INVESTIGATING BLUNT-NOSED LEOPARD LIZARD POPULATION SIZE, DEMOGRAPHICS, SPACE USE, AND FUTURE POPULATION TRENDS ON DEPARTMENT ECOLOGICAL RESERVES

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EXECUTIVE SUMMARY

The blunt-nosed leopard lizard (*Gambelia sila*; BNLL) is a relatively large, predatory lizard that once occurred throughout much of the San Joaquin Valley and adjacent foothill and valley areas, such as the Carrizo Plain, Cuyama Valley, and Panoche Valley. This species currently persists on less than 15% of its historical range, largely due to habitat loss from agricultural development, oil extraction, and urbanization. Despite having endangered status for over 40 years and creating several important protected areas, no current population size estimates or a Population Viability Analysis (PVA) exist for BNLL. In the 1990s, research on BNLL focused on population ecology using plot-based studies on two core areas: the Elkhorn Plain (adjacent to the Carrizo Plain) and Pixley National Wildlife Refuge. While some research from these sites has been published, monitoring efforts were discontinued in the late 1990s. A recent USFWS 5-year review found that BNLL are declining throughout their range and that most recovery goals have not been met. The primary objectives of this project were to provide critical information on BNLL population size, demographic trends, and space use, as well as support development of predictive modeling techniques to inform conservation and management.

We researched population trends and demographic characteristics on three core protected sites for BNLL in the San Joaquin Desert over three years (2015-2017): Lokern Ecological Reserve (ER), Semitropic ER, and Pixley National Wildlife Refuge (NWR). We completed space use research at Semitropic ER and Pixley NWR. In addition to these sites, we also conducted opportunistic surveys at Buttonwillow and Allensworth ERs.

The results of our data on population and demographic trends showed that during the three years of our study, the population structure (distribution of Snout Vent Lengths (SVLs)) at each site did not vary significantly between years. During the short duration of our study, we observed no major fluctuations in rainfall, which likely contributed to the relative stability of BNLL populations at our sites. Between sites, we found the population structure at Pixley differed significantly from both Lokern and Semitropic, but Lokern and Semitropic did not differ significantly from each other. Pixley had higher numbers of hatchling/juvenile lizards each year than Semitropic and Lokern. Thus, large numbers of juveniles and small adults dominated the size distribution each year. In the spring, we typically found more small adults at Pixley than large lizards. Therefore, size parameters, such as mean and upper quartile mean of SVL, Total Length (TL), and mass of lizards at Pixley were in some characteristics significantly smaller than size parameters at Semitropic and Lokern. Clutch size at each site did not differ significantly and was 2.5 eggs/clutch at each site.

Pixley had higher numbers of lizards in both the adult (except 2015) and hatchling seasons than Semitropic and Lokern. Available prey items at Pixley often did not differ from Semitropic and Lokern, with the one exception being grasshoppers during the hatchling season. At Pixley, grasshopper numbers were the same during the adult and hatchling seasons, or increased during the hatchling season, whereas grasshopper numbers often decreased during the hatchling season at Semitropic and Lokern.

Based on the detection data we collected at Semitropic and Pixley via radio telemetry, we estimated mean detection probability at both sites was 0.605, which means that on average

we detected 60% of the lizards that were available for detection during a census. We view this estimate of mean detection probability with caution and consider it a first attempt to calculate detection probability for BNLL. We used the mean detection probability estimate of 0.605 calculate abundance and density at our three monitoring sites. We found that at Pixley, where we had the highest numbers of lizards, our density estimates were 0.36 – 1.61 adults/hectare (ha) and 0.87 – 1.17 hatchlings/ha. Semitropic density estimates were 0.42 – 0.68 adults/ha and 0.10 – 0.14 hatchling/ha and estimates at Lokern were 0.16 – 0.59 adults/ha and 0.32 – 0.42 hatchling/ha. When choosing our long-term monitoring sites we surveyed large portions of the Semitropic and Lokern reserves and attempted to choose areas with the highest numbers of lizards. At Pixley, we used the same monitoring plot that the Endangered Species Recovery Program had previously used in the 1990s and known to have high densities of lizards at one time. To the best of our knowledge, our monitoring plots represent some of the best areas for BNLL on each reserve. At Buttonwillow and Allensworth ERs, we have consistently been able to detect BNLL adults and hatchlings during opportunistic surveys, but at a much lower density than our long-term monitoring sites.

The home range data we collected at Semitropic and Pixley was significantly different between the two sites, with Semitropic home range sizes being 3-6 times larger than Pixley. In previous home range studies, mean male home range sizes were over twice as large as females, but in our study, we did not find significant differences between males and females at either Semitropic or Pixley. In addition, while the mean distance moved between consecutive days was greater for males than females at both Semitropic and Pixley, at least three of our radio-collared females at Semitropic made long distance movements associated with egg laying (movements ranged from 597 – 1345m). One female at Pixley also moved in association with egg laying (moved 235 m). It appeared at both sites that some females make long movements in association with egg laying and some do not. It also appeared that some females would move long distances to lay eggs and then subsequently return to their typical home range area, and some would not return. This behavior contributed to the large and highly variable home range sizes (1.66 – 19.58 ha) and greatest distances moved data (136.8 – 1152.0 m) for females at Semitropic.

Our results indicate that large home ranges and long-distance movements by females associated with egg laying, especially at sites like Semitropic, are often the case with BNLL. This data further demonstrates that BNLL need large areas to sustain populations.

INTRODUCTION

The blunt-nosed leopard lizard (*Gambelia sila*; BNLL) is a relatively large, predatory lizard that once occurred throughout much of the San Joaquin Valley and adjacent foothill and valley areas, such as the Carrizo Plain, Cuyama Valley, and Panoche Valley. This species currently persists on less than 15% of its historical range, largely due to habitat loss from agricultural development, oil extraction, and urbanization (Germano and Williams 1992a; Jennings 1995). The Federal government listed it as endangered in 1967 and the State followed, listing it as endangered listing in 1971.

Despite having endangered status for over 40 years and creating several important protected areas, no current population size estimates or a Population Viability Analysis

(PVA) exist for BNLL (USFWS 1998; 2010). In the 1990s, research on BNLL focused on population ecology using plot-based studies on two core areas: the Elkhorn Plain (adjacent to the Carrizo Plain) and Pixley NWR. While some research from these sites has been published (Uptain et al. 1992; Germano and Williams 2005), monitoring efforts were discontinued in the late 1990s. Recent reconnaissance at Pixley suggested that lizards have declined (L. Shaskey, personal communication; Endangered Species Recovery Program, unpublished data). Furthermore, a recent USFWS 5-year review found that BNLL are declining throughout their range and that nearly all recovery goals have not been met (USFWS 2010).

Since the mid-1990s, the Department of Fish and Wildlife (Department) has acquired land and created several Ecological Reserves (ERs) in the southern San Joaquin Desert. Most of these properties are outside BNLL core habitat areas, and likely represent satellite areas characterized by more fragmented or lower quality habitat. One hypothesis suggests that due to their large home ranges, territoriality, and preference for open habitats, BNLL densities may be lower on smaller and more fragmented reserves (Warrick et al. 1998). Despite the need, to date there have been virtually no demographic and space use studies conducted in more recently acquired satellite areas.

Basic population estimates and demographic data are crucial for understanding the status of BNLL throughout their range and gaining traction toward recovery actions. Furthermore, to make a more accurate assessment of a population, information on the probability of detection, which is, the percentage of individuals missed during a standard survey effort, is crucial. While we have standardized the procedures for optimal survey conditions for BNLL (see Germano and Williams 2005; CDFG 2004), we have never tested the probability of detection.

We report on a three-year study, which took place from 2015-2017 to investigate the population ecology of BNLL at three sites: Lokern Ecological Reserve (ER), Semitropic ER and Pixley National Wildlife Refuge (NWR) and space use at two sites: Semitropic ER and Pixley NWR. The primary objectives were to provide critical information that would allow us to estimate BNLL population size, demographic trends, research space use, and support efforts to develop predictive modeling techniques to inform conservation and management.

To support predictive modeling techniques we collaborated with University of California, Santa Cruz researchers Dr. Barry Sinervo and Ph.D. student Joseph Stewart. The Sinervo lab, with funding from the Bureau of Land Management's Dr. Michael Westphal and The Nature Conservancy's Dr. H. Scott Butterfield, were working to model habitat suitability, estimate climate change impacts, model demographic responses to environmental variables and create a PVA for BNLL. We provide a recent draft manuscript from their work as appendix to this report.

METHODS

STUDY AREA

The study area for this project was several protected sites in the southern San Joaquin Valley, California (Figure 1). The area is also known as the San Joaquin Desert (Germano et al. 2011). The regional climate is Mediterranean in nature, and characterized by hot, dry summers, and cool, wet winters. Mean maximum and minimum temperatures are 35°C and 18°C in summer, and 17°C and 5°C in winter. Annual precipitation averages ca. 150 mm and occurs primarily as rain falling between October and April (National Oceanic and Atmospheric Administration 2017).

We choose three sites with significant BNLL populations for this study. These sites were Lokern ER, Semitropic ER, and Pixley NWR (Figure 1). We completed space use research at Semitropic ER and Pixley NWR. In addition to these sites, we also conducted opportunistic surveys at Buttonwillow and Allensworth ERs.

Lokern ER

Lokern ER is located within the Lokern Natural Area, which is a patchwork of protected lands in western Kern County, California near the town of Buttonwillow. The site is gently sloping (2-5%) alluvial plain with several small dry washes. The habitat on our study site is classified as *Bromus rubens-Schismus* (*arabicus,barbatus*) herbaceous semi-natural alliance (Sawyer et al. 2009). Previously, the site was likely classified as *Atriplex polycarpa* shrubland alliance, but a wildfire burned through the site in 1997 and, except for a few large *A. polycarpa* in the area, which were likely spared in the fire, only some scattered *A. polycapa* have regenerated. In the small washes on the site, there are a few scattered *Ambrosia salsola* and *Gutierrezia californica*. Depending on rainfall patterns, some years can also have stands of invasive Russian thistle (*Salsola tragus*). The soils are Kimberlina sandy loam and Kimberlina gravelly sandy loams, which originate from granitic and sedimentary rock (Soil Survey Staff, NRCS, 2018). Historically this area has been sheep grazed, but no grazing has occurred on or around the study site in the last 10 years.

Semitropic ER

Semitropic ER is a patchwork of protected lands located in northwestern Kern County, California, west of the town of Delano and east of the town of Lost Hills. The study site is on a low ridge on the valley floor located between the floodplain and sloughs of the Kern River and Poso Creek as they flowed into the historic Tulare Lake. We classified the habitat on the study site as *Atriplex spinifera* shrubland alliance and *Atriplex polycarpa* shrubland alliance (Sawyer et al. 2009). Depending on rainfall patterns, the shrub understory is dominated by either bare ground or a composition of native and non-native grasses and forbs. Typical grass/forb alliances include *Bromus rubens-Schismus* (*arabicus,barbatus*) herbaceous semi-natural alliance or *Centromadia* (*pungens*) herbaceous alliance (Sawyer et al. 2009). Soil on the study site consists of Garces silt loam (Soil Survey Staff, NRCS, 2018). Alkali playa pools that hold water in above average rainfall years are present on the site. Historically this area has been sheep grazed. We often found sheep trespass grazing adjacent to the site in high vegetation years. No grazing occurred during the period of our study.

Pixley NWR

Pixley NWR is a protected site in Tulare County, California, west of the town of Earlimart, and east of the town of Alpaugh. The topography is flat, with scattered small mounds or hummocks and alkali playas that can fill with water in above average rainfall years. Agricultural lands that are largely associated with the dairy industry surround the refuge; thus, crops mostly consist of alfalfa, wheat, silage, and corn. Vegetation alliances on the refuge include *Centromadia (pungens)* herbaceous alliance and *Bromus rubens-Schismus (arabicus,barbatus)* herbaceous semi-natural alliance (Sawyer et al. 2009). The site lacks shrubs aside from a few scattered small *Suaeda moquinii* and *Isocoma acradenia*. Soils are classified as Gareck-Garces Association and Kimberlina fine sandy loam, which are both alluvial soils with granitic rock sources (Soil Survey Staff, NRCS, 2018). A cattle grazing program has been in place on the refuge since the 1960s. The duration and timing of grazing depends on rainfall and grass levels, but generally grazing occurs from November to April with a target of <800 lbs/acre (1976.8 lbs/ha) of residual dry matter (Geoff Grisdale, Refuge biologist, personal communication).

Buttonwillow ER

Buttonwillow ER is an isolated protected site in western Kern County, California east of the town of Buttonwillow. The vegetation community is similar to Semitropic ER and is classified as *Atriplex polycarpa* and *A.spinifera* shrubland alliance (Sawyer et al. 2009). Depending on rainfall patterns, either bare ground or a composition of native and non-native grasses and forbs dominates the shrub understory. Typical grass/forb alliances include *Bromus rubens-Schismus* (*arabicus,barbatus*) herbaceous semi-natural alliance or *Centromadia* (pungens*)* herbaceous alliance (Sawyer et al. 2009). Soils on the site are Garces silt loam and Jerryslu loam (Soil Survey Staff, NRCS, 2018). The topography is flat, although there are small mounds and alkaline playa pools that can hold water in above average rainfall years. Historically this area was likely sheep grazed, but no grazing has occurred on the reserve in the last 10 years.

Allensworth ER

Allensworth ER is a protected area that consists of several disconnected units in northwestern Kern County and southeastern Tulare County, California west of the town of Delano, and east of the town of Alpaugh. The site is approximately 8 kilometers south of Pixley NWR. Irrigated agriculture dominates the surrounding lands, with crops such as pistachios, almonds, and alfalfa. The topography is generally flat, with scattered small mounds or hummocks and alkali playas that can hold water in above average rainfall years. Vegetation communities consist of *Suaeda moquinii* shrubland alliance, *Allenrolfea occidentalis* shrubland alliance, and *Atriplex polycarpa* and *A.spinifera* shrubland alliance (Sawyer et al. 2009). The understory and shrub free areas are generally classified as *Centromadia (pungens)* herbaceous alliance and *Bromus rubens-Schismus (arabicus,barbatus)* herbaceous semi-natural alliance (Sawyer et al. 2009). Soils consist of Gareck-Garces association, Atesh-Jerryslu association, and Kimberlina fine sandy loam (Soil Survey Staff, NRCS, 2018). Trespass cattle grazing from a neighboring landowner does occur on a portion of the reserve.
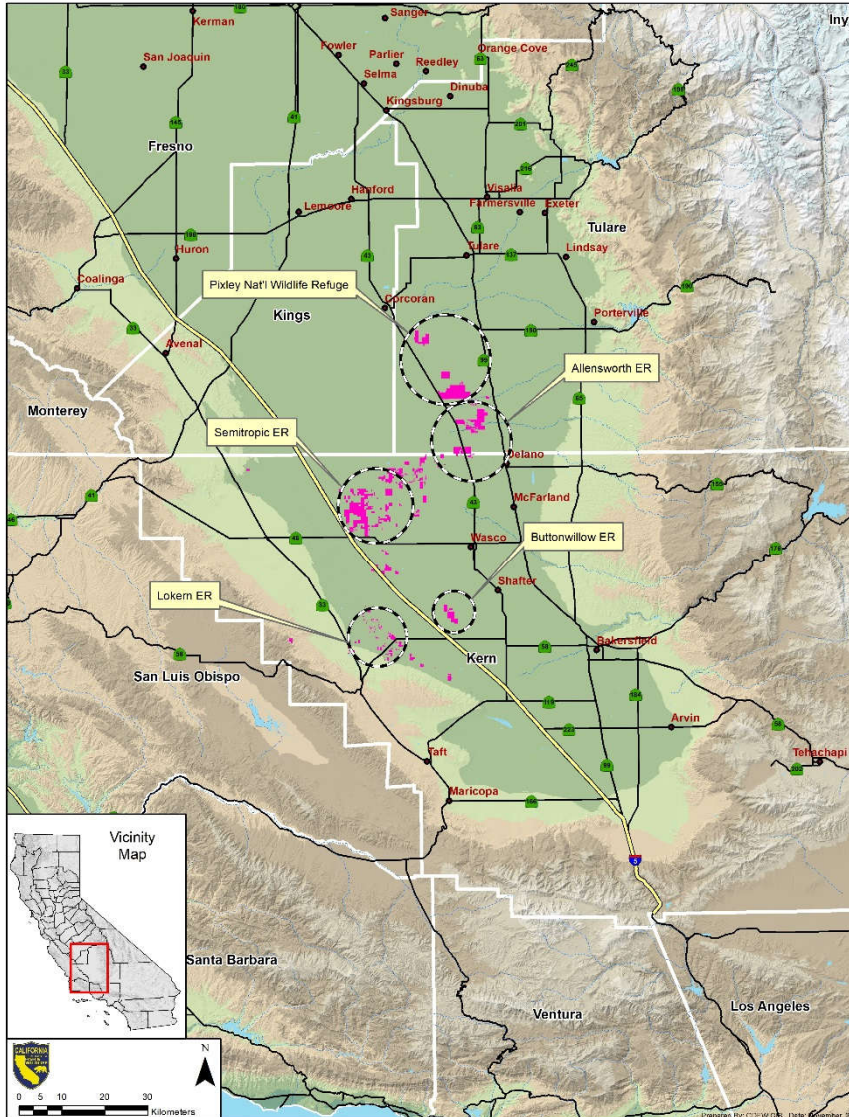
Figure 1. Location of *Gambelia sila* monitoring sites, including Lokern Ecological Reserve (ER), Buttonwillow ER, Semitropic ER, Allensworth ER, and Pixley National Wildlife Refuge in the southern San Joaquin Desert, California.

