again between 14 March and 23 May 2010 (spring). All surveys took place during daylight hours and air temperatures between 20–36º C.

Lizard data collection.—I hand captured all Blainville's Horned Lizards located during transect surveys. I collected standard morphological data: snout-to-vent length (SVL), tail length (TL), and weight (WT) using a 30 g or 60 g Pesola® spring scale (Pesola AG, Baar, Switzerland), depending on the size of lizard. I determined sex by visual examination for the presence of enlarged postanal scales on males. I scored a lizard as an adult if SVL ≥ 65 mm; this differs from Howard (1974) and Pianka and Parker (1975) whose dissection-based work in other parts of the range found sexually mature Blainville's Horned Lizards at a minimum of SVL of 61 mm and 73 mm, respectively. Rather than take the mean of the sizes reported by these authors, I selected 65 mm on the basis that on the Arena Plains, males of this size typically display swollen tail bases in the spring, and I have palped females of this size and felt developing eggs. If SVL was > 50 mm, I fitted the lizard with a unique 9 mm, 134.2 kHz radio frequency identification (RFID) tag (Biomark Inc., Boise, Idaho, USA) for future identification. I inserted RFID tags subcutaneously on the left margin of the dorsum using a MK-7 applicator (Biomark Inc., Boise, Idaho, USA) and the application site was sealed using New-Skin Liquid Bandage (Prestige Brands, Inc., Jackson, Wyoming, USA). All lizards were provided an external color marking using a Sharpie® marker (Sanford Corporation,

TABLE 1. The elevation, topography, soil composition, and vegetation of six 400 m x 10 m transects surveyed for Blainville's Horned Lizards (*Phrynosoma blainvillii*) on the Merced National Wildlife Refuge in California.

Transect	Coordinates Start	Coordinates End	Elevation Range	Soil Type	Description
A	N 37.28698° W 120.71918°	N 37.28455° W 120.71586°	30.8–32.0 m	Loamy fine sand and loamy sand	Dune and non-native grassland
B	N 37.28081° W 120.71753°	N 37.27905° W 120.71408°	29.7–30.0 m	Loamy fine sand and loamy sand	Dirt road through non-native grassland
C	N 37.28040° W 120.70956°	N 37.27757° W 120.70680°	31.0 m	Loamy fine sand	Dune with native vegetation
D	N 37.27961° W 120.71037°	N 37.27707° W 120.70716°	30.3–31.0 m	Clay	Non-native grassland
E	N 37.28271° W 120.72428°	N 37.27975° W 120.72169°	29.0 m	Loam and loamy sand	Ground squirrel mounds, non-native grass, vernal pools
F	N 37.26786° W 120.73389°	N 37.26540° W 120.73062°	28.0–29.0 m	Loamy sand	Dune with native vegetation and non-native grassland

Oak Brook, Illinois, USA) unique to the sampling date to minimize the overestimation of total numbers of lizards in the case of recapture in a single season. At each lizard-capture locality, I measured the surface temperature using a Raytek MiniTemp MT4 infrared thermometer (Raytek Corp., Santa Cruz, California, USA) and I collected a geographic positioning system (GPS) coordinate using a handheld Garmin GPS V (Garmin International, Olathe, Kansas, USA). Each lizard was subsequently released at its original location.

Soil and elevation data.—I determined soil type and elevation for each transect (Table 1). Classification of soil type at each transect was derived from USFWS data. I derived elevation ranges for each transect from the United States Geological Survey National Elevation Dataset using GPS Visualizer (Schneider, A. 2010. GPS Visualizer. Available from http://www.gpsvisualizer.com [Accessed 3 January 2011]).

Data analysis.—I tested morphological and encounter data for normality and homoscedasticity prior to analysis; no transformations of the data were necessary. I tested for differences in the numbers of lizards found by sampling date using ANOVA and tested for differences in lizard encounter rate per sampling day between fall and spring sampling using a Student's t-test (two-tailed). I used recapture data to estimate an average population size for the total area represented by the six transects using the Jolly-Seber method (Jolly 1965; Seber 1965; Greenwood and Robinson 2006). The Jolly-Seber estimate was designed for use in open systems and was well-suited to this study: the study took place over an extended time frame (8 mo) and it was possible for individual lizards to move in or out of the transect areas between sampling dates, and deaths and births occurred during the study. I took the average of the Jolly-Seber estimates for the last four survey dates to produce a single tentative metric of lizard abundance. I chose the last four dates because they fell within a short (23 d) time frame during which surveys were made weekly, they exhibited some stabilization of the estimate, and they were the estimates which included the greatest quantity of sampling data. I also tested for differences in the SVL of adult males versus that of adult females using a Student's t-test (two-tailed). The proportion of male versus female juveniles captured was compared using a Chi-square analysis. I compared the number of adult and juvenile lizards found on each transect using ANOVA. I used SPSS 16.0 statistical software (IBM Corp, Somers, New York, USA) to conduct analyses with the exception of the Jolly-Seber estimates, which I performed following Greenwood and Robinson (2006). For all tests, $\alpha = 0.05$.