POPULATION AND DEMOGRAPHIC DATA COLLECTION

Censuses and Measurements

We used census plots and guidelines for visual survey protocols (California Department of Fish and Game 2004; Germano and Williams 2005) to monitor BNLL populations on census plots at Lokern ER, Semitropic ER and Pixley NWR. Census plots were based on the cruise survey method (Degenhardt 1966) and we used the same grid survey techniques that have been used in several previous published studies involving BNLL (Germano and Williams 2005; Germano et al. 2012). At each permanent monitoring site, we used a nine-ha plot, with 16 permanent transect lines that were 300-m long and spaced 20-m apart. Our plots were slightly larger than plots used in previous studies (Tollestrup 1979; Uptain et al.

1992; Germano and William 2005 used 8.1 ha plots with 277-m census lines and 18.2 m spacing), but our plots were the same as those used in a grazing study at Lokern Natural Area (Germano et al. 2012). We used white schedule 40 PVC to mark the grid transect lines every 20-m. Grids at each site were walked in an east-west orientation with a varying start location by either one or two surveyors. If two surveyors were used each surveyor walked their own grid line in tandem.

From 2015-2017, we censured the grids approximately two days a week during the BNLL active season (late April through the middle of October). In 2015, we delayed surveys until approximately mid-late May, because we had to site and build the census grids. At all sites, we captured and recorded data on lizards using the same methods established during a population ecology study on the Elkhorn Plain (Germano and Williams 2005).

We captured lizards using a pole and noose. For each lizard captured, we recorded its sex, location on the grid, and wrote a sequential number on its back with a blue felt-tipped Sharpie pen. We placed each lizard in a separate, small cloth bag. If a new capture, we held the lizard until after the census in order to take body measurements including snout-vent length (SVL), total length (TL) and mass. We recorded body measurements to the nearest millimeter using a 15-inch clear plastic ruler and weight measurements with a 100-g or 50-g Pesola scale to the nearest gram. We palpated each adult female captured to determine whether she was gravid and the number and size of the eggs she carried. We felt confident in our accuracy because experienced surveyors (Germano and Tennant) trained each surveyor to palpate for eggs, and typically, we captured individuals multiple times during the gestation period. In addition, we classified eggs as small, medium or large, which helped us document gestation timing. Lizards were permanently marked with a Passive Integrated Transponder (PIT) subdermally or interabdominally (Germano and Williams 1993). We marked hatchling/juvenile lizards by creating a unique toe clip pattern on each individual. After processing, we released all lizards caught during each census to their original capture location.

Opportunistic Surveys

Because of low population densities at Buttonwillow and Allensworth ERs, it was not possible to collect enough data on lizards using a census plot. Instead, we opportunistically surveyed each site using meandering walking transects and slowly driving targeted interior roads of both reserves. We captured lizards using the same methods described for census plots, except that we did not PIT tag adults or toe clip hatchling/juveniles. We did write a sequential number on the backs of lizards with a blue felt-tipped Sharpie pen so that we could identify recaptures during sequential survey days.

Size and Population Comparisons

We followed the size comparisons for lizards described in Germano and Williams 2005. Lizards were grouped into four categories: hatchlings (40-57 mm SVL), juveniles (58-82 mm SVL), small adults (83-97 mm SVL), and adults ($\geq$ 98 mm SVL).

We compared the distribution of SVLs for each site by year using a Kolmogorov-Smirnov test. Since SVLs did not differ by year, and because of small sample sizes, we pooled the data from 2015-2017 to compare the distribution of SVLs between sites. For this and all other tests $\alpha = 0.05$.

We followed the methods of Case (1976) and Germano and Williams (2005), who used the upper decile size (upper 10%) of adult lizards in order to minimize the effect of age structure on size estimates. Because of small sample sizes, we used both the mean and upper quartile size (upper 25%) of lizards for size comparisons and we pooled data from 2015-2017. When we pooled data, we used the largest measurement recorded for each individual lizard over the study period. Thus, if a lizard was captured over multiple years we only used one measurement (the largest) for each individual.

We calculated the upper quartile size and mean size for SVL (mm), Total Length (TL; mm), mass (g) across sex and sites. We used only non-gravid females in mass comparisons. If lizards had the tip or more of their tail missing, we excluded them from our analysis of TL. Because some of the datasets were nonparametric even after transformations, we used Kruskal-Wallis to determine if there were significant differences between groups. Because both mean and upper quartile means differed significantly for SVL, TL and mass we made pair-wise comparisons using Mann-Whitney tests with P values adjusted using the method by Legendre and Legendre (1998). We compared sex ratios at each site to 1 to 1 using a Chi-square test.

For each female captured, we determined multiple clutches in one season by successive recaptures when either the female did not have eggs between clutches or there was a change in the number or decrease in the size of eggs (Germano and Williams 1992b). Because of low sample sizes, we pooled data across years to compare the mean number of eggs per clutch at each site. Because some of the datasets were nonparametric even after transformations, we used Kruskal-Wallis to test among groups.

Survivorship

We made survivorship estimates as percentages of lizards marked in the previous year, or in the case of hatchlings/juveniles, the number marked in the previous fall. Since this was a three-year study, we calculated estimates for Year 2 (2016) and Year 3 (2017).

Prey Abundance

During each census, we counted the number of grasshoppers, side-blotched lizards (*Uta stansburiana*), and western whiptails (*Aspidoscelis tigris*). Principal prey items of BNLL include grasshoppers, small lizards, and other arthropods (Germano et al. 2007). Because of this, and because the only site with any significant *A. tigris* population was Semitropic (typically more than one *A. tigris* seen per grid census), we excluded *A. tigris* from prey assessments. We compared the mean index of *U. stansburiana* and grasshoppers for the adult (April – July) and hatchling/juvenile (July – October) activity periods at each site for each year.

Because some of the datasets were nonparametric even after transformations, we used Kruskal-Wallis to determine if there were significant differences between groups. We followed up with Mann-Whitney pair-wise comparisons with P values adjusted using the method by Legendre and Legendre (1998).

Precipitation and Plant Productivity

We used rainfall data from the nearest functioning weather station to each study site from the Western Regional Climate Center (WRCC; https://wrcc.dri.edu/), except for Lokern ER, where we used data from a rain gauge located near Lokern Road and operated by the

Center for Natural Lands Management (G. Warrick, unpublished data). For Semitropic ER we used WRCC data from Wasco, CA and for Pixley NWR we used data from Delano, CA.

From 2015-2017 we estimated the amount of annual herbaceous material produced on each census plot by collecting residual dry matter (RDM) in September/October following established methodology used in similar studies (see Germano and Saslaw 2017). We used 30 randomly selected plots on each grid by numbering each area formed between four grid stakes. We walked five paces north/south and five paces east/west (depending on grid orientation) and set down a 0.25 x 0.25 m quadrat. Within each quadrat, we clipped herbaceous, annual plant material and took care to exclude perennial plant material, rocks, dirt, woody material, and rabbit pellets. We used the average weight of the 30 quadrats to estimate herbaceous plant material on the plot each year.

Although we only had three sample data points (three years of data), we tested for correlations between various data scenarios on all sites using a Pearson's product moment correlation. These scenarios included RDM – rainfall, RDM/rainfall – BNLL adult/hatchling census numbers, RDM/rainfall – adult/hatchling grasshopper numbers, and RDM/rainfall – adult/hatchling side-blotch lizard numbers.

TELEMETRY, MOVEMENT, AND HOME RANGE ESTIMATION

We radio-tracked BNLL in 2015 and 2016 at Semitropic ER and Pixley NWR. Once census plots were established, we began to catch lizards according to the process described in the Census and Measurements (see section above). We specifically tried to radio-collar as many lizards as possible on the census plots in order to test detection probability. However, we only attached radio-collars to adult BNLL that were > 95 mm SVL or 25 g mass. We attached radio transmitters to BNLL using the same methods established in a previous study at Lokern Natural Area (see Germano and Rathbun 2016). We used radio transmitters (model BD-2, battery life 16-18 weeks, weight 2.0 g; Holohil Systems, Carp, Ontario, Canada) fitted to aluminum beaded chain collars (Harker et al. 1999). We attached the beaded chain to the radio transmitters using several loops of thin brass wiring and used epoxy glue to cover the wire. The transmitters, with the beaded chain collars, weighed approximately 2.2 g, which was < 8.5% of the weight of the smallest lizards we collared.

In both years, we tracked lizards from May until mid-July. We used three element folding yagi antennas with Communications Specialists receivers (Model R-1000) to radio-locate lizards using the homing method (Kenward 2001). We used a Motorola Moto G (2nd generation) with the locus map pro application (www.locusmap.eu). We tested the accuracy of GPS locations at our sites and recorded points within 3-5 m accuracy. We located each radio-collared lizard every 1-5 days, with the bulk of the detections occurring on a daily basis. We intended to collect >40 locations for each individual (Stone and Baird 2002), but often lizards were preyed upon, or we lost the signal from the study area, before we were able to collect > 40 locations. We did not use data in our analysis for any lizards that had < 20 locations.

We calculated home range using 95% Minimum Convex Polygons (MCP) using R 3.4.4 (https://www.R-project.org). While MCP does sometimes overestimate home range size, it is a commonly used method, which allows us to compare lizard home ranges to other published studies. We determined mean daily distance moved and greatest distance moved

between consecutive daily locations using the field calculator feature in ArcMap 10.5.1 (ArcGIS, ESRI, Redlands, California).

To analyze data we transformed datasets with either square root or log transformations. If transformed data were normal and homoscedastic we used t-tests for independent measures to compare between groups. For data that was nonparametric we used a Mann-Whitney pairwise comparison. We compared home range size, mean distance moved and greatest distance moved between males and females at both sites. We also compared home range size, mean distance moved and greatest distance moved between the two sites for males and females.

PROBABILITY OF DETECTION

We wanted to assess probability of detection for BNLL in order to better estimate the population size at each protected site. Using the telemetry methods described above we estimated our detection rate each time we walked the census plot by determining whether radio-collared lizards were on or off the plot and, if they were on the plot and available for detection, whether they were detected during the census plot walking survey. To compile data we simultaneously censured the plot and had a separate technician complete radio tracking of lizards or we completed radio tracking immediately after the plot census. In one or two instances, we completed radio tracking before walking the census plot. If a separate technician completed tracking while the plot was simultaneously being censured, the technician did so with knowledge of the direction and timing of the surveyors walking the plot so as not to bias their knowledge of where lizards might be located.

Because of small sample sizes, we pooled probability of detection data over the two survey years. Since data were nonparametric even after transformations, we used a Mann-Whitney test to compare the pooled means at both sites.

POPULATION ABUNDANCE AND DENSITY

We used the mean number of adult BNLL sighted from April – July at each site each year to estimate population abundance. We used the mean pooled detection probability calculated at Semitropic and Pixley to correct our estimates of abundance using the equation:

$$\widehat{N} = \frac{C}{\hat{p}}$$

In this case, $\widehat{N}$ is the estimate of abundance, C is the count statistic, which in our case is the mean number of BNLL sighted per census during the adult or hatchling/juvenile season, and $\hat{p}$ is the estimate of detection probability.

Densities of lizards were calculated using abundance estimates and the area sampled. Sometimes the area sampled is corrected by altering the width of the census lines to reflect sighting distances to lizards. This is needed because the distance a lizard is sighted from the census line varies from year to year depending on vegetation levels. For example, Germano and William altered their area sampled by using only the distance at which 90% of lizards were sighted from the census lines (2005). During our study period, we never had extremely high vegetation cover, and we typically sighted lizards at 20 m or more from the census lines. Thus, we consider the width of each census line to be the distance

between the two lines, which is 20 m. We also estimated that the width of the two end lines was 20 m. All plots consisted of 16 census lines that were 300 m long and two end lines connecting the census lines that were 300 m long. Area was determined as

$$A = w[16\,(l' - w) + 2\,(l'' + w)],$$

where w is the width of the census line (20 m), l' is the length of the census lines (300 m) and l'' is the length of the end lines (300 m). Thus, the area of each plot for density estimate purposes was 102,400 m^2 or 10.24 ha.

RESULTS

POPULATION AND DEMOGRAPHIC DATA

Size and Population Characteristics

We completed three years of monitoring at three demographic study plots at Lokern ER, Semitropic ER and Pixley NWR. We also surveyed opportunistically for several days at Buttonwillow and Allensworth ERs to determine BNLL presence or absence. We detail the results from each site separately and then detail results between sites.

Lokern ER

Over three years we made 237 recaptures of 107 unique lizards. In 2015, we made 57 recaptures of 28 unique adult lizards, and 45 recaptures of 16 unique hatchlings/juveniles (Table 1). In 2016, we made 32 recaptures of 20 unique adult lizards and 34 recaptures of 15 unique hatchlings/juveniles (Table 1). In 2015 and 2016, we also captured several adults on the periphery of the census plot because other colleagues were completing a radio telemetry study on the same site. We included these lizards only in our estimates of size characteristics. In 2017, we made 29 recaptures of 14 unique adults and 40 recaptures of 16 unique hatchlings/juveniles (Table 1).

Table 1. Number of unique adult and hatchling/juvenile *Gambelia sila* captured per year at Lokern Ecological Reserve (NCD = number of census days).

	NCD	Adults			Hatchlings/Juveniles		
		Males	Females	Total	Males	Females	Total
2015	42	15	13	28	15	1	16
2016	50	13	6	19	12	2	14
2017	51	9	5	14	12	4	16
Total	**143**	**37**	**24**	**61**	**39**	**7**	**46**

During each of the three years of our study we had adults in the spring that generally were 100-120 SVL and hatchlings, juveniles and small adults in the fall that often reached 90-95 SVL before the end of our fall survey season. The distribution of SVLs at Lokern did not differ significantly between years (D=0.11-0.21, P = 0.742 – 1.000; Figure 2).

Because the distribution of SVLs did not differ significantly between years and because of low sample sizes each year, we pooled the data across all three years to compare size

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characteristics and sex ratios. Sex radio of adult males to females was 1.4:1, which was not significantly different from 1 to 1 ($\chi^2 = 1.421$, P = 0.233).

We calculated the mean and the upper quartile for SVL, TL and mass for males and females. For females, we separated gravid and non-gravid females for mass comparisons. The mean SVL of males was 114.1 mm (SE = 0.678, N = 31; Table 2) and the upper quartile SVL of males was 118.1 mm (SE = 0.479 , N = 8; Table 3). The mean SVL of females was 107.8 mm (SE = 1.085, N = 22; Table 2) and the upper quartile SVL of females was 113.8 mm (SE = 0.601, N = 6; Table 3). The largest male was 120 mm SVL and the largest female was 116 mm SVL (Table 2). The mean TL of males was 340.1 mm (SE = 2.42, N = 29; Table 4) and the upper quartile total length (TL) of males was 353.1 mm (SE = 0.80, N = 7; Table 5). The mean TL of females was 313.5 mm (SE = 3.28, N=20) and the upper quartile TL of females was 332.0 mm (SE = 2.70, N = 5; Table 5). The largest male was 356 mm TL and the largest female was 340 mm TL (Table 4). The mean mass of males was 42.4 g (SE = 1.11, N = 31; Table 6) and the upper quartile mass of males was 50.0 g (SE = 0.88 , N = 8; Table 7) with the heaviest male 53.5 g (Table 6). The mean mass of non-gravid females was 30.6 g (SE = 0.94, N = 14; Table 6) and the upper quartile mass of females was 34.8 g (SE = 0.73, N = 4; Table 7). The largest non-gravid female was 37 g (Table 6). The heaviest gravid female was 46 g.

Table 2. Comparison of the mean snout-vent length (SVL; mm) for male and female *Gambelia sila* at three monitoring sites (L = Lokern, S = Semitropic, P = Pixley) in the Southern San Joaquin Desert. We pooled data over three years (2015-2017). All groups differed significantly from each other (H = 87.15, df = 5, P < 0.001)

	n	Mean	SE	Low	High	95% CI
L-Male	31	114.1	0.678	106	120	1.385
L-Female	22	107.8	1.085	95	116	2.256
S-Male	29	109.2	1.442	89	119	2.955
S-Female	28	104.1	1.209	93	115	2.481
P-Male	34	105.6	1.281	86	121	2.606
P-Female	55	98.8	0.791	80	115	1.586

Table 3. Comparison of the mean upper quartile snout-vent length (SVL; mm) for male and female *Gambelia sila* at three monitoring sites (L = Lokern, S = Semitropic, P = Pixley) in the Southern San Joaquin Desert. We pooled data over three years (2015-2017). All groups differed significantly from each other (H=38.36, df=5, P<0.001).

	n	Mean	SE	Low	High	95% CI
L-Male	8	118.1	0.479	117	120	1.134
L-Female	6	113.8	0.601	112	116	1.545
S-Male	7	117.0	0.436	116	119	1.068
S-Female	7	112.0	0.845	109	115	2.068
P-Male	9	114.7	1.167	110	121	2.690
P-Female	14	105.4	0.899	102	115	1.943

Table 4. Comparison of the mean total length (mm) for male and female *Gambelia sila* at three monitoring sites (L = Lokern, S = Semitropic, P = Pixley) in the Southern San Joaquin Desert. We pooled data over three years (2015-2017). All groups differed significantly from each other (H = 126.40, df = 5, P < 0.001)

	n	Mean	SE	Low	High	95% CI
L-Male	29	340.1	2.42	309	356	4.95
L-Female	20	313.5	3.28	280	340	6.86
S-Male	29	313.8	3.03	273	335	6.21
S-Female	28	289.8	4.48	214	323	9.19
P-Male	34	294.0	3.23	240	344	6.58
P-Female	55	272.1	2.48	225	309	4.98

Table 5. Comparison of the mean upper quartile total length (mm) for male and female *Gambelia sila* at three monitoring sites (L = Lokern, S = Semitropic, P = Pixley) in the Southern San Joaquin Desert. We pooled data over three years (2015-2017). All groups differed significantly from each other (H = 41.77 df = 5, P < 0.001).

	n	Mean	SE	Low	High	95% CI
L-Male	7	353.1	0.80	350	356	1.96
L-Female	5	332.0	2.70	324	340	7.50
S-Male	7	331.6	0.75	329	335	1.84
S-Female	7	313.3	1.89	309	323	4.62
P-Male	9	316.7	4.44	303	344	10.23
P-Female	14	293.4	1.94	285	309	4.19

Table 6. Comparison of the mean mass (g) for male and non-gravid female *Gambelia sila* monitoring sites (L = Lokern, S = Semitropic, P = Pixley) in the Southern San Joaquin Desert. We pooled data over three years (2015-2017). All groups differed significantly from each other (H = 65.43, df = 5, P < 0.001).

	n	Mean	Sx	Low	High	95% CI
L-Male	31	42.4	1.11	29	54	2.26
L-Female	14	30.6	0.94	25	37	2.02
S-Male	29	40.5	1.71	17	55	3.50
S-Female	19	31.1	1.47	18	42	3.09
P-Male	34	34.9	1.30	25	55	2.64
P-Female	31	27.0	1.03	16	36	2.10

Table 7. Comparison of the mean upper quartile mass (g) for male and non-gravid female *Gambelia sila* at three monitoring sites (L = Lokern, S = Semitropic, P = Pixley) in the Southern San Joaquin Desert. We pooled data over three years (2015-2017). All groups differed significantly from each other (H = 31.85, df = 5, P < 0.001)

	n	Mean	Sx	Low	High	95% CI
L-Male	8	50.0	0.88	47	54	2.07
L-Female	4	34.8	0.73	34	37	2.34
S-Male	7	50.6	0.91	49	55	2.23
S-Female	5	38.4	1.38	35	42	3.84
P-Male	9	45.3	1.52	41	55	3.50
P-Female	8	34.2	0.53	32	36	1.25

We found the first date that hatchlings or juveniles appeared on the plot was July 7 in 2015, July 11 in 2016, and July 10 in 2017. The smallest hatchling caught was a male on July 7, 2015 who was 51 mm SVL and 4 g. We only caught 6 hatchlings (40-57 mm SVL) over 3 years; the majority of young (78.3%) captured between July and October were captured as juveniles (58-82 mm SVL) or small adults (83-97 SVL; Figure 2). The ratio of hatchling males to females was 5.6:1, which differed significantly from 1 to 1 ($\chi^2 = 22.261$, P < 0.001).

Figure 2. Size distribution by year of *Gambelia sila* at Lokern Ecological Reserve from 2015-2017. Males are solid bars and females are striped bars. We used only the SVL of lizards at first capture. The distributions of SVLs did not differ between years (D=0.11-0.21, P = 0.742 – 1.000).

Mean clutch size in 2015 was 2 (SE = 0, N = 8) with all females having 2 eggs. In 2015, we began surveys in late April and found three females with large eggs between April 28 and May 2. We did not document any individual females with more than one clutch of eggs in 2015, but suspect that some lizards may have had two clutches because one new female captured on June 23 had two large eggs and we suspect this may have been her second clutch. June 23 was the latest date that a female had eggs in 2015; all females captured beyond this point (N = 5) were not gravid.

Mean clutch size in 2016 was 3 (SE = 0.4, N = 4) with a range of 2-4. We had few females on the plot in 2016 and rarely recaptured them, thus our data in 2016 was too sparse to evaluate the number of clutches.

Mean clutch size in 2017 was 2.8 (SE = 0.2, N = 5) with a range of 2-3 and a mode of 3. We found small eggs in two females in mid-May. The latest date we captured a female with eggs was July 3, with two medium eggs. We documented one female who clearly had two clutches of eggs. During the first clutch she had three large eggs on June 16 and during the second clutch had two medium eggs that were found on July 3. We also documented two pulses of hatchings, with the majority 50-60 mm SVL hatchlings appearing from July – late August and then another set of hatchlings in the 50-60 mm SVL range appearing around the 15 September.

Mean clutch size for pooled data for 2015-2017 was 2.5 (SE = 0.6, N = 17) with a mode of 2 and a range of 2-4.

Semitropic ER

Over three years we made 203 recaptures of 89 lizards. In 2015, we made 63 recaptures of 23 unique adult lizards, and recaptured 5 unique hatchlings/juveniles only once (Table 8). In 2016, we made 54 recaptures of 29 unique adult lizards and 3 recaptures of 7 unique hatchlings/juveniles in the fall (Table 8). In 2015 and 2016, we also captured several adults on the periphery of the census plot because we were also completing a radio telemetry study on the same site. We included these lizards only in our estimates of size characteristics. In 2017, we made 77 recaptures of 21 unique adults and 6 recaptures of 5 unique hatchlings/juveniles (Table 8).

Table 8. Number of unique adult and hatchling/juvenile *Gambelia sila* captured per year at Semitropic Ecological Reserve (NCD = number of census days).

	NCD	Adults			Hatchlings/Juveniles		
		Males	Females	Total	Males	Females	Total
2015	48	11	12	23	2	3	5
2016	51	10	18	28	3	4	7
2017	46	12	9	21	2	3	5
Total	**145**	**33**	**39**	**72**	**7**	**10**	**17**

During each of the three years of our study, we had adults in the spring that generally were 90-115 SVL and very few hatchlings and juveniles in the fall. The distribution of SVLs at Semitropic did not differ significantly between years (D=0.105-0.263, P = 0.462-1.000; Figure 3).

Figure 3. Size distribution by year of *Gambelia sila* at Semitropic Ecological Reserve, from 2015-2017. Males are solid bars and females are striped bars. We used only the SVL of lizards at first capture. The distributions of SVLs did not differ between years (D=0.105-0.263, P = 0.462-1.000).

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Because of low sample sizes each year we pooled the data across all three years. Sex radio of adult males to females was exactly 1:1. The mean SVL of males was 109.2 mm (SE = 1.442, N = 29; Table 2) and the upper quartile SVL was 117.0 mm (SE = 0.436, N = 7; Table 3). The mean SVL of females was 104.1 mm (SE = 1.209, N = 28; Table 2) and the upper quartile SVL of females was 112.0 mm (SE = 0.845, N = 7; Table 3). The largest male was 119 mm SVL and the largest female was 115 mm SVL (Table 2). The mean TL of males was 313.8 (SE = 3.03, N = 29; Table 4) and the upper quartile total length was 331.6 mm (SE = 0.75, N = 7; Table 5). The mean TL of females was 289.8 (SE = 4.48, N = 28; Table 4) and the upper quartile total length was 313.3 mm (SE = 1.89, N = 7; Table 5). The largest male was 335 mm TL and the largest female was 323 mm TL (Table 5). The mean mass of males 40.5 g (SE = 1.71, N = 29; Table 6) and upper quartile mass of males was 50.6 g (SE = 0.91, N = 7; Table 7) with the heaviest male 55 g (Table 6). For non-gravid females, the mean mass was 31.1 g (SE = 1.47, N = 19; Table 6) and the upper quartile mass was 34.8 g (SE = 1.38, N = 5; Table 7). The heaviest non-gravid female was 42 g (Table 6). The heaviest gravid female was 46.1 g.

We found the first date that hatchlings or juveniles appeared on the grid was August 12 in 2015, July 19 in 2016, and August 30 in 2017. The smallest hatchling caught was a male on July 21, 2016 who was 55 mm SVL and 3 g. We only caught 5 hatchlings (40-57 mm SVL) over 3 years; the majority of young (70.6%) captured between July and October were captured as juveniles (58-82 mm SVL) or small adults (83-97 SVL). The ratio of hatchling males to females was 0.7:1, which did not differ significantly from 1 to 1 (χ^2 = 0.529, P = 0.467).

Mean clutch size in 2015 was 2.3 (SE = 0.2, N = 17) and range was 1-4 and mode was 2. In 2015, we began surveys on May 1 and found one female with 4 large eggs. On the same date, another female had 2 small eggs; but, both were gravid by this date. In 2015, we found one female that had at least three clutches of eggs, 4 females that had at least two clutches, and all others we know had a least one clutch. In mid-July 2015 we still found females with medium sized eggs (N = 5). July 28 was the latest date that a female had eggs in 2015; all females captured beyond this point (N = 4) were not gravid.

Mean clutch size in 2016 was 2.6 (SE = 0.2, N = 16), range was 1-3 and mode was 3. We began surveys on April 29 and found one female with 3 medium eggs. In 2016, two females had at least two clutches, and an additional 13 females we know had at least one clutch. On July 7 we had one female with 2 large eggs, but all females captured after this date had no eggs (N = 5).

Mean clutch size in 2017 was 2.6 (SE = 0.1, N = 14) range was 2-3 and mode was 3. We began surveys on May 1 and found one female with 3 medium eggs. The latest date we captured a female with eggs was August 11, with three large eggs. After this date any females captured were not gravid (N = 3). We found 3 females that had at least 3 clutches and 1 female that had at least 2 clutches. Another 3 females we know had at least one clutch.

Mean clutch size for pooled data for 2015-2017 was 2.5 (SE = 0.1, N = 47), range was 1-4 and mode was 3.

Pixley NWR

Over three years we made 321 recaptures of 242 unique lizards. In 2015, we made 26 recaptures of 16 unique adult lizards, and made 28 recaptured 33 unique

hatchlings/juveniles (Table 3). In 2016, we made 76 recaptures of 47 unique adult lizards and 43 recaptures of 42 unique hatchlings/juveniles in the fall (Table 3). In 2015 and 2016, we also captured several adults on the periphery of the census plot because we were also completing a radio telemetry study on the same site. We included these lizards only in our estimates of size characteristics. In 2017, we made 77 captures of 39 unique adults and 71 recaptures of 65 unique hatchlings/juveniles (Table 3).

Table 9. Number of unique adult and hatchling/juvenile _Gambelia sila_ captured per year at Pixley National Wildlife Refuge (NCD = number of census days).

	NCD	Adults			Hatchlings/Juveniles		
		Males	Females	Total	Males	Females	Total
2015	47	3	13	16	22	11	33
2016	50	18	29	47	23	19	42
2017	50	17	22	39	31	34	65
Total	**147**	**38**	**64**	**102**	**76**	**64**	**140**

The distribution of SVLs at Pixley had most adult lizards in the 95-100 SVL range and a large number of juveniles and small adults. The distribution of SVLs at Pixley did not differ significantly between years (D = 0.235-0.412, P = 0.081-0.673; Figure 4).

To compare size characteristics and sex ratios, we pooled the data across all three years. Sex radio of adult males to females was 0.618 to 1, which was significantly different from 1 to 1 (χ^2 = 4.955, P = 0.026). The mean SVL of males was 105.6 mm (SE = 1.281, N = 34; Table 2) and the upper quartile SVL of males was 114.7 mm (SE = 1.167, N = 9; Table 3). The mean SVL of females was 98.8 mm (SE = 0.791, N = 55; Table 2) and the upper quartile SVL of females was 105.4 mm (SE = 0.899, N = 14; Table 3). The largest male was 121 mm SVL and the largest female was 115 mm SVL (Table 2). The mean TL of males was 294.0 (SE = 3.23, N = 34; Table 4) and the upper quartile TL of males was 316.7 mm (SE = 4.44, N = 9; Table 5). The mean TL of females was 272.1 mm (SE = 2.48, N = 55; Table 4) and the upper quartile TL of females was 293.4 mm (SE = 1.94, N = 14; Table 5). The largest male was 344 mm TL and the largest female was 309 mm TL (Table 4). The mean mass of males was 34.9 g (SE = 1.30, N = 34; Table 6) and the upper quartile mass of males was 45.3 g (SE = 1.52, N = 9; Table 7) with the heaviest male 55 g (Table 6). The mean mass of non-gravid females was 27.0 (SE = 1.03, N = 31; Table 6) and the upper quartile mass was 34.2 g (SE = 0.53, N = 8; Table 7) with the heaviest non-gravid female 36 g (Table 6). The heaviest gravid female was 45 g.