RESULTS

I surveyed each transect seven times in the fall and nine times in the spring, for a total of 16 person-hours of survey time per transect. I encountered lizards on all six transects for a total of 163 captures of 145 individual Blainville's Horned Lizards. The average encounter rate was 1.7 lizards/person/h. The numbers of lizards found varied by date ($F_{15,63} = 2.55$, $P = 0.008$; Table 2), with significantly more lizards encountered per sampling day in the spring ($t = 3.89$, df = 14, $P = 0.0016$). I fitted 95

TABLE 2. Dates of transect surveys and numbers of male, female, and juvenile Blainville's Horned Lizards (*Phrynosoma blainvillii*) captured at the Merced National Wildlife Refuge in California. Individuals < 65 mm in snout-to-vent length were classified as juveniles.

Survey Date	Adult Male	Adult Female	Juvenile Male	Juvenile Female	Total
20 September 2009	0	0	0	2	2
26 September 2009	0	0	2	2	4
3 October 2009	0	0	1	1	2
17 October 2009	0	0	6	1	7
24 October 2009	0	0	4	2	6
1 November 2009	0	0	4	3	7
7 November 2009	0	0	0	3	3
14 March 2010	1	0	1	2	4
21 March 2010	0	2	11	8	21
28 March 2010	3	2	7	6	18
17 April 2010	4	3	5	2	14
24 April 2010	4	6	4	1	15
1 May 2010	4	2	4	1	11
8 May 2010	2	7	2	4	15
15 May 2010	1	4	3	0	8
23 May 2010	9	3	10	4	26
TOTALS	28	29	64	42	163

TABLE 3. Jolly-Seber estimates of the number (N) and density of Blainville's Horned Lizards (*Phrynosoma blainvillii*) in the population on the Merced National Wildlife Refuge, with standard errors (SE) and 95% confidence intervals. I made estimates beginning with the second survey date, both including and excluding transect D (see Methods).

	Transect D included				Transect D excluded			
Survey date	N	SE	95% C.I.	Lizards /ha	N	SE	95% C.I.	Lizards/ha
26 Sep 2009	10	7.07	0–23.9	4.2	10	7.07	0–23.9	5.0
3 Oct 2009	18	5.66	6.9–29.1	7.5	18	5.66	6.9–23.9	9.0
17 Oct 2009	32	11.14	10.2–53.8	13.3	32	11.14	10.2–53.8	16.0
24 Oct 2009	84	33.27	18.8–149.2	35.0	84	33.27	18.8–149.2	42.0
1 Nov 2009	76	33.91	9.53–142.5	31.7	76	33.91	9.5–142.5	38.0
7 Nov 2009	100	37.98	25.6–174.4	41.7	100	37.98	25.6–174.4	50.0
14 Mar 2010	70	35.24	0.93–139.1	29.2	70	35.24	0.9–139.1	35.0
21 Mar 2010	620	202.15	223.8–1016.2	258.3	620	202.16	223.8–1016.2	310.0
28 Mar 2010	800	293.59	224.6–1375.4	333.3	800	293.59	224.6–1375.4	400.0
17 Apr 2010	161.2	277.09	0–704.3	67.2	161.2	277.09	0–704.3	80.6
24 Apr 2010	770	314.54	153.5–1386.5	320.8	630	293.49	54.8–1205.2	315.0
1 May 2010	440	304.92	0–1037.6	183.3	429	285.30	0–988.2	214.5
8 May 2010	667.5	312.54	54.9–1280.1	278.1	652.5	294.82	74.7–1230.3	326.3
15 May 2010	408	301.77	0–999.5	170.0	400	284.96	0–958.5	200.0
23 May 2010	749	312.66	136.2–1361.8	312.1	735	297.51	151.9–1318.1	367.5

individuals with RFID tags. During the study, I recaptured four individuals with RFID tags and an additional 14 individuals with temporary color markings from the fall or spring transect sampling.