We found the first date that hatchlings or juveniles appeared on the grid was July 9 in 2015, July 7 in 2016, and July 13 in 2017. The smallest hatchling caught was a male on July 28, 2015 who was 49 mm SVL and 1 g. We caught 32 hatchlings (40-57 mm SVL) over 3 years; the majority of young (75.9%) we captured between July and October were juveniles (58-82 mm SVL) or small adults (83-97 SVL). The ratio of hatchling males to females was 1.188 to 1, which was not significantly different from 1 to 1 (χ^2 = 1.029, P = 0.311).
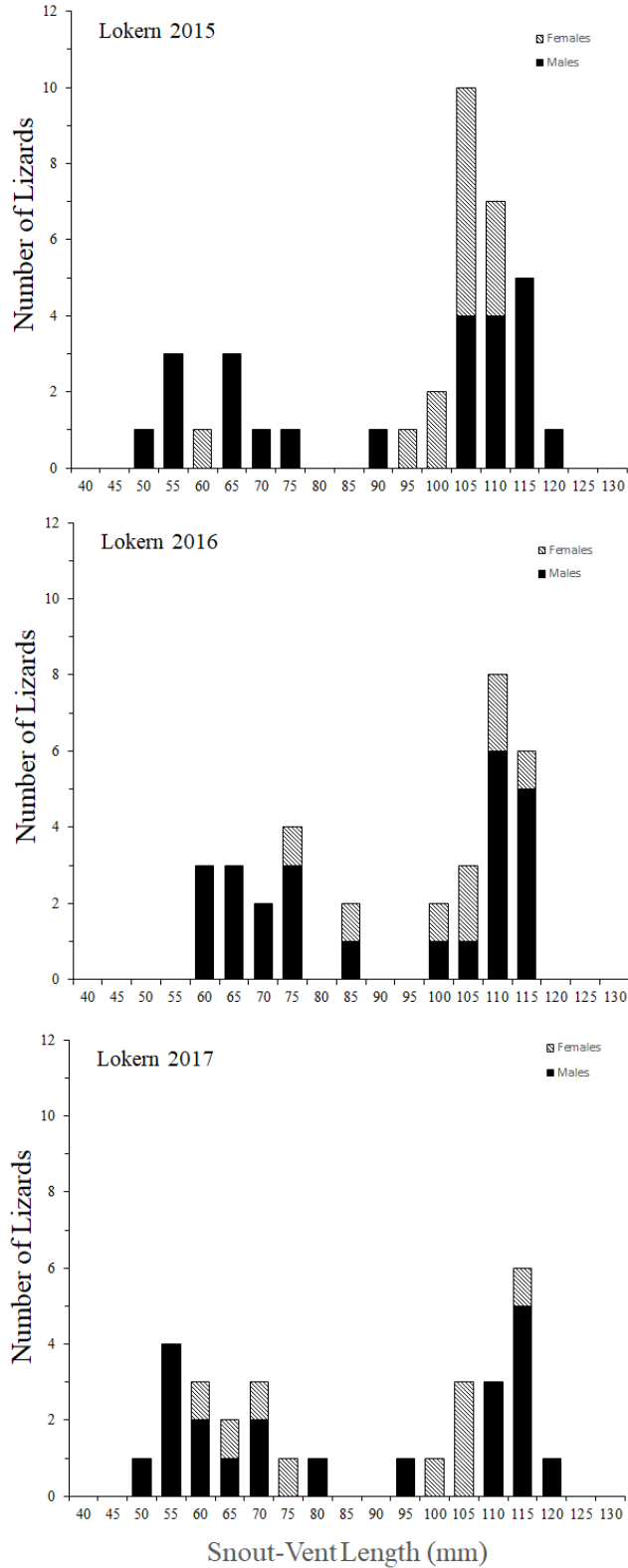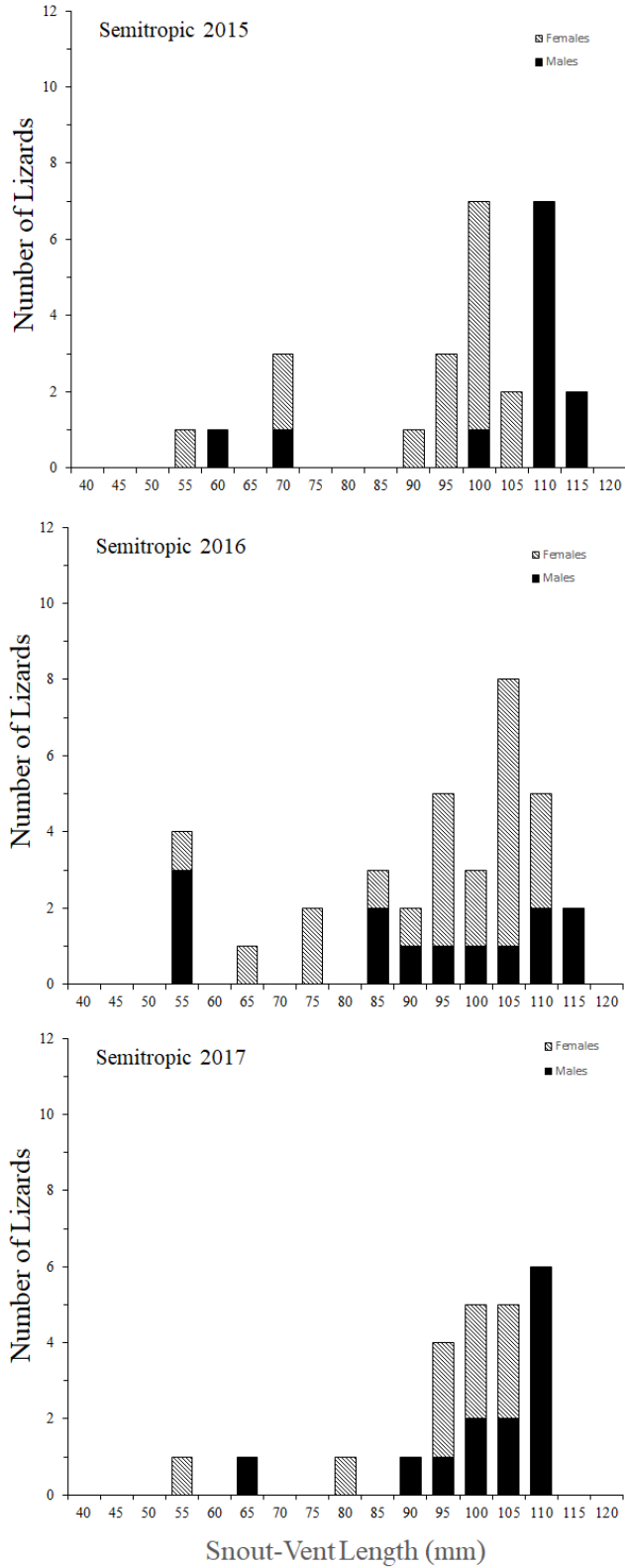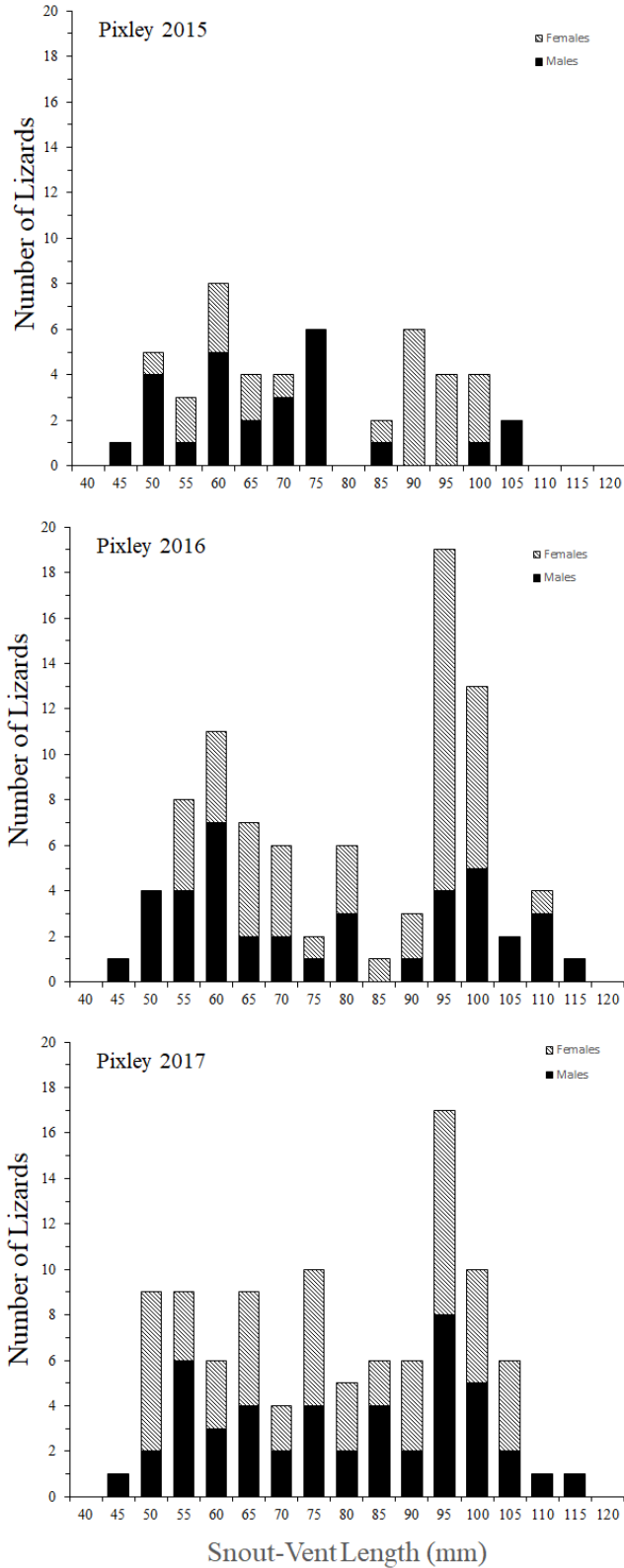
Figure 4. Size distribution by year of *Gambelia sila* at Pixley National Wildlife Refuge from 2015-2017. Males are solid bars and females are striped bars. We used only the SVL of lizards at first capture. The distributions of SVLs did not differ between years (D = 0.235-0.412, P = 0.081-0.673).

Mean clutch size in 2015 was 2.8 (SE = 0.4, N = 5) and range was 2-4 and mode was 3. In 2015 we began surveys on May 29 and found several females with eggs during the first week of June. There were only a few females that we were able to recapture during the 2015 survey season, but we did have one female with at least two clutches, and 3 additional females we know had at least one clutch. Also, we did notice at least two pulses of hatchlings, with small hatchlings appearing July-August, and then another set of small hatchlings appearing in early September. We had one female with three large eggs on June 25, but after this date females were not gravid (N = 6).

Mean clutch size in 2016 was 2.3 (SE = 0.3, N = 30), range was 1-4 and mode was 2. We began surveys on May 2 and all four females captured on this date were gravid, with three having large eggs. In 2016, we found one female that had at least three clutches, five females that had at least two clutches, and an additional 17 females we know had at least one clutch. On July 22 we had one female with 2 medium/large eggs, but all females captured after this date had no eggs (N = 6).

Mean clutch size in 2017 was 2.8 (SE = 0.2, N = 23) range was 2-4 and mode was 2. We began surveys on April 26 and found our first gravid female on May 2, with small eggs. We found 4 females that had at least 2 clutches and another 15 females had at least one clutch. The latest date we captured a female with eggs was August 7, with two large eggs. After this date any females captured were not gravid (N = 8).

Mean clutch size for pooled data for 2015-2017 was 2.5 (SE = 0.1, N = 58), range was 1-4 and mode was 2.

Demographic comparisons between sites

The distribution of SVLs did not differ between years at each site. Therefore, we pooled the data from all three years and compared the distribution of SVLs between sites. When data were pooled the distribution of SVLs did not differ significantly between Lokern and Semitropic (D = 0.177, P = 0.930), but both Lokern and Semitropic differed significantly from Pixley (D = 0.529, P = 0.010 for both comparisons).

We compared the mean and upper quartile (upper 25%) SVL, TL, and mass across sex and sites (Tables 2-7). We used a Kruskal-Wallis test to test for differences between groups. We found that the mean and upper quartile differed significantly for SVL (mean: H = 87.15, df = 5, P < 0.001; upper quartile: H = 38.36, df = 5, P < 0.001), TL (mean: H = 126.40, df = 5, P < 0.001; upper quartile: H = 41.77, df = 5, P < 0.001), and mass (mean: H = 65.43, df = 5, P < 0.001; upper quartile H = 31.85, df = 5, P < 0.001).

We used Mann-Whitney pair-wise comparisons with Legendre and Legendre (1998) adjusted P values to compare between groups. For SVL we found that means differed significantly between males and females at each of the three sites (Table 10) with males being larger than females (Table 2-3). Furthermore, all groups differed significantly from each other except Lokern males - Semitropic males, Semitropic males - Pixley males, Semitropic males - Lokern females, Pixley males - Lokern females, Pixley males - Semitropic females, and Lokern females - Semitropic females (Table 10). For the mean upper quartile SVL we found significant differences between all groups except that males did not differ significantly between the three sites, Pixley males did not differ from Lokern and Semitropic females, and Lokern females did not differ from Semitropic females (Table 11).

Table 10. Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values of mean snout-vent length (SVL; mm) of male and female *Gambelia sila* at Lokern Ecological Reserve (L), Semitropic Ecological Reserve (S) and Pixley National Wildlife Refuge (P).

Comparison	*W*	Adj. *P*-Value	Significance
L-Male / S-Male	1108.5	0.097	No
/ P-Male	1377.0	< 0.001	Yes
/ L-Female	1075.0	< 0.001	Yes
/ S-Female	1293.0	< 0.001	Yes
/ P-Female	2177.0	< 0.001	Yes
S-Male / P-Male	1085.5	0.170	No
/ L-Female	826.0	0.522	No
/ S-Female	1010.0	0.049	Yes
/ P-Female	1795.0	< 0.001	Yes
P-Male / L-Female	888.5	0.359	No
/ S-Female	1119.5	0.497	No
/ P-Female	2030.5	< 0.001	Yes
L-Female / S-Female	663.5	0.185	No
/ P-Female	1331.0	< 0.001	Yes
S-Female / P-Female	1538.5	0.040	Yes

Table 11. Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values of mean upper quartile snout-vent length (SVL; mm) of male and female *Gambelia sila* at Lokern Ecological Reserve (L), Semitropic Ecological Reserve (S) and Pixley National Wildlife Refuge (P).

Comparison	*W*	Adj. *P*-Value	Significance
L-Male / S-Male	78.0	0.591	No
/ P-Male	96.0	0.142	No
/ L-Female	84.0	0.022	Yes
/ S-Female	92.0	0.018	Yes
/ P-Female	148.0	0.003	Yes
S-Male / P-Male	74.5	0.499	No
/ L-Female	68.5	0.046	Yes
/ S-Female	77.0	0.024	Yes
/ P-Female	126.0	0.004	Yes
P-Male / L-Female	75.5	0.724	No
/ S-Female	90.5	0.459	No
/ P-Female	166.0	0.004	Yes
L-Female / S-Female	52.0	0.349	No
/ P-Female	100.5	0.023	Yes
S-Female / P-Female	117.5	0.022	Yes

For TL we found that means differed significantly, between all groups except that Semitropic males did not differ from Lokern females and Pixley males did not differ from Semitropic females (Table 12). For the mean upper quartile TL we found that means differed significantly between all groups except that Semitropic and Pixley males did not

differ significantly and Semitropic males - Lokern females, Pixley males - Lokern females, and Pixley males - Semitropic females did not differ significantly (Table 13).

Table 12. Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values of mean total length (TL; mm) of male and female *Gambelia sila* at Lokern Ecological Reserve (L), Semitropic Ecological Reserve (S) and Pixley National Wildlife Refuge (P).

Comparison	*W*	Adj. *P*-Value	Significance
L-Male / S-Male	1194.0	< 0.001	Yes
/ P-Male	1391.0	< 0.001	Yes
/ L-Female	964.0	< 0.001	Yes
/ S-Female	1236.0	< 0.001	Yes
/ P-Female	2029.5	< 0.001	Yes
S-Male / P-Male	1231.0	< 0.001	Yes
/ L-Female	739.0	1.000	No
/ S-Female	1098.0	< 0.001	Yes
/ P-Female	1958.0	< 0.001	Yes
P-Male / L-Female	772.5	< 0.001	Yes
/ S-Female	1081.0	0.893	No
/ P-Female	2124.0	< 0.001	Yes
L-Female / S-Female	661.0	< 0.001	Yes
/ P-Female	1274.0	< 0.001	Yes
S-Female / P-Female	1578.5	< 0.001	Yes

Table 13. Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values of mean upper quartile total length (TL; mm) of male and female *Gambelia sila* at Lokern Ecological Reserve (L), Semitropic Ecological Reserve (S) and Pixley National Wildlife Refuge (P).

Comparison	*W*	Adj. *P*-Value	Significance
L-Male / S-Male	77.0	0.015	Yes
/ P-Male	91.0	0.011	Yes
/ L-Female	63.0	0.035	Yes
/ S-Female	77.0	0.018	Yes
/ P-Female	126.0	0.004	Yes
S-Male / P-Male	81.0	0.105	No
/ L-Female	44.5	0.935	No
/ S-Female	77.0	0.020	Yes
/ P-Female	126.0	0.004	Yes
P-Male / L-Female	52.0	0.137	No
/ S-Female	78.0	1.000	No
/ P-Female	168.0	0.003	Yes
L-Female / S-Female	661.0	< 0.001	Yes
/ P-Female	1274.0	< 0.001	Yes
S-Female / P-Female	1578.5	< 0.001	Yes

For mass we found that means did not differ significantly between Lokern and Semitropic males, or between Semitropic and Pixley males (Table 14). Pixley males did not differ significantly between Lokern and Semitropic females (Table 14). Females did not differ from each other at any of the sites (Table 14). For the mean upper quartile mass, the only significant differences found were between Lokern males and Pixley females, Semitropic males and Pixley females, and Pixley males and Pixley females (Table 15).

Table 14. Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values of mean mass (g) of male and female *Gambelia sila* at Lokern Ecological Reserve (L), Semitropic Ecological Reserve (S) and Pixley National Wildlife Refuge (P).

Comparison	*W*	Adj. *P*-Value	Significance
L-Male / S-Male	967.5	1.000	No
/ P-Male	1321.5	0.001	Yes
/ L-Female	910.0	0.001	Yes
/ S-Female	1031.5	< 0.001	Yes
/ P-Female	1432.5	< 0.001	Yes
S-Male / P-Male	1121.0	0.055	No
/ L-Female	771.5	0.005	Yes
/ S-Female	876.0	0.005	Yes
/ P-Female	1226.5	< 0.001	Yes
P-Male / L-Female	900.5	0.514	No
/ S-Female	994.5	0.476	No
/ P-Female	1408.0	0.002	Yes
L-Female / S-Female	230.5	0.799	No
/ P-Female	396.5	0.348	No
S-Female / P-Female	586.5	0.255	No

Table 15. Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values of mean upper quartile mass (g) of male and female *Gambelia sila* at Lokern Ecological Reserve (L), Semitropic Ecological Reserve (S) and Pixley National Wildlife Refuge (P).

Comparison	*W*	Adj. *P*-Value	Significance
L-Male / S-Male	58.5	0.563	No
/ P-Male	94.0	0.154	No
/ L-Female	68.0	0.085	No
/ S-Female	68.0	0.077	No
/ P-Female	100.0	0.013	Yes
S-Male / P-Male	83.0	0.089	No
/ L-Female	56.0	0.075	No
/ S-Female	56.0	0.086	No
/ P-Female	84.0	0.020	Yes
P-Male / L-Female	81.0	0.076	No
/ S-Female	33.0	0.290	No
/ P-Female	117.0	0.009	Yes
L-Female / S-Female	11.0	0.181	No
/ P-Female	30.0	1.000	No
S-Female / P-Female	41.0	0.069	No

We calculated the mean clutch size for each site by pooling data from 2015-2017 because of small sample sizes. Mean clutch size for Lokern was 2.47 (SE = 0.15, N = 17), Semitropic was 2.47 (SE = 0.10, N = 47), and Pixley was 2.53 (SE = 0.11, N = 53; Table 16). Because data was nonparametric even after transformations we compared the pooled 2015-2017 mean clutch size between sites using a Kruskal-Wallis test. We found that the mean clutch size did not differ between sites (H = 0.020, df = 2, P = 0.990).

Table 16. Comparison of the mean clutch size of *Gambelia sila* at three study sites in the Southern San Joaquin Desert. We pooled data over three years (2015-2017). The groups did not differ significantly (H = 0.020, df = 2, P = 0.990).

	n	Mean	SE	Low	High	95% CI
Lokern	17	2.47	0.15	2	4	0.32
Semitropic	47	2.47	0.10	1	4	0.20
Pixley	58	2.53	0.11	1	4	0.22

Opportunistic Surveys

Buttonwillow ER

We surveyed Buttonwillow ER opportunistically during the three years of this study. We found hatchlings/juveniles present on the site each year of the study, although in very low numbers (Table 17).

Table 17. Number of unique adult and hatchling/juvenile *Gambelia sila* captured per year at Buttonwillow Ecological Reserve (NCD = number of census days, PH = person hours (number of surveyors * hours spent surveying)). We conducted no surveys during the adult season in 2016.

	NCD	PH	Adults	Hatchlings/Juveniles
2015	8	54.6	4	1
2016	3	4.3	--	2
2017	3	6.7	1	2
Total	**14**	**65.6**	**5**	**5**

Allensworth ER

We surveyed Allensworth ER opportunistically during the three years of this study. We found hatchlings/juveniles present on the site in 2015 and 2017, but not in 2016 (Table 18).