Population characteristics.—Total population size in the area of all transects combined varied by sampling date (Table 3). The population size average for the final four survey dates was 566 (408–749 lizards), or 235.9 lizards/ha in the surveyed area. When transect D, which yielded only two lizards on one date, was excluded from the analysis, the population size average for the final four survey dates was 554 (400–735 lizards), or 277.1 lizards/ha in the area of the remaining transects. Line plots of the Jolly-Seber estimates, both including and excluding transect D, constructed by averaging each point with the immediately previous point, indicate that the population estimates were converging on a value

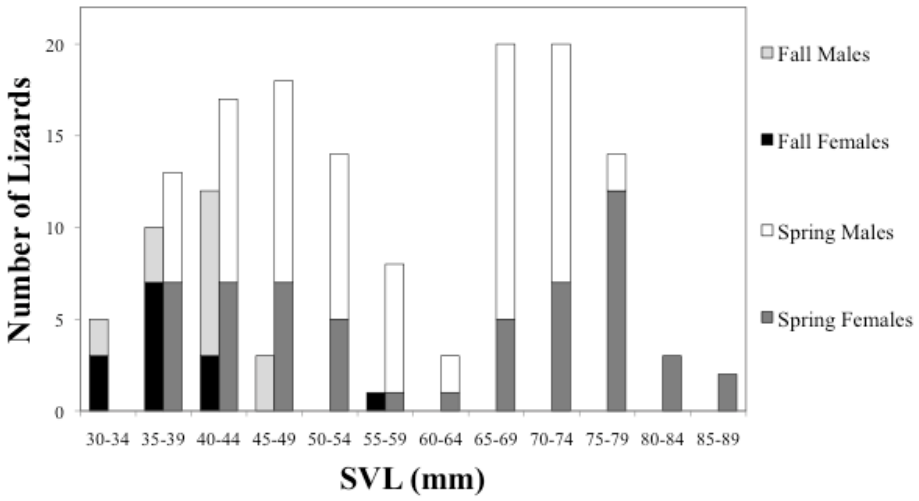

FIGURE 2. Histogram of sizes of male and female Blainville's Horned Lizards (*Phrynosoma blainvillii*) found in fall 2009 and spring 2010 surveys on the Arena Plains Unit of the Merced National Wildlife Refuge, Merced County, California, USA.

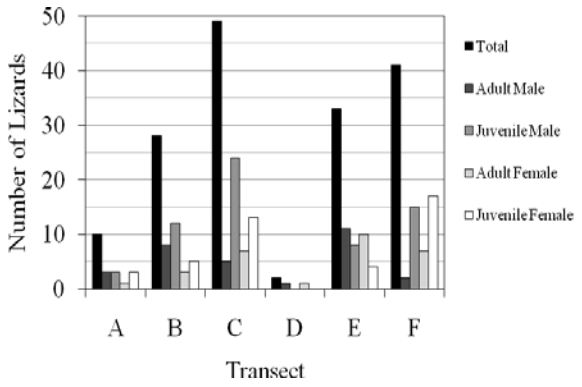

FIGURE 3. Number of adult and juvenile male and female Blainville's Horned Lizards (*Phrynosoma blainvillii*) found by transects on the Arena Plains Unit of the Merced National Wildlife Refuge, Merced County, California, USA.

between 400–500 lizards. There were equivalent numbers of adults of both sexes (28 males and 29 females; Table 2); however, the sex ratio of juveniles was significantly skewed to males (64 males:42 females, or 1.5:1; χ^2 = 4.57, df = 1, P = 0.033). Body sizes ranged from SVL 31–87 mm (Fig. 2). Average adult male body size (69.8 mm SVL; range 65–75 mm) was significantly smaller than that of females (75.1 mm SVL; range 66–87 mm; t = 4.55, df = 52, P < 0.001).

Transect associations.—Surface substrate temperatures where I captured lizards ranged from 27–63º C. The vegetation on transects A, C, E, and F was characterized as a mix of native and non-native forbs and non-native grasses. On transects B and D, non-native grasses predominated with few forbs present. The total number of lizards I encountered varied by transect ($F_{5,23}$ = 3.30, P = 0.027). The greatest number of lizards I found was on transect C (49 lizards), and the fewest on transect D (2 lizards; Fig. 3). The proportions of adult and juvenile males and females significantly differed between transects (χ^2 = 30.70, df = 15, P < 0.001).