Table 18. Number of unique adult and hatchling/juvenile *Gambelia sila* captured per year at Allensworth Ecological Reserve (NCD = number of census days PH = person hours (number of surveyors * hours spent surveying)).

	NCD	PH	Adults	Hatchlings
2015	5	25.0	5	1
2016	2	5.0	2	0
2017	2	13.8	4	2
Total	**9**	**43.8**	**11**	**3**

Survivorship

We estimated a minimum survivorship percentage at our three study sites for Year 2 (2016) and Year 3 (2017) of our study (Table 19). Survivorship of hatchlings ranged from 6.3 – 40.0% at the three sites in 2016 and 2017 (Table 19). Survivorship of 2-year olds was similar and ranged from 7.1 – 35.7% (Table 19). Semitropic was the only site that we found lizards in their third year (30.0% of those marked in 2015 survived).

Table 19. Estimated minimum survivorship (%) of *Gambelia sila* in Year 2 (2016) and Year 3 (2017) of this study at three sites in the Southern San Joaquin Desert. Number marked refers to the number of lizards marked during the period in parenthesis. Number found refers to age class in each row.

Study year / Site / Age group	Number marked	Number found	Survivorship (%)
Year 2 - 2016			
Lokern			
1-year old			
(hatched fall 2015)	16	1	6.3%
At least 2-year old			
(found on grid spring 2015 – start of study)	14	5	35.7%
Semitropic			
1-year old			
(hatched fall 2015)	5	2	40.0%
At least 2-year old			
(found on grid spring 2015 – start of study)	20	9	45.0%
Pixley			
1-year old			
(hatched fall 2015)	33	11	33.3%
At least 2-year old			
(found on grid spring 2015 – start of study)	16	5	29.4%
Year 3 - 2017			
Lokern			
1-year old			
(hatched fall 2016)	15	3	20.0%
At least 2-year old			
(marked in spring 2016)	11	3	27.3%
At least 3-year old			
(found on grid spring 2015– start of study)	14	0	0%
Semitropic			
1-year old			
(hatched fall 2016)	7	2	28.6%
At least 2-year old			
(marked in spring 2016)	28	2	7.1%
At least 3-year old			
(found on grid spring 2015– start of study)	20	3	30.0%
Pixley			
1-year old			
(hatched fall 2016)	42	9	21.4%
At least 2-year old			
(marked in spring 2016)	43	9	19.1%
At least 3-year old			
(found on grid spring 2015– start of study)	16	0	0%

Prey Abundance

We compiled primary prey abundance data for BNLL, which are grasshoppers and side-blotch lizards (*Uta stansburiana)*, on our three monitoring sites over three years (Tables 20 and 21). Western whiptail lizards (*Aspidoscelis tigris*) were also present on our three sites and we counted them during censuses, but we did not consider them a primary prey item of BNLL. At Pixley, we only detected one or two whiptails during the entire three year survey period. At Lokern, we sometimes detected one during a census (range 0-3). At Semitropic, we detected whiptails in the range of 0-8 per census during our survey years.

Grasshoppers

For grasshoppers at Lokern ER, we found that the adult season grasshopper numbers were highest in 2017 at 437.1 (SE = 96.3, N = 29; Table 20). In both the 2016 and 2017 adult season, we had a short spike in grasshopper number in early May (Table 20). We used a Kruskal-Wallis test to determine that there were significant differences in the mean number of grasshoppers during the adult and hatchling/juvenile season over the three years of our study (adult: H = 18.7, df = 2, P < 0.001; hatchling/juvenile: H = 9.4, df = 2, P = 0.009). We followed up with Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values (1998) and found that the mean number of grasshoppers per census during the adult season only differed significantly from 2015 to 2016 (Table 21). The hatchling season grasshopper mean differed significantly from 2015 to 2016 and the adult and hatchling season grasshopper mean only differed significantly in 2016 (Table 21).

For grasshoppers at Semitropic ER, we found that the adult season grasshopper numbers were highest in 2017 at 291.1 (SE = 24.2, N = 28; Table 20) and the hatchling season grasshoppers were highest in 2017 at 238.9 (SE = 19.5, N = 30; Table 20). We used a Kruskal-Wallis test to determine that there were significant differences in the mean number of grasshoppers during the adult and hatchling/juvenile season over the three years of our study (adult: H = 32.6, df = 2, P < 0.001; hatchling/juvenile: H = 41.7, df = 2, P < 0.001). We followed up with Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values (1998) and found that the mean number of grasshoppers per census during the adult season differed significantly in all years (Table 21). The hatchling season grasshopper mean differed significantly between 2015 and 2017 and 2016 and 2017 (Table 21). The adult and hatchling season grasshopper mean differed significantly between 2015 and 2016, but not 2017 (Table 21). In 2015 and 2016, the grasshopper mean was lower during the hatchling season (Table 20).

For grasshoppers at Pixley NWR, we found that the adult season grasshopper numbers were highest in 2017 at 225.8 (SE = 17.6, N = 26; Table 20) and the hatchling season grasshoppers were highest in 2017 at 342.9 (SE = 18.3, N = 32; Table 21). We used a Kruskal-Wallis test to determine that there were significant differences in the mean number of grasshoppers during the adult and hatchling/juvenile season over the three years of our study (adult: H = 25.4, df = 2, P < 0.001; hatchling/juvenile: H = 62.6, df = 2, P < 0.001). We followed up with Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values (1998) and found that the mean number of grasshoppers per census during the adult season differed significantly between 2015 and 2017 and also between 2016 and 2017 (Table 21). The hatchling season grasshopper mean also differed significantly between 2015 and 2017 and 2016 and 2017 (Table 21). The adult and

hatchling season grasshopper mean differed significantly only in 2017 (Table 21) and in this case Pixley was the only site were the grasshopper mean increased during the hatchling season (Table 20).

Table 20. Number of census days (NCD), mean, standard error (SE), Range (Low, High) and 95% confidence interval (CI) for grasshoppers counted during walking surveys for *Gambelia sila* at three monitoring plots in the San Joaquin Desert from 2015-2017. We separated data by adult season (April-July) and hatchling/juvenile season (July-October).

	NCD	Mean	SE	Low	High	95% CI
Adult season (April-July)						
Lokern						
2015	19	105.9	7.5	52	192	15.8
2016	26	352.2	67.6	100	1316	139.2
2017	29	437.1	96.3	41	1779	197.3
Semitropic						
2015	26	111.3	5.7	57	177	11.8
2016	28	177.8	15.2	70	462	31.2
2017	28	291.1	24.2	30	518	49.6
Pixley						
2015	24	119.9	6.8	84	200	14.1
2016	27	111.0	6.9	47	165	14.2
2017	26	225.8	17.6	57	400	36.2
Hatchling/Juvenile season (July-October)						
Lokern						
2015	33	93.9	6.7	16	168	13.6
2016	32	121.4	5.2	58	166	10.6
2017	31	116.3	6.9	31	196	14.0
Semitropic						
2015	33	72.4	5.4	22	126	11.1
2016	32	78.3	6.0	26	192	12.2
2017	30	238.9	19.5	47	470	39.8
Pixley						
2015	31	117.8	7.3	55	206	15.0
2016	32	115.3	5.6	39	165	11.4
2017	32	342.9	18.3	192	564	37.3

Table 21. Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values of mean number of grasshoppers sighted per census during the adult season (April – July) at Lokern Ecological Reserve (L), Semitropic Ecological Reserve (S) and Pixley National Wildlife Refuge (P).

Comparison	*W*	Adjusted *P*-value	Significance
L adult 2015 / L adult 2016	43	0.003	Yes
/ L adult 2017	153	0.914	No
/ L hatch 2015	264	2.470	No
L adult 2016/ L adult 2017	303	1.720	No
/ L hatch 2016	123	0.003	Yes
L hatch 2015 / L hatch 2016	305.5	0.047	Yes
/ L hatch 2017	343.5	0.293	No
L hatch 2016/ L hatch 2017	453.5	2.810	No
L adult 2017 / L hatch 2017	302.5	0.330	No
S adult 2015 / S adult 2016	154.5	0.005	Yes
/ S adult 2017	74.5	0.003	Yes
/ S hatch 2015	158	0.003	Yes
S adult 2016/ S adult 2017	182	0.008	Yes
/ S hatch 2016	74	0.002	Yes
S hatch 2015 / S hatch 2016	485	2.302	No
/ S hatch 2017	78.5	0.002	Yes
S hatch 2016/ S hatch 2017	91.5	0.002	Yes
S adult 2017 / S hatch 2017	308.5	0.836	No
P adult 2015 / P adult 2016	287.5	2.979	No
/ P adult 2017	100	0.002	Yes
/ P hatch 2015	345.5	1.320	No
P adult 2016/ P adult 2017	98	0.002	Yes
/ P hatch 2016	401.5	1.937	No
P hatch 2015 / P hatch 2016	469.5	0.719	No
/ P hatch 2017	4	0.002	Yes
P hatch 2016/ P hatch 2017	0	0.002	Yes
P adult 2017 / P hatch 2017	176.5	0.003	Yes

Between sites grasshoppers only differed significantly during the adult season in 2016 (2015: H = 1.67, df = 2, P = 0.428; 2016: H = 26.27, df = 2, P < 0.001; 2017: H = 2.90, df = 2, P = 0.235). Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values (1998) on 2016 data showed that all three sites differed from each other (Table 22).

Table 22. Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values of mean number of grasshoppers sighted per census during the adult season (April – July) in 2016 at Lokern Ecological Reserve (L), Semitropic Ecological Reserve (S) and Pixley National Wildlife Refuge (P).

Comparison	*W*	Adjusted *P*-value	Significance
L adult 2016 / S adult 2016	240.5	0.033	Yes
/ P adult 2016	86.5	<0.001	Yes
S adult 2016 / P adult 2016	164.5	<0.001	Yes

For the hatchling/juvenile season, there were significant differences in the mean number of grasshoppers per census between sites in all three years (2015: H = 17.9, df = 2, P < 0.001; 2016: H = 27.5, df = 2, P < 0.001; 2017: H = 51.6, df = 2, P < 0.001). We followed up with Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values (1998) and found that the mean number of grasshoppers per census during the hatchling/juvenile season differed significantly between sites in all years except Lokern and Semitropic in 2015 and Lokern and Pixley in 2016 (Table 23).

Table 23. Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values of mean number of grasshoppers sighted per census during the hatchling/juvenile season (July – October) at Lokern Ecological Reserve (L), Semitropic Ecological Reserve (S) and Pixley National Wildlife Refuge (P).

Comparison	W	Adjusted P-value	Significance
L hatch 2015 / S hatch 2015	371	0.158	No
/ P hatch 2015	357.5	<0.001	Yes
S hatch 2015 / P hatch 2015	199.5	<0.001	Yes
L hatch 2016 / S hatch 2016	157.5	<0.001	Yes
/ P hatch 2016	467	0.519	No
S hatch 2016 / P hatch 2016	195.5	<0.001	Yes
L hatch 2017 / S hatch 2017	157.5	<0.001	Yes
/ P hatch 2017	2	<0.001	Yes
S hatch 2017 / P hatch 2017	243.5	0.003	Yes

Side-blotch lizards (Uta stansburiana)

For side-blotch lizards at Lokern ER, we found that the side-blotch lizard numbers were highest in 2016 for both the adult season at 55.1 (SE = 6.8, N = 26) and the hatchling/juvenile season at 113.8 (SE = 9.7, N = 32; Table 24). We used a Kruskal-Wallis test to determine that there were significant differences in the mean number of side-blotch lizards during the adult and hatchling/juvenile season over the three years of our study (adult: H = 13.3, df = 2, P = 0.001; hatchling/juvenile: H = 16.7, df = 2, P = 0.001). We followed up with Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values (1998) and found that the mean number of side-blotch lizards per census during the adult season differed from the hatchling season in all years (Table 25). The hatchling season had more than double the number of side-blotch lizards as the adult season (Table 24). The adult season side-blotch lizard mean only differed significantly between 2016 and 2017 (Table 25). The hatchling season side-blotch lizard mean differed significantly between 2015 and 2016 and between 2016 and 2017 (Table 25).

For side-blotch lizards at Semitropic ER, we found that the adult season side-blotch lizard mean was highest in 2015 at 11.4 (SE = 1.6, N = 26) and the hatchling season side-blotch lizard mean was highest in 2017 at 32.1 (SE = 4.5, N = 30; Table 24). We used a Kruskal-Wallis test to determine that there were significant differences in the mean number of side-blotch lizards during the adult and hatchling/juvenile season over the three years of our study (adult: H = 6.03, df = 2, P = 0.049; hatchling/juvenile: H = 8.10, df = 2, P = 0.017). We followed up with Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values (1998) and found that the mean number of side-blotch lizards per census during the adult season and during the hatchling/juvenile season had no significant

differences (Table 25). The only significant difference was between the adult and hatchling/juvenile seasons in 2016 (Table 25). The mean in the hatchling/juvenile season was double the adult season mean (Table 24).

For side-blotch lizards at Pixley NWR, we found that the adult season side-blotch lizard mean was highest in 2015 at 47.1 (SE = 6.2, N = 24) and the hatchling season side-blotch lizard mean was highest in 2015 at 39.5 (SE = 3.6, N = 31; Table 24). We used a Kruskal-Wallis test to determine that there were significant differences in the mean number of side-blotch lizards during the adult and hatchling/juvenile season over the three years of our study (adult: H = 26.97, df = 2, P < 0.001; hatchling/juvenile: H = 12.20, df = 2, P = 0.002). We followed up with Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values (1998) and found that the mean number of side-blotch lizards per census in the adult season and the hatchling/juvenile season was significantly different between 2016 and 2017 but not 2015 (Table 25). In 2016 and 2017 the hatchling/juvenile season side-blotch lizard mean was larger than the adult season mean (Table 24). The 2015 adult season side-blotch lizard mean was significantly different from the 2016 and 2017 means (Table 25). The mean in the hatchling/juvenile season was only significantly different between 2015 and 2016 (Table 25).

Table 24. Number of census days (NCD), mean, standard error (SE), Range (Low, High) and 95% confidence interval (CI) for side-blotch lizards (*Uta stansburiana*) counted during walking surveys for *Gambelia sila* at three monitoring plots in the San Joaquin Desert from 2015-2017. We separated data by adult season (April-July) and hatchling/juvenile season (July-October).

	NCD	Mean	SE	Low	High	95% CI
Adult season (April-July)						
Lokern						
2015	19	31.1	4.3	4	74	9.0
2016	26	55.1	6.8	6	129	14.1
2017	29	23.6	2.9	8	64	6.0
Semitropic						
2015	26	11.4	1.6	0	26	3.2
2016	28	10.5	1.2	1	26	2.5
2017	28	6.7	1.0	0	22	2.1
Pixley						
2015	24	47.1	6.2	7	98	12.8
2016	27	13.9	1.6	0	33	3.4
2017	26	10.1	1.4	2	28	2.9
Hatchling/Juvenile season (July-October)						
Lokern						
2015	33	70.9	6.9	4	147	14.0
2016	32	113.8	9.7	6	238	19.8
2017	31	69.7	5.3	22	143	10.9
Semitropic						
2015	33	18.2	1.8	2	49	3.7
2016	32	23.4	1.5	6	41	3.1
2017	30	32.1	4.5	3	92	9.3
Pixley						
2015	31	39.5	3.6	8	91	7.3
2016	32	23.0	1.4	10	46	2.8
2017	32	28.2	2.6	2	59	5.3

Table 25. Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values of mean number of side-blotched lizards (*Uta stansburiana)* sighted per census during the adult season (April – July) at Lokern Ecological Reserve (L), Semitropic Ecological Reserve (S) and Pixley National Wildlife Refuge (P).

Comparison	*W*	Adjusted *P*-value	Significance
L adult 2015 / L adult 2016	153.5	0.291	No
/ L adult 2017	197.5	0.619	No
/ L hatch 2015	117	0.006	Yes
L adult 2016/ L adult 2017	173.5	0.010	Yes
/ L hatch 2016	144.5	0.002	Yes
L hatch 2015 / L hatch 2016	275.5	0.014	Yes
/ L hatch 2017	504	0.928	No
L hatch 2016/ L hatch 2017	222.5	0.005	Yes
L adult 2017 / L hatch 2017	67	0.003	Yes
S adult 2015 / S adult 2016	356.5	1.809	No
/ S adult 2017	246.5	0.339	No
/ S hatch 2015	266.5	0.189	No
S adult 2016/ S adult 2017	258.5	0.293	No
/ S hatch 2016	103	<0.001	Yes
S hatch 2015 / S hatch 2016	342	0.196	No
/ S hatch 2017	321	0.198	No
S hatch 2016/ S hatch 2017	433	1.547	No
S adult 2017 / S hatch 2017	75.5	<0.001	Yes
P adult 2015 / P adult 2016	111.5	<0.001	Yes
/ P adult 2017	71.5	<0.001	Yes
/ P hatch 2015	325	1.172	No
P adult 2016/ P adult 2017	250	0.514	No
/ P hatch 2016	188.5	0.004	Yes
P hatch 2015 / P hatch 2016	245	0.010	Yes
/ P hatch 2017	336	0.314	No
P hatch 2016/ P hatch 2017	420	1.09	No
P adult 2017 / P hatch 2017	107.5	<0.001	Yes

Between sites side-blotch lizards differed significantly during the adult season in every year (2015: H = 24.57, df = 2, P < 0.001; 2016: H = 33.21, df = 2, P < 0.001; 2017: H = 34.64, df = 2, P < 0.001). Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values (1998) showed significant differences in all comparisons except Lokern and Pixley in 2015, and Semitropic and Pixley in 2016 and 2017 (Table 26).

Table 26. Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values of mean number of side-blotch lizards (*Uta stansburiana)* sighted per census during the adult season (April – July) at Lokern Ecological Reserve (L), Semitropic Ecological Reserve (S) and Pixley National Wildlife Refuge (P).

Comparison	*W*	Adjusted *P*-value	Significance
L adult 2015 / S adult 2015	73	<0.001	Yes
/ P adult 2015	161.5	0.215	No
S adult 2015 / P adult 2015	94	<0.001	Yes
L adult 2016 / S adult 2016	64	<0.001	Yes
/ P adult 2016	92	<0.001	Yes
S adult 2016 / P adult 2016	296.5	0.174	No
L adult 2017 / S adult 2017	61	<0.001	Yes
/ P adult 2017	128.5	<0.001	Yes
S adult 2017 / P adult 2017	261	0.230	No

For the hatchling/juvenile season, there were significant differences in the mean number of side-blotch lizards per census between sites in all three years (2015: $H = 43.77$, df $= 2$, $P < 0.001$; 2016: $H = 45.83$, df $= 2$, $P < 0.001$; 2017: $H = 33.50$, df $= 2$, $P < 0.001$). We followed up with Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values (1998) and found that the mean number of side-blotch lizards per census during the hatchling/juvenile season differed significantly between sites all years except Semitropic and Pixley in 2016 and 2017 (Table 27).

Table 27. Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values of mean number of side-blotch lizards (*Uta stansburiana)* sighted per census during the hatchling season (July – October) at Lokern Ecological Reserve (L), Semitropic Ecological Reserve (S) and Pixley National Wildlife Refuge (P).

Comparison	*W*	Adjusted *P*-value	Significance
L hatch 2015 / S hatch 2015	92	<0.001	Yes
/ P hatch 2015	253	0.002	Yes
S hatch 2015 / P hatch 2015	169.5	<0.001	Yes
L hatch 2016 / S hatch 2016	77	<0.001	Yes
/ P hatch 2016	77	<0.001	Yes
S hatch 2016 / P hatch 2016	474.5	1.234	No
L hatch 2017 / S hatch 2017	145.5	<0.001	Yes
/ P hatch 2017	106	<0.001	Yes
S hatch 2017 / P hatch 2017	478.5	0.992	No

Precipitation and Plant Productivity

We began our study in the spring of 2015, just following a multiyear drought (Figure 5). We had no major fluctuations in precipitation at our three sites from 2015-2017 (Figure 5). In the 2014-2015 water year, rainfall was below normal, and in the following 2 years, rainfall was near normal or just above normal. The final year of the study, 2016-2017, had the highest amounts of precipitation at all three sites and, again, was near normal or just above normal (Figure 5).

Residual dry matter (RDM) collected at the three study sites was lowest in at each site in 2016 and highest in 2017 (Table 28).

Table 28. Residual dry matter (RDM; g/m^2) for Lokern, Semitropic and Pixley from 2015-2017. We collected RDM each fall, in late September through early October. Pixley was cattle grazed each year during our study.

Year	Lokern	Semitropic	Pixley
2015	26.0	22.6	76.8
2016	16.5	14.0	35.1
2017	101.1	76.5	107.2

Although we only had three sample data points (three years of data), we tested for correlations between various data scenarios on all sites using a Pearson's product moment correlation. These scenarios included RDM – rainfall, RDM/rainfall – BNLL adult/hatchling census numbers, RDM/rainfall – adult/hatchling grasshopper numbers, and RDM/rainfall – adult/hatchling side-blotch lizard numbers. We found no significant correlations in these data.
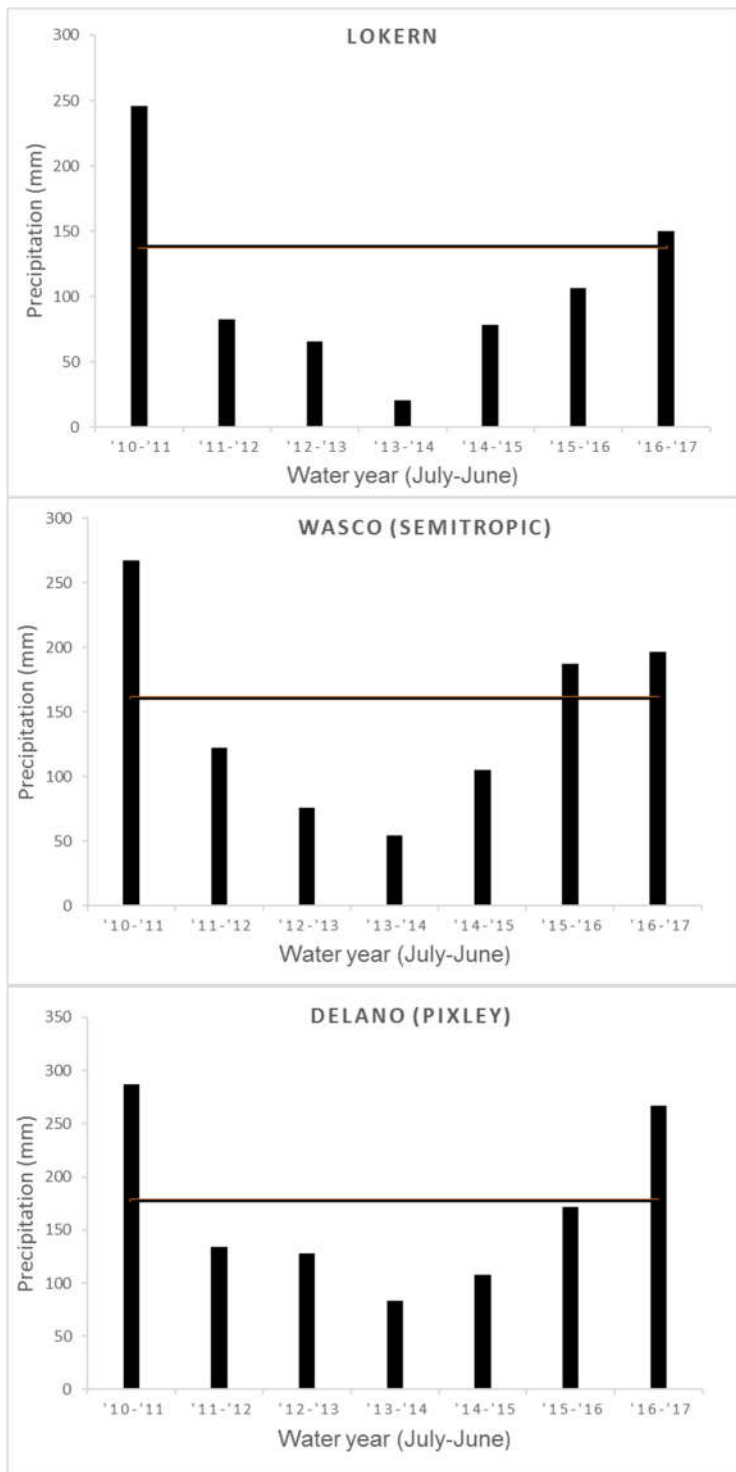
Figure 5. Precipitation data from the nearest weather stations to the study plots, except Lokern ER data, which is from a local rain gauge operated by the Center for Natural Lands Management. The monitoring station at Wasco is closest to Semitropic ER, and Delano the closest to Pixley NWR. The horizontal line is the mean annual rainfall calculated for each site by the Western Regional Climate Center (https://wrcc.dri.edu/). For Buttonwillow the mean is 138.4 mm, for Wasco the mean is 160.7 mm and for Delano the mean is 177.4 mm.

TELEMETRY, MOVEMENT, AND HOME RANGE

We radio-tracked BNLL in 2015 and 2016 at Semitropic ER and Pixley NWR.

At Semitropic, we had 20 or more locations for 11 males and 13 females. In 2015 the mean number of locations on radio-collared lizards was 35.0 (SE = 1.99; range 22-47) and in 2016 the mean number of locations was 43.6 (SE = 2.79, range 20-55). At Semitropic, we had two males and two females that were radio-collared in both years.

At Pixley, we had 23 or more locations for 11 males and 8 females. In 2015, we only successfully tracked one male and 2 females, but in 2016 we tracked 10 males and 6 females. The mean number of locations in 2015 was 32.7 (SE = 1.20, range 31-35) and in 2016 it was 37.4 (SE = 0.66, range 23-53). At Pixley, we had one male and one female that we tracked in both years.

We pooled data between 2015 and 2016 because of small sample sizes (Table 29). At Pixley, the mean home range for males was just slightly larger than females, but this difference was not significant (t = 1.42, P = 0.087; Table 29). At Semitropic, the mean home range for females was larger than males, but, again, this difference was not significant (t = -0.465, P = 0.647; Table 29).

Between sites, we found that males at Semitropic had home ranges nearly 3 times that of males at Pixley (Table 29). We also found that females at Semitropic had home ranges nearly 6 times larger than Pixley (Table 29). We found means were significantly different between sites for both males (t = -5.59, P <0.001) and females (t = -3.33, P <0.001).

Table 29. Sample size (n), mean, standard error (SE) and range of 95% Minimum Convex Polygon (MCP) home range sizes (ha) of male and female *Gambelia sila* in 2015 and 2016 at Semitropic ER and Pixley NWR.

Site/Year/Sex	n	Mean	SE	Range
Semitropic				
2015				
Males	5	5.59	0.85	3.47 - 8.19
Females	7	6.16	2.53	1.66 - 13.51
2016				
Males	6	5.58	0.92	2.66 - 9.06
Females	6	8.39	1.45	2.34 - 19.58
Years combined				
Males	11	5.58	0.60	2.66 - 9.06
Females	13	7.19	1.37	1.66 - 19.58
Pixley				
2015				
Males	1	1.62	--	--
Females	2	1.14	0.05	1.09 - 1.18
2016				
Males	10	1.92	0.43	0.73 - 4.99
Females	6	1.25	0.44	0.22 - 1.91
Years combined				
Males	11	1.89	0.39	0.73 - 4.99
Females	8	1.22	0.32	0.22 - 1.91

Mean distance moved between consecutive days was greater for males than females at both sites (Table 30). The means between males and females were significantly different at both sites (Pixley: t = 2.19, P = 0.043; Semitropic: t = 3.62, P = 0.002) and different between males and females between sites (males: t = -4.10, P < 0.001; females: t = -3.01, P = 0.007).

Table 30. Sample size (n), mean, standard error (SE), and range of mean distance moved (m) between consecutive days by male and female *Gambelia sila* in 2015 and 2016 at Semitropic ER and Pixley NWR.

Site/Year/Sex	n	Mean	SE	Range
Semitropic				
2015				
Males	5	131.52	8.29	103.8 – 155.5
Females	7	94.15	8.78	69.4 – 117.8
2016				
Males	6	114.97	9.12	76.6 – 141.2
Females	6	78.91	8.56	51.0 – 135.4
Years combined				
Males	11	122.49	6.48	76.6 – 155.5
Females	13	78.91	8.56	51.0 – 135.4
Pixley				
2015				
Males	1	50.6	--	--
Females	2	65.3	3.7	61.6 – 69.0
2016				
Males	10	81.1	10.9	52.2 – 170.9
Females	6	51.3	9.44	36.1 – 72.9
Years combined				
Males	11	78.3	10.23	50.6 – 170.9
Females	8	54.8	4.76	36.1 – 72.9

Mean greatest distance moved between consecutive days was greater for females than males at Semitropic and nearly the same for both sexes at Pixley (Table 31). The means between males and females were not significantly different at either site (Pixley: t = 0.736, P = 0.472; Semitropic: W = 55, P = 0.352). Between sites, males and females were significantly different, with the mean greatest distance moved between consecutive days being larger at Semitropic for males (t = -2.84, P = 0.010) and for females (t = -2.37, P = 0.028) than at Pixley. At least three of our radio-collared females at Semitropic made long distance movements associated with egg laying (movements ranged from 597.2 – 1344.7 m). One female at Pixley also moved in association with egg laying (moved 234.7 m).

Table 31. Sample size (n), mean, standard error (SE), and range of greatest distance moved (m) between consecutive days by male and female *Gambelia sila* in 2015 and 2016 at Semitropic ER and Pixley NWR.

Site/Year/Sex	n	Mean	SE	Range
Semitropic				
2015				
Males	5	328.94	20.82	275.7 – 386.9
Females	7	312.42	48.52	136.8 – 441.8
2016				
Males	6	294.72	30.44	199.2 – 402.1
Females	6	439.04	91.75	156.0 – 1152.0
Years combined				
Males	11	310.27	18.99	275.7 – 402.1
Females	13	380.60	70.75	136.8 – 1152.0
Pixley				
2015				
Males	1	247.70	--	--
Females	2	200.00	17.60	182.4 – 217.6
2016				
Males	10	238.32	28.36	155.1 – 475.5
Females	6	247.22	40.28	116.6 – 356.5
Years combined				
Males	11	239.17	25.67	155.1 – 475.5
Females	8	235.41	30.66	116.6 – 356.5

PROBABILITY OF DETECTION

We estimated our detection rate each time we walked the census plot by determining whether radio-collared lizards were on or off the plot and, if they were on the plot and available for detection, whether they were detected during the census walking survey. At Semitropic in 2015 we calculated mean detection as 0.48 (SE = 0.09, N = 17) and in 2016 we calculated mean detection as 0.71 (SE = 0.05, N = 25). Because of small sample sizes we pooled the data between the two years and found a mean detection at Semitropic as 0.62 (SE = 0.05, N = 42). At Pixley in 2015 we calculated a mean detection as 0.34 (SE = 0.08, N = 17) and in 2016 we calculated the mean detection as 0.78 (SE = 0.04, N = 22). Again, because of small sample sizes we pooled the data between the two years and found

a mean detection at Pixley of 0.59 (SE = 0.05, N = 39). Pooled means did not differ significantly between the two sites (W = 785.5, P = 0.757).

POPULATION ABUNDANCE AND DENSITY

Census data Lokern ER

At Lokern ER, we found that the population on the census plot was highest in 2015 at a mean of 3.68 adults/census (SE = 0.34, N = 19) and the smallest in 2016 at 1.00 (SE = 0.18, N = 26; Figure 6; Table 32). In both 2015 and 2017, the mean number of lizards found on the census plot peaked in June (Figure 6). In 2016, the mean number of lizards on the plot was slightly higher in August (Figure 6), although low numbers of lizards were found on the plot during 2016. We used a Kruskal-Wallis test to determine that the number of lizards sighted per census at Lokern was significantly different between years (H = 28.33, df = 2, P < 0.001). We followed up with Mann-Whitney pair-wise comparisons with Legendre and Legendre adjusted P values (1998) to determine that the mean number of adult lizards per census differed significantly each year (Table 33).

The mean number of hatchlings/juveniles sighted per census on the plot at Lokern ER was highest in 2016 at 2.63 (SE = 0.37, N = 32) and lowest in 2015 at 2.00 (SE = 0.26, N = 33; Figure 6; Table 32). The hatchlings/juveniles first emerged each year in early July. In 2016 and 2017, we found the highest number of hatchlings/juveniles per census in September, while in 2015 the highest number was found in August (Figure 6). We used a Kruskal-Wallis test to determine that the number of hatchlings/juveniles sighted per census at Lokern was not significantly different between years (H = 1.21, df = 2, P = 0.55).

Table 32. Mean number of *Gambelia sila* adults (April – July) and hatchlings/juveniles (July-October) sighted per census (NCD = number of census days) at three monitoring plots in the Southern San Joaquin Desert from 2015-2017.

	NCD	Mean	SE	Low	High	95% CI
Adults (April-July)						
Lokern						
2015	19	3.68	0.34	1	6	0.72
2016	26	1.00	0.18	0	3	0.36
2017	29	2.48	0.29	0	7	0.60
Semitropic						
2015	26	2.62	0.30	0	6	0.63
2016	28	4.21	0.31	2	8	0.63
2017	28	3.89	0.39	0	7	0.80
Pixley						
2015	24	2.25	0.26	0	5	0.55
2016	27	10.00	0.54	5	16	1.12
2017	26	4.92	0.39	2	8	0.81
Hatchling/Juveniles (July-October)						
Lokern						
2015	33	2.00	0.26	0	5	0.52
2016	32	2.63	0.37	0	8	0.75
2017	31	2.32	0.31	0	7	0.64
Semitropic						
2015	33	0.64	0.12	0	2	0.25
2016	32	0.88	0.15	0	3	0.31
2017	30	0.63	0.17	0	3	0.35
Pixley						
2015	31	5.42	0.52	0	10	1.06
2016	32	5.84	0.61	0	13	1.25
2017	32	7.28	1.03	0	19	2.10

Figure 6. Mean number of adult (top) and hatchling/juvenile (bottom) *Gambelia sila* **sighted during each census month at Lokern ER from 2015-2017. We first sighted hatchlings/juveniles in early July each year.**

Table 33. Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values of mean number of *Gambelia sila* sighted per census during the adult season (April – July) at Lokern Ecological Reserve (L), Semitropic Ecological Reserve (S) and Pixley National Wildlife Refuge (P).