DISCUSSION

The low number of recaptured lizards in this survey resulted in a population size estimate that is somewhat unreliable. Difficulty in detecting cryptic animals can also lead to poor estimates of population size (Grant and Doherty 2007). During my surveys, Blainville's Horned Lizards may have been out of sight below the surface in burrows or under the sand, on the surface in the center of dense shrubs, or hidden from detection in the dappled shade of vegetation. I did not notice any difference in detectability between adults and juveniles, but further study to validate this observation is warranted. Correction factors for lizards missed during surveys are not available for incorporation into population size estimates; however, a failure to detect all individuals present would have led to an underestimate of the number of lizards, making my population size estimates of 566 (408–749) lizards/2.4 ha, or 554 (400–735) lizards/2.0 ha when excluding transect D, conservative. As there are not published estimates of population density of Blainville's Horned Lizards from other sites, it is difficult to say how the population at the Arena Plains compares to those in other parts of the range. Daily surveys over the course of one to two weeks from late March through May, the time frame during which the greatest numbers of lizards were encountered, would likely result in greater numbers of recaptures and a more robust estimate of population size. It should be noted that while additional habitat exists in the proximity of the transects I surveyed, there are not other areas on the Arena Plains where horned lizards have been regularly observed, with the exception of refuge roads. Thus, the total population size on the Arena Plains is not likely to be extraordinarily high.

Nonetheless, the results of this survey suggest a vigorous population, consisting of nearly equal numbers of males and females and with a complex age structure, using the range of lizard SVLs as a proxy for a range of ages. New individuals are being recruited on a yearly basis (unpubl. data from fall 2008 and fall 2010). Hatchlings and juveniles dominated the fall captures, with 96% of lizards discovered between September and November having SVL < 65 mm; while, spring captures included a higher proportion of adults (42.2%). The sex ratio of sampled juveniles is skewed to males (1.5 : 1), but with limited data, is not possible to determine whether this represents a skew in the ratio of males and females at hatching, a difference in juvenile mortality rates, or a difference in surface activity patterns. The sexual size dimorphism previously noted for other horned lizard species (Pigmy Short-horned Lizard, *P. douglasii*; Rock Horned Lizard, *P. ditmarsi*; and Greater Short-horned Lizard, *P. hernandesi*; Zamudio 1998) was apparent in the significantly longer SVL of females compared to males in this population of Blainville's Horned Lizards.

Four of the seven transects I surveyed accounted for 92.7% of the lizards I encountered, with three of these (C, E, and F) each contributing > 20% of the total count. These three transects were in areas with either sandy loam or loamy sand, confirming Montanucci's (1968) assertion that these and alkali soils are key predictors for the presence of Blainville's Horned Lizards in the San Joaquin Valley. This soil type is ecologically important as it provides a substrate in which lizards can burrow with ease; additionally, in the San Joaquin Valley there is little to no precipitation through the summer months, such that these sandy loams do not support the growth of tall perennial vegetation, favoring instead native annuals

and arid-adapted perennials. Furthermore, all three of these transects exhibited either elevated dunes or ground squirrel mounds with sparse vegetation on the crown, in combination with dense grasses off the dunes and mounds. The combined effects of soil type and topography at all three of these transects results in a habitat with low stature vegetation interspersed with open spaces through which Blainville's Horned Lizards can move with relative ease, providing a combination of basking and foraging sites, burrowing locations, and shelter from both sun and predators. Similar to the south Texas study site of Burrow et al. (2001), air temperatures on the Arena Plains often exceed 38° C spring through fall, and I measured surface temperatures greater than 45° C. At these temperatures, Blainville's Horned Lizards were most often found in the shade of small shrubs.

The loamy sands on transect E are interspersed with loam. This was also the only area I surveyed that had a high density of ground squirrel mounds and burrows. Barrows and Allen (2009) demonstrated that the Flat-tailed Horned Lizard (*Phrynosoma mcallii*) requires moderately impacted soil in which burrows can not only be excavated but also maintained without collapse. In my study, the only location in which Blainville's Horned Lizards were observed to use semi-permanent burrows was on transect E, where lizards were observed to escape down ground squirrel burrows on several occasions. Thus, Blainville's Horned Lizards were able to use both sandy loams and pure loam soils.