Comparison	*W*	Adjusted *P*-value	Significance
L adult 2015 / L adult 2016	42	<0.001	Yes
/ L adult 2017	155	0.034	Yes
L adult 2016/ L adult 2017	151	<0.001	Yes
S adult 2015 / S adult 2016	172.5	0.004	Yes
/ S adult 2017	220.5	0.026	Yes
S adult 2016/ S adult 2017	388	0.952	No
P adult 2015 / P adult 2016	3	<0.001	Yes
/ P adult 2017	89.5	<0.001	Yes
P adult 2016/ P adult 2017	65	<0.001	Yes

Census data Semitropic ER

At Semitropic ER, we found that the population on the census plot was highest in 2016 at a mean of 4.21 adults/census (SE = 0.31, N = 28) and the smallest in 2015 at 2.62 (SE = 0.30, N = 26; Figure 7; Table 32). In both 2015 and 2016, the mean number of lizards found on the census plot was highest in May (Figure 7). In 2017, the mean number of lizards found per census was highest in July (Figure 7). We used a Kruskal-Wallis test to determine that the number of lizards sighted per census at Semitropic was significantly different between years (H = 11.19, df = 2, P = 0.004). We followed up with Mann-Whitney pair-wise comparisons with Legendre and Legendre adjusted P values (1998) and determined that the mean number of adult lizards per census in 2015 differed significantly from 2016 and that the 2015 mean differed significantly from the 2017 mean (Table 33). However, the mean number of adults per census in 2016 and 2017 did not differ significantly (Table 33).

The mean number of hatchlings/juveniles sighted per census on the plot at Semitropic ER was highest in 2016 at 0.88 (SE = 0.15, N = 32) and lowest in 2017 at 0.63 (SE = 0.17, N = 30; Figure 7; Table 32). The date of first sighted for hatchling/juveniles ranged from late July in 2015, to mid-July 2016 to late August in 2017. In 2016 and 2017 the highest number of hatchlings/juveniles per census was found in October, while in 2015 the highest number was found in September (Figure 7). We used a Kruskal-Wallis test to determine that the number of hatchlings/juveniles sighted per census at Semitropic was not significantly different between years (H = 1.79, df = 2, P = 0.41).

Figure 7. Mean number of adult (top) and hatchling/juvenile (bottom) *Gambelia sila* **sighted during each census month at Semitropic ER from 2015-2017. The date of first sighted for hatchling/juveniles ranged from late July in 2015, to mid-July 2016 to late August in 2017.**

Census data Pixley NWR

At Pixley NWR, we found that the population on the census plot was highest in 2016 at a mean of 10.00 adults/census (SE = 0.54, N = 27) and the smallest in 2015 at 2.25 (SE = 0.26, N = 24; Figure 8; Table 32). In both 2016 and 2017, the mean number of lizards found on the census plot was highest in May (Figure 8). In 2015, the mean number of lizards found per census was slightly higher in July (Figure 8). We used a Kruskal-Wallis test to determine that the number of lizards sighted per census at Pixley was significantly different between years (H = 52.16, df = 2, P = <0.001). We followed up with Mann-Whitney pair-wise comparisons with Legendre and Legendre adjusted P values (1998) and determined that the mean number of adult lizards per census differed significantly each year (Table 33).

The mean number of hatchlings/juveniles sighted per census on the plot at Pixley NWR was highest in 2017 at 7.28 (SE = 1.03, N = 32) and lowest in 2015 at 5.42 (SE = 0.52, N = 31; Figure 8; Table 32). The hatchlings/juveniles first emerged each year in early July. In 2015 and 2017 the highest number of hatchlings/juveniles per census was found in October, while in 2016 the highest number was found in September (Figure 8). We used a Kruskal-Wallis test to determine that the number of hatchlings/juveniles sighted per census at Pixley NWR was not significantly different between years (H = 1.14, df = 2, P = 0.57).
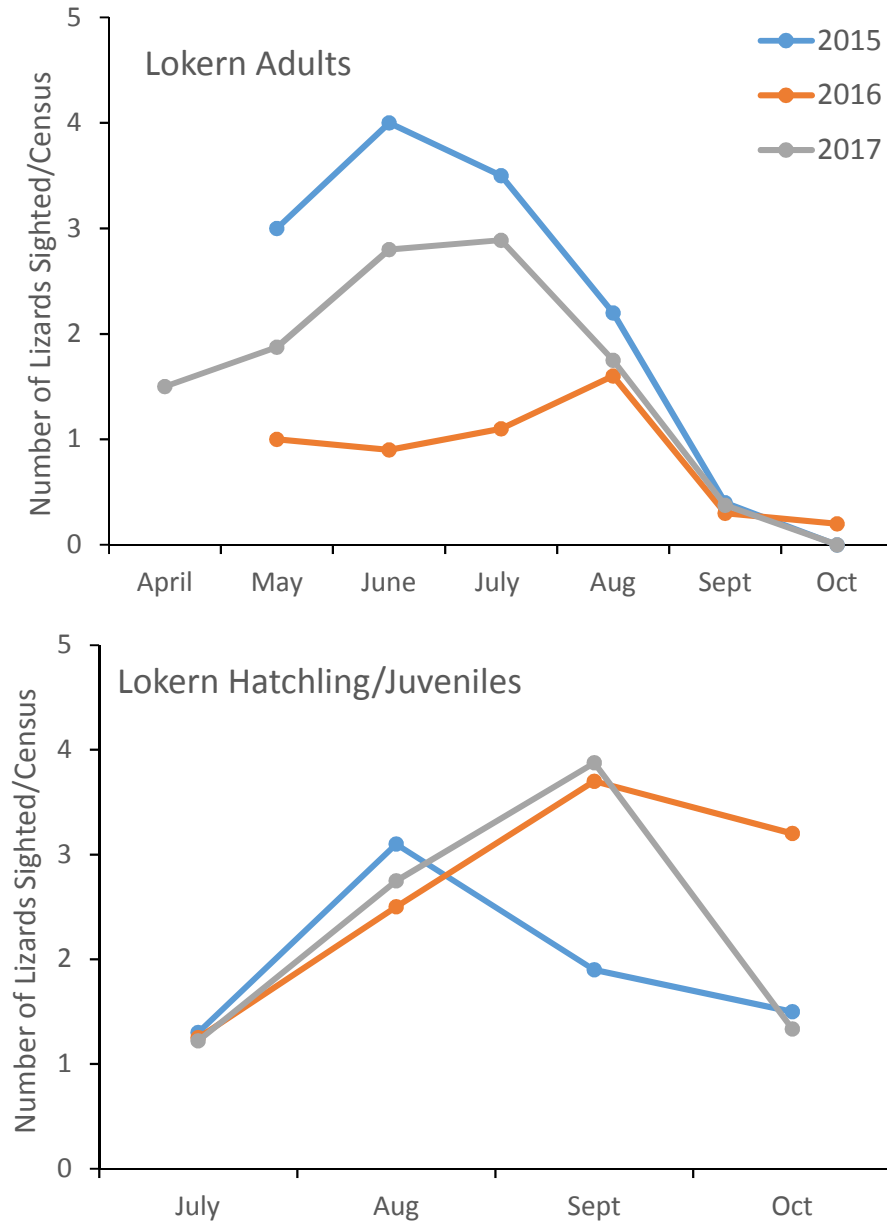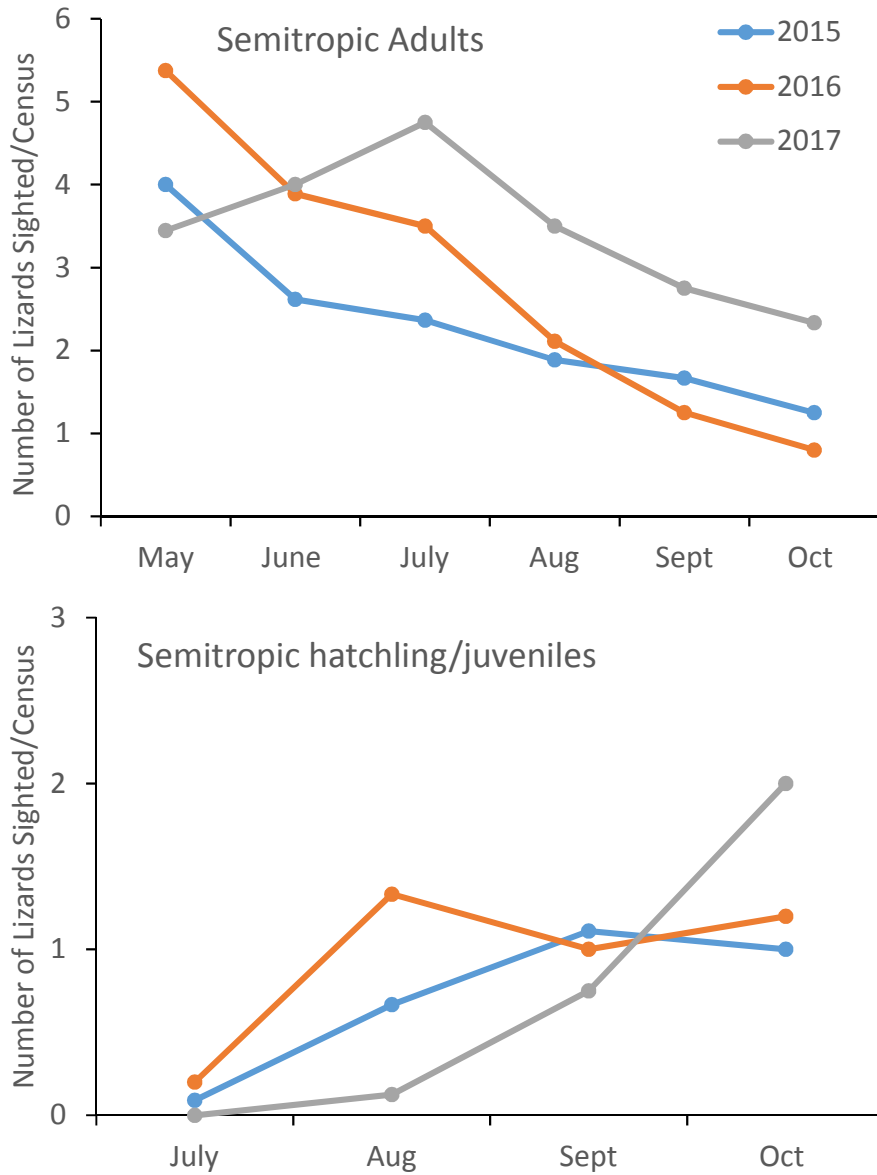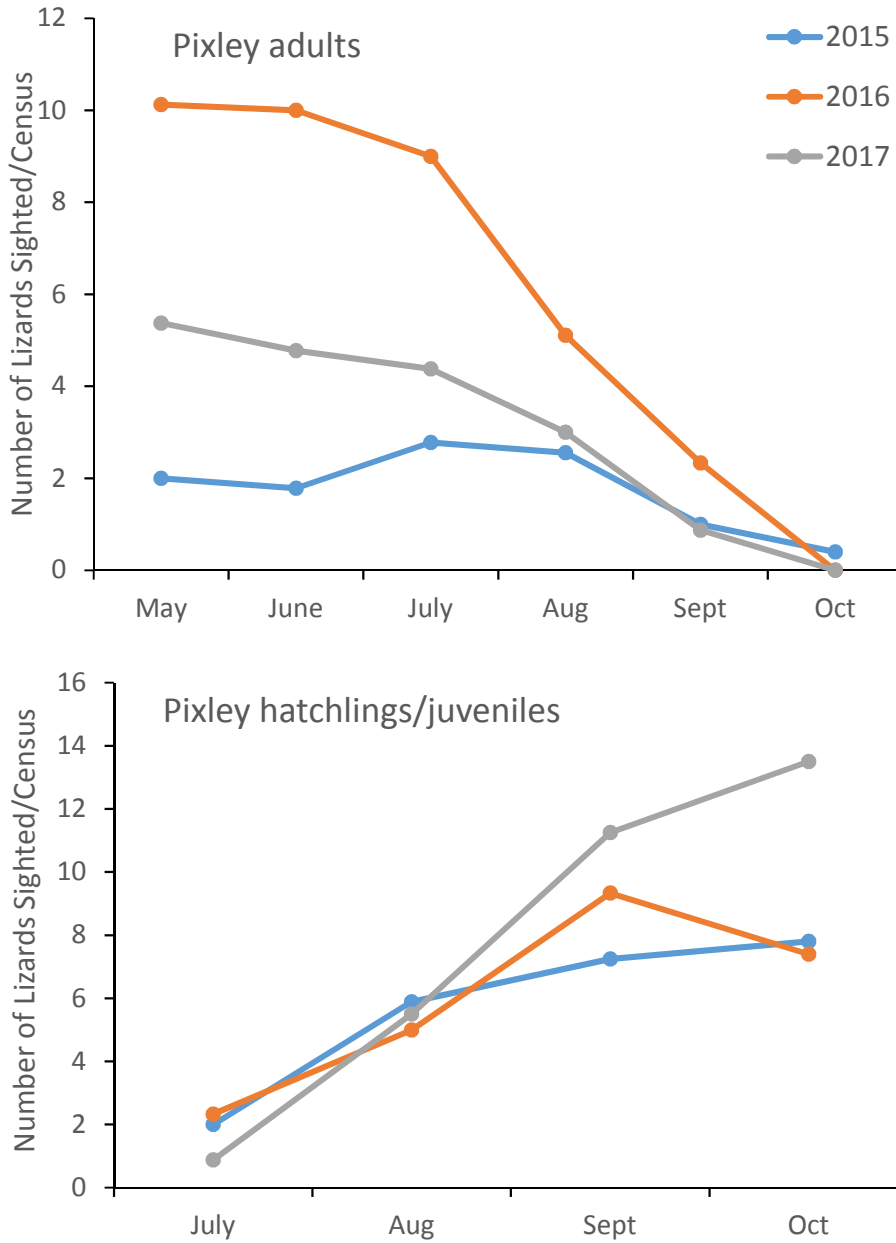
Figure 8. Mean number of adult (top) and hatchling/juvenile (bottom) *Gambelia sila* **sighted during each census month at Pixley NWR from 2015-2017. We first sighted hatchlings/juveniles in early July each year.**

Census data comparisons between sites

We used a Kruskal-Wallis test to compare the mean number of adult and hatchling/juvenile lizards sighted per census each year between sites. We found that the mean number of adults sighted per census at our three sites was significantly different in 2015 ($H = 9.371$, $df = 2$, $P = 0.01$), 2016 ($H = 66.12$, $df = 2$, $P < 0.001$), and 2017 ($H = 18.73$, $df = 2$, $P < 0.001$). Mann-Whitney pair-wise comparisons Legendre-Legendre adjusted P values (1998) showed significant differences between all groups except Lokern adults in 2015 and Pixley adults in 2015 and Semitropic adults and Pixley adults 2015 and 2017 (Table 34).

Table 34. Mann-Whitney pair-wise comparisons with Legendre-Legendre adjusted P values of mean number of *Gambelia sila* sighted per census year (2015-2017) during the adult season (April – July) between sites (Lokern Ecological Reserve (L), Semitropic Ecological Reserve (S) and Pixley National Wildlife Refuge (P)).

Comparison	*W*	Adjusted *P*-value	Significance
L adult 2015 / S adult 2015	146	0.086	No
/ P adult 2015	110.5	0.021	Yes
S adult 2015 / P adult 2015	263	0.347	No
L adult 2016 / S adult 2016	19	<0.001	Yes
/ P adult 2016	0	<0.001	Yes
S adult 2016 / P adult 2016	32.5	<0.001	Yes
L adult 2017 / S adult 2017	232	0.022	Yes
/ P adult 2017	132	<0.001	Yes
S adult 2017 / P adult 2017	261.5	0.153	No

For hatchling/juvenile lizards we found that the mean number of lizards sighted per census at our three sites was significantly different in 2015 ($H = 17.87$, $df = 2$, $P < 0.001$), 2016 ($H = 25.53$, $df = 2$, $P < 0.001$), and 2017 ($H = 51.57$, $df = 2$, $P < 0.001$). Mann-Whitney pair-wise comparisons showed significant differences between all groups (Table 35).

Table 35. Mann-Whitney Pair-wise comparisons with Legendre-Legendre adjusted P values of mean number of *Gambelia sila* sighted per census year (2015-2017) during the hatchling/juvenile season (July-October) between sites (Lokern Ecological Reserve (L), Semitropic Ecological Reserve (S) and Pixley National Wildlife Refuge (P)).

Comparison	*W*	Adjusted *P*-value	Significance
L hatch 2015 / S hatch 2015	246	<0.001	Yes
/ P hatch 2015	172	<0.001	Yes
S hatch 2015 / P hatch 2015	68.5	<0.001	Yes
L hatch 2016 / S hatch 2016	251	0.001	Yes
/ P hatch 2016	226.5	<0.001	Yes
S hatch 2016 / P hatch 2016	60.5	<0.001	Yes
L hatch 2017 / S hatch 2017	176.5	<0.001	Yes
/ P hatch 2017	269.5	<0.001	Yes
S hatch 2017 / P hatch 2017	120.5	<0.001	Yes

Population abundance and density

The pooled mean detection probability at Semitropic was 0.62 and the pooled mean at Pixley was 0.59, and the mean from these two sites did not differ significantly. We took the mean of these two sites, 0.605, and used this as our standard detection probability for population abundance estimates. We found that estimated population densities on our plots was never > 1.61 lizards/ha during the adult or hatchling/juvenile season at all three sites during 2015-2017 (Table 36).