Transect D, which was characterized by clay soils and dense non-native grasses, yielded only two lizards, despite being adjacent to dune transect C, which yielded the greatest number of lizards overall. This suggests that horned lizards avoided this habitat. It might be contended that difficulty in detecting lizards in this habitat was the reason for the low number observed; however, horned lizards do not move easily through grass, there were no open patches suitable for basking, and clay soils present difficulty for burrowing. It seems unlikely that horned lizards are present but undetected on this transect. The two lizards encountered on transect D were found on a single date, 24 April 2009, and were within 15 m of a small dune that extends into the grassland, potentially explaining their presence.

While soil type appears to be an important predictor for the presence of Blainville's Horned Lizards on the Arena Plains, management practices aimed at controlling the biomass of introduced grasses in the upland habitats may also contribute to the persistence of the lizard population by promoting open habitat patches suited to the movement and basking activities of these lizards. Grazing has been the primary means of controlling the biomass of introduced grasses on the Arena Plains and a controlled burn was conducted on the dune system at transect C on 3 October 2007 (Rich Albers, pers. comm.). Given the difficulty that horned lizards exhibit in moving through dense grass and the relative lack of lizards on transect D, I suggest that Silveira (2000) is well-founded in the assertion that the control of non-native grasses is important for maintenance of horned lizard habitat on the Arena Plains. Experimental manipulation to directly ascertain the impacts of grazing and prescribed burns on both native vegetation and the Blainville's Horned Lizard should be undertaken if the opportunity presents itself. These preliminary data on the Blainville's Horned Lizard suggest that the Arena Plains population has a reasonable likelihood of sustainability in the areas of the refuge that exhibit sandy loam and loam soils. I suggest that population should continue to be monitored and appropriate management techniques applied to maintain the open habitats, environmental heterogeneity, and diet that the lizards require.

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LITERATURE CITED

Audsley, B.W., C.E. Bock, Z.F. Jones, J.H. Bock, and H.M. Smith. 2006. Lizard abundance in an exurban southwestern savanna, and the possible importance of roadrunner predation. American Midland Naturalist 155:395–401.

Barrows, C.W., and M.F. Allen. 2009. Conserving species in fragmented habitats: population dynamics of the Flat-tailed Horned Lizard, *Phrynosoma mcallii*. Southwestern Naturalist 54:307–316.

Barrows, C.W., K.L. Preston, J.T. Rotenberry, and M.F. Allen. 2008. Using occurrence records to model historic distributions and estimate habitat losses for two psammophilic lizards. Biological Conservation 141:1885–1893.

Beauchamp, B., B. Wone, S. Bros, and M. Kutilek. 1998. Habitat use of the Flat-tailed Horned Lizard

(*Phrynosoma mcallii*) in a disturbed environment. Journal of Herpetology 32:210–216.

Burrow, A.L., R.T. Kazmaier, E.C. Hellgren, and D.C. Ruthven, III. 2001. Microhabitat selection by Texas Horned Lizards in southern Texas. Journal of Wildlife Management 65:645–652.

Donaldson, W., A.H. Price, and J. Morse. 1994. The current status and future prospects of the Texas Horned Lizard (*Phrynosoma cornutum*) in Texas. Texas Journal of Science 46:97–113.

Fair, W.S., and S.E. Henke. 1997. Effects of habitat manipulations on Texas Horned Lizards and their prey. Journal of Wildlife Management 61:1366–1370.

Fisher, R.N., A.V. Suarez, and T.J. Case. 2002. Spatial patterns in the abundance of the Coastal Horned Lizard. Conservation Biology 16:205–215.

Galina-Tessaro, P., L.L. Grismer, B.D. Hollingsworth, and A. Ortega-Rubio. 2002. Distribution and conservation of lizards in the Vizcaíno Biosphere Reserve, Baja California Sur, México. Southwestern Naturalist 47:40–55.

Germaine, S.S., and B.F. Wakeling. 2001. Lizard species distributions and habitat occupation along an urban gradient in Tucson, Arizona, USA. Biological Conservation 97:229–237.

Grant, T.J., and P.F. Doherty, Jr. 2007. Monitoring of the Flat-Tailed Horned Lizard with methods incorporating detection probability. Journal of Wildlife Management 71:1050–1056.

Greenwood, J.J.D., and R.A. Robinson. 2006. General census methods. Pp. 87–185 *In* Ecological Census Techniques. 2nd Edition. Sutherland, W.J. (Ed.). Cambridge University Press, Cambridge, UK.

Hager, S.B., and B.H. Brattstrom. 1997. Surface Activity of the San Diego Horned Lizard, *Phrynosoma coronatum* blainvillii. Southwestern Naturalist 42:339–344.

Hayes, M.P., and C. Guyer. 1981. The herpetofauna of Ballona. Pp. H1–H8 *In* The Biota of the Ballona Region, Los Angeles County. Supplement I, Marina Del Rey/Ballona Local Coastal Plan. Schreiber, R.S. (Ed.). Los Angeles County Natural History Museum Foundation, Los Angeles, California, USA.

Hollingsworth, B., and G.A. Hammerson. 2007. *Phrynosoma coronatum*. *In* IUCN 2010. IUCN Red List of Threatened Species. Version 2010.1. <www.iucnredlist.org>. Downloaded on 15 June 2010.

Howard, C.W. 1974. Comparative reproductive ecology of horned lizards (Genus *Phrynosoma*) in southwestern United States and northern Mexico. Journal of the Arizona Academy of Science 9:108–116.

Jennings, M.R. 1987. Impact of the curio trade for San Diego Horned Lizards (*Phrynosoma coronatum blainvillii*) in the Los Angeles Basin, California: 1885–1930. Journal of Herpetology 21:356–358.

Jennings, M.R., and M.P. Hayes. 1994. Amphibian and Reptile Species of Special Concern in California. Final Report. Contract Number 8023. California Department of Fish and Game Inland Fisheries Division, Rancho Cordova, California, USA. 255 p.

Jolly, G.M. 1965. Explicit estimates from capture-recapture data with both death and immigration-stochastic model. Biometrika 52:225–247.

Klauber, L.M. 1939. Studies of reptile life in the arid southwest. Bulletin of the Zoological Society of San Diego 14:1–100.

Leaché, A.D., M.S. Koo, C.L. Spencer, T.J. Papenfuss, R.N. Fisher, and J.A. McGuire. 2009. Quantifying ecological, morphological, and genetic variation to delimit species in the Coast Horned Lizard species complex (*Phrynosoma*). Proceedings of the National Academy of Sciences 106:12418–12423.

Lovich, J.E., and D. Bainbridge. 1999. Anthropogenic degradation of the southern California desert ecosystem and prospects for natural recovery and restoration. Environmental Management 24:309–326.

Montanucci, R.R. 1968. Notes on the distribution and ecology of some lizards in the San Joaquin Valley, California. Herpetologica 24:316–320.

Mulcahy, D.G., A.W. Spaulding, J.R. Mendelson, III, and E.D. Brodie, Jr. 2006. Phylogeography of the Flat-tailed Horned Lizard (*Phrynosoma mcallii*) and systematics of the *P. mcallii-platyrhinos* mtDNA complex. Molecular Ecology 15:1807–1826.

Pianka, E.R., and W.S. Parker. 1975. Ecology of horned lizards: a review with special reference to *Phrynosoma platyrhinos*. Copeia 1975:141–162.

Price, A.H. 1990. *Phrynosoma cornutum*. Catalogue of American Amphibians and Reptiles 469:1–7.

Seber, G.A.F. 1965. A note on the multiple-recapture census. Biometrika 52:249–259.

Sherbrooke, W.C. 2003. Introduction to Horned Lizards of North America. University of California Press, Berkeley, California, USA.

Silveira, J.G. 2000. Vernal pools and relict duneland at Arena Plains. Fremontia 27–28:38–47.

Stebbins, R.C. 1995. Offroad vehicle impacts on desert plants and animals. Pp. 467–480 *In* The California Desert: An Introduction to Natural Resources and Man's Impact, Volume II. Latting, J., and P.G. Rowlands (Eds.). June Latting Books, Riverside, California, USA.

Suarez, A.V., D.T. Bolger, and T.J. Case. 1998. Effects of fragmentation and invasion of native ant communities in coastal southern California. Ecology 79:2041–2056.

Suarez, A.V., and T.J. Case. 2002. Bottom up effects on persistence of a specialist predator: ant invasions and horned lizards. Ecological Applications 12:291–298.

Suarez, A.V., J.Q. Richmond, and T.J. Case. 2000. Prey selection in horned lizards following the invasion of Argentine Ants in southern California. Ecological Applications 10:711–725.

Turner, F.B., and P.A. Medica. 1982. The distribution and abundance of the Flat-tailed Horned Lizard *Phrynosoma mcallii*. Copeia 1982:815–823.

Zamudio, K.R. 1998. The evolution of female-biased sexual size dimorphism: a population-level comparative study in horned lizards (*Phrynosoma*). Evolution 52:1821–1833.

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