Table 36. Mean number of *Gambelia sila* adults (April – July) and hatchlings/juveniles (July-October) sighted per census (*C*), estimate of abundance ($\widehat{N}$), estimate of density (lizards/ha; *D*) and 95% confidence intervals (CI) for density estimates at three monitoring plots in the southern San Joaquin Desert from 2015-2017.

Class/Site/Year	C	$\widehat{N}$	D	95% CI
Adults (April-July)				
Lokern				
2015	3.68	6.08	0.59	0.48 – 0.71
2016	1.00	1.65	0.16	0.10 – 0.31
2017	2.48	4.10	0.40	0.30 – 0.50
Semitropic				
2015	2.62	4.33	0.42	0.32 – 0.52
2016	4.21	6.96	0.68	0.58 – 0.78
2017	3.89	6.43	0.63	0.50 – 0.77
Pixley				
2015	2.25	3.72	0.36	0.27 – 0.45
2016	10.00	16.53	1.61	1.43 – 1.79
2017	4.92	8.13	0.79	0.66 – 0.92
Hatchling/Juveniles (July-October)				
Lokern				
2015	2.00	3.31	0.32	0.24 - 0.41
2016	2.63	4.35	0.42	0.30 - 0.55
2017	2.32	3.83	0.37	0.27 – 0.48
Semitropic				
2015	0.64	1.06	0.10	0.06 – 0.14
2016	0.88	1.45	0.14	0.09 – 0.33
2017	0.63	1.04	0.10	0.05 – 0.16
Pixley				
2015	5.42	8.96	0.87	0.70 – 1.04
2016	5.84	9.65	0.94	0.74 – 1.14
2017	7.28	12.03	1.17	0.84 – 1.51

DISCUSSION

POPULATION AND DEMOGRAPHIC DATA

We researched demographic characteristics and population trends on three core protected sites for BNLL over three years. During the three years of our study, the population structure (distribution of SVLs) at each site did not vary significantly between years. Variation in wildlife populations in arid environments, such as the San Joaquin Desert, tends to be high (see San Joaquin Desert examples from Germano et al. 1994b; Cypher et al. 2000; Germano and Williams 2005; Germano et al. 2012; Westphal et al. 2016; Germano and Saslaw 2017). However, during the short duration of our study we observed no major fluctuations in rainfall (Figure 5), which likely contributed to the relative stability of BNLL populations at our sites. This was in contrast to the six-year BNLL population ecology study completed on the Elkhorn Plain from 1989-1994, which took place during large rainfall fluctuations including a drought and several above average rainfall years (Germano and Williams 2005).

We began our study in April 2015, which was just following a severe drought in Western North America (Griffin et al. 2014). We suspected that, at the start of our study, populations at our sites would be low, given that other researchers have documented low to no recruitment of BNLL during drought years (Germano et al. 1994b; Germano and Williams 2005; Westphal et al. 2016). We did see overall population increases at both Pixley and Semitropic over the course of our study years. Unlike Pixley and Semitropic, the adult population at Lokern decreased by 50% from 2015 to 2017, and we suspect that this was due to an unequal sex ratio of hatchlings (male to female ratio 5.6:1) and subsequently a lower number of females on the plot area.

Pixley had more variation with the adult population increasing 65.2% from 2015 to 2016. In addition, the number of unique hatchlings at Pixley increased each year with double the number of unique hatchlings found in 2017 as 2015. We suspect this increase was in response to a release from drought conditions, which perhaps affected the population at Pixley more than Lokern and Semitropic. We also found that sex ratios at Pixley were unequal and favored more females (male to female ratio 0.618 to 1), which certainly contributed to the high numbers of hatchlings found each year. Clutch size at each site did not differ significantly and was 2.5 eggs per clutch at each site and we often saw two, sometimes 3, clutches per season in some females. At the Elkhorn Plain in the early 1990s, mean clutch size was higher at 3.4 eggs per clutch and multiple clutching was common, but this included two very good years with irruptive grasshopper populations (Germano and Williams 2005). Historic data from Valley floor sites of 2.9 – 3.3 eggs per clutch (Montanucci 1965, 1967; Tollestrup 1979) is also higher than the data we collected. However, historic valley floor data found that few females produced a second clutch, whereas during our survey we found 2 clutches per season was often the case.

Due to the short duration of our study, we are unsure whether the unequal sex ratios we observed among hatchlings at Lokern and adults at Pixley represent long-term trends. Other studies have found that during most of the year males outnumber females by almost 2:1 (Montanucci 1965; Uptain et al. 1992), but that sex ratios can vary over the course of the season. The most comprehensive demographic study completed over 6 years on the Elkhorn Plain found even sex ratios (Germano and Williams 2005).

The population structure (distribution of SVLs) at Pixley differed significantly from both Lokern and Semitropic, but Lokern and Semitropic did not differ significantly from each other. This is interesting because, in a recent range-wide genetic study, Semitropic and Pixley grouped together as having a shared ancestry, whereas Lokern grouped with Elkhorn Plain and the Carrizo Plain (Richman et al. 2017). During our study period at Lokern hatchlings/juveniles grew quickly and, typically, we never found hatchlings/juveniles in the small adult size range during our survey period of April - October. The hatchlings/juveniles that we recaptured on the plot in early spring were already in the adult size class (≥ 98 mm SVL). At Semitropic only 5-7 unique hatchlings were caught on the plot each year in the fall, the least of all three sites, and much lower than historic data from the Elkhorn Plain (Germano and Williams 2005). At Semitropic, we found that, typically, in the spring, small adults in the 85-95 mm SVL range were the previous fall's hatchlings and large adults were often in their second spring season. It also appeared that Semitropic had better survivorship than Pixley and Lokern, being the only site with lizards surviving into the third year of the study (Table 19). At Pixley, large numbers of juveniles and small adults dominated the size distribution. In the spring, we typically found more small adults than large lizards. Therefore, size parameters, such as mean and upper quartile mean of SVL, TL, and mass of lizards at Pixley were in some characteristics significantly smaller than size parameters at Semitropic and Lokern.

Pixley had higher numbers of lizards in both the adult (except 2015) and hatchling seasons than Semitropic and Lokern. Pixley is a flat, grassland site that has been consistently been cattle grazed likely since the 1930s, but at least since the 1960s (Geoff Grisdale, Refuge biologist, personal communication). The site is devoid of shrubs except for small bush seepweed (*Suaeda moquinii*). Even with a grazing program, RDM was higher at Pixley in all three years than Semitropic and Lokern. Available prey at Pixley often did not differ from Semitropic and Lokern, one exception being grasshoppers during the hatchling season. In 2017, Pixley was the only site that had a large increase (>100) in the mean grasshopper numbers from the adult to hatchling season. Furthermore, at Semitropic and Lokern it was typical to see the mean grasshopper numbers decrease from the adult to hatchling season. At Pixley, the mean grasshopper numbers during the hatchling season remained about the same as the adult season, or increased (2017). We suspect that higher grasshopper numbers are due to higher amounts of RDM at Pixley, but correlations between grasshoppers and RDM were not significant, and have not been significant in previous studies on the Elkhorn Plain (Germano and Williams 2005). There are likely other factors that influence grasshopper abundance and more research on prey base at these long-term monitoring sites is needed.

Based on the detection data we collected at Semitropic and Pixley via radio telemetry, we estimated mean detection probability at both sites was 0.605, which means that on average we detected 60% of the lizards that were available for detection during a census. We view this estimate with caution and consider it a first attempt to calculate detection probability for BNLL. Detection probability varies greatly depending on a number of factors, including habitat, observer, species sex, behavior, and age (hatchling/juvenile/adult). For example, dense annual vegetation or shrubs on the census plots can obscure lizards even if they are up and available for detection. Thus, we know it is flawed to apply the same detection probability to multiple sites over multiple years, as each site has parameters that make detection rates different. However, for now, we decided to use our detection probability estimate broadly as a first attempt to estimate population abundance and

density with this correction factor. We need further work and modeling exercises on detection probability and availability of lizards on the census plot during a wide range of habitat and vegetation variables to improve population abundance and density estimates.

At Pixley, where we had the highest numbers of lizards, and with a correction for detection probability, our density estimates of 0.36 – 1.61 adults/ha and 0.87 – 1.17 hatchlings/ha were low compared to the Elkhorn Plain, which from 1992-1994 ranged from 4.4 – 16.0 adults/ha and 3.5 – 35.6 hatchlings/ha (Germano and Williams 2005). It appears that the Elkhorn Plain, at least in the early 1990s, may have some of the highest densities of BNLL recorded anywhere in their range (Germano and Williams 2005; USFWS 2010).

Pixley and Lokern are the only sites that we studied where previous estimates of BNLL densities have been compiled. At Pixley, estimates of lizard densities during short-term studies have reported 3.3 adults/ha (Tollestrup 1979), 0.3 – 10.8 adults/ha (Uptain et al. 1992), and 6.7 – 7.0 adults/ha (CSU-Stanislaus, Endangered Species Recovery Program, unpublished data reported in USFWS 2010). Previous long-term monitoring work at Pixley by the Endangered Species Recovery Program have documented dramatic declines at the site due to high rainfall and annual vegetation in the mid-late 1990s (CSU-Stanislaus, Endangered Species Recovery Program, unpublished data reported in USFWS 2010). At Lokern, lizard density during a 1997-2005 grazing study ranged from 0.06 – 1.50 adults/ha with grazed plots showing higher abundance (Germano et al. 2012), which is in the range our estimates of 0.16 – 0.59 adults/ha.

In our initial proposal for this study, we intended to set up a long-term monitoring plot at Buttonwillow ER. However, during intensive survey efforts in spring 2015 we detected very few BNLL at Buttonwillow. As an alternative, we also surveyed Allensworth ER intensively in spring 2015, but similarly found few lizards. We continued to monitor these two sites in 2016 and 2017, and continued to detect BNLL adults and hatchlings, but at a much lower density than our long-term monitoring sites. In fact, when choosing our long-term monitoring sites we surveyed large portions of the Semitropic and Lokern reserves and attempted to choose areas with the highest numbers of lizards. At Pixley, we used the same monitored plot that the Endangered Species Recovery Program previously used and that was known to have high densities of lizards at one time. Thus, to the best of our knowledge, our monitoring plots represent some of the best areas for BNLL on each reserve.

Criteria for downlisting of BNLL requires that population stability of 2 lizards/ha be achieved on 5 or more protected areas of approximately 2,400 ha of contiguous habitat in 5 specific areas (USFWS 1998, 2010). Based on the limited data collected during this study, lizards densities at monitoring plots at Lokern, Semitropic and Pixley likely rarely reach as high as 2 lizards/ha. Surrounding habitats and adjacent reserves, like Buttonwillow and Allensworth, likely support even lower densities than our monitoring plots.

TELEMETRY, MOVEMENT, AND HOME RANGE

The home range data we collected at Semitropic and Pixley was different between the two sites, with Semitropic home range sizes being 3-6 times larger than Pixley. Tollestrup (1983), made the only other home range estimates of BNLL at Pixley and relied on visual observations of individuals, and it is unknown whether an observer affect may have influenced movement patterns. Tollestrup estimated male home ranges as 0.21 ha (n = 10) and female home ranges as 0.10 ha (n = 7), both of which are much smaller than our MCP

estimates of 1.89 ha for males and 1.22 ha for females. The smaller estimates calculated are likely due to a limited number of locations (5-20 locations/individual), small sample size and time period, and potential observer bias. It is also possible that densities of lizards were higher during the Tollestrup study and this influenced the home range size of lizards.

Semitropic MCP home range estimates of 5.58 ha for males and 7.19 ha for females were more similar to previous MCP home range estimates calculated at Lokern Natural Area of 8.61 ha for males and 5.18 ha for females (Germano and Rathbun 2016). In the home range study at Lokern, mean male home range sizes were over twice as large as females, but in our study, we did not find significant differences between males and females at either Semitropic or Pixley. Since male BNLL are territorial and defend areas for access to females (Montanucci 1965; Tollestrup 1983) we expected that our data would follow the same pattern as previous datasets. While the mean distance moved between consecutive days was greater for males than females at both Semitropic and Pixley, several females at Semitropic and at least one female at Pixley made long distance movements associated with laying eggs. At Semitropic, we had one female move 1150 m to lay eggs in an area where she was never previously located, stay underground for two days in a backfilled burrow, and then return the approximate 1150 m to her previous typical home range area. Another female at Semitropic twice went missing for 3-4 days when she was large with eggs, and then reappeared both times in her consistent home range area. We suspect that she went out of her transmitter signal range to lay eggs because we could not locate her. Another radio-collared female at Semitropic went missing for several days and we finally found her 1344 m from her last location and previous typical home range area. She never returned to her previous home range area, which was on the census grid. Finally, another female at Semitropic went missing and we eventually found her over a month later approximately 1500 m from her original location. At Pixley, we only documented this behavior in one female and she moved twice approximately 235 m from her typical home range area to lay eggs. It appeared at both sites that some females make long movements in association with egg laying and some do not. It also appeared that some females would move long distances to lay eggs and then subsequently return to their typical home range area, and some would not return. This behavior contributed to the large and highly variable home range sizes (1.66 – 19.58 ha) and greatest distances moved data (136.8 – 1152.0 m) for females at Semitropic.

To our knowledge movements associated with egg-laying have not been documented in BNLL, but Germano and Rathbun did see some large home ranges for females in Lokern, although the majority of females used home ranges of < 5.0 ha (2016). We suspect that this may be due to some females making movements associated with egg laying, and plan to reevaluate the dataset. In previous research on the long-nosed leopard lizard, *Gambelia wislizenii*, there have been movements documented in association with egg-laying (Parker and Pianka 1976), and a radio telemetry study in southeastern Colorado on *G. wislizenii* documented two > 1 km movements in females that may have been associated with egg-laying (Schorr et al. 2011). Like us, Schorr et al. (2011) speculated that these long-distance movements could be associated with reducing competition (Ryberg et al. 2004; Le Galliard et al. 2005), preventing cannibalism of young (McCoy 1967; Germano and Williams 1994a), or searching for appropriate nesting locations (Parker and Pianka 1976; Anguilletta et al. 2009).

Several differences between Semitropic and Pixley may have mediated smaller home ranges at Pixley. While we did not find any major differences in prey availability between

the two sites, densities of lizards at Pixley were on average higher than Semitropic and since male lizards are territorial, higher densities may cause less movement. Sex ratios at Pixley were unequal with more females than males, which may also influence home range and movement, as males perhaps move less to find mates. Finally, sparely spaced large *Atriplex* shrubs, generally 0.5-2 m in height and 0.5-1 m in width dominate the habitat at Semitropic and this may facilitate long movements by providing cover to evade predators (Warrick et al. 1998). Although, home range data at Lokern suggested that the presence or absence of shrubs do not affect home range sizes (Germano and Rathbun 2016). More research on shrubs and their influence on lizards is needed (Germano and Rathbun 2016). The Bureau of Land Management in Panoche Valley and the Carrizo/Elkhorn Plain is currently pursuing research projects related to shrubs, BNLL, and climate change (M.Westphal, BLM ecologist, personal communication).

Our results indicate that large home ranges and long-distance movements by females associated with egg laying, especially at sites like Semitropic, are often the case with BNLL. These data further demonstrate that BNLL need large areas to sustain populations (Bailey and Germano 2015; Germano and Rathbun 2016).

RECOMMENDATIONS

Based on the results of this project, we offer the following recommendations for BNLL conservation.

1. ADDITIONAL SURVEYS ON LONG-TERM MONITORING PLOTS

This study provides crucial information on BNLL on three protected sites in the San Joaquin Desert during the same period. However, this study was short in duration compared to other long-term studies that inevitably encompass more environmental variation (see San Joaquin Desert examples from Germano et al. 1994b; Cypher et al. 2000; Germano and Williams 2005; Germano et al. 2012; Westphal et al. 2016; Germano and Saslaw 2017). To further refine population abundance and density estimates, and provide adequate data for modeling, which are all crucial to meeting recovery criteria, additional survey years are imperative. Furthermore, it will be important to improve the accuracy of abundance and density estimates by improving upon our initial estimate of detection probability.

2. ADDITIONAL WORK ON PREY ABUNDANCE AND FOOD HABITATS

We did not find large differences in prey abundance between years and sites, but it is important to study prey abundance under more environmental variation to see if we can detect differences and patterns. In addition, determining food preferences of lizards through scat analysis in relation to prey availability on each site would help to understand site-specific differences, which may explain the higher abundance and density of lizards at Pixley.

3. FURTHER WORK ON MODELING DEMOGRAPHIC AND POPULATION PARAMETERS, CLIMATE CHANGE AND CREATING A POPULATION VIABILITY ANALYSIS (PVA)

During this study, we collaborated with University of California, Santa Cruz researchers Dr. Barry Sinervo and Ph.D. student Joseph Stewart. The Sinervo lab, with funding from the Bureau of Land Management's Dr. Michael Westphal and The Nature Conservancy's Dr. Scott Butterfield, were working on various modeling exercises for BNLL, and we provided two of the products from their work in the appendix of this report.

Our collaborators have created a very preliminary Population Viability Analysis (PVA) from historic data collected from the Elkhorn Plain (Germano and Williams 2005) using fecundity and winter precipitation as predictor variables (Figure 9). Additional work to continue to build on this PVA with data collected as part of this study and additional years of survey data from San Joaquin Desert valley floor sites is still an important recovery priority for BNLL.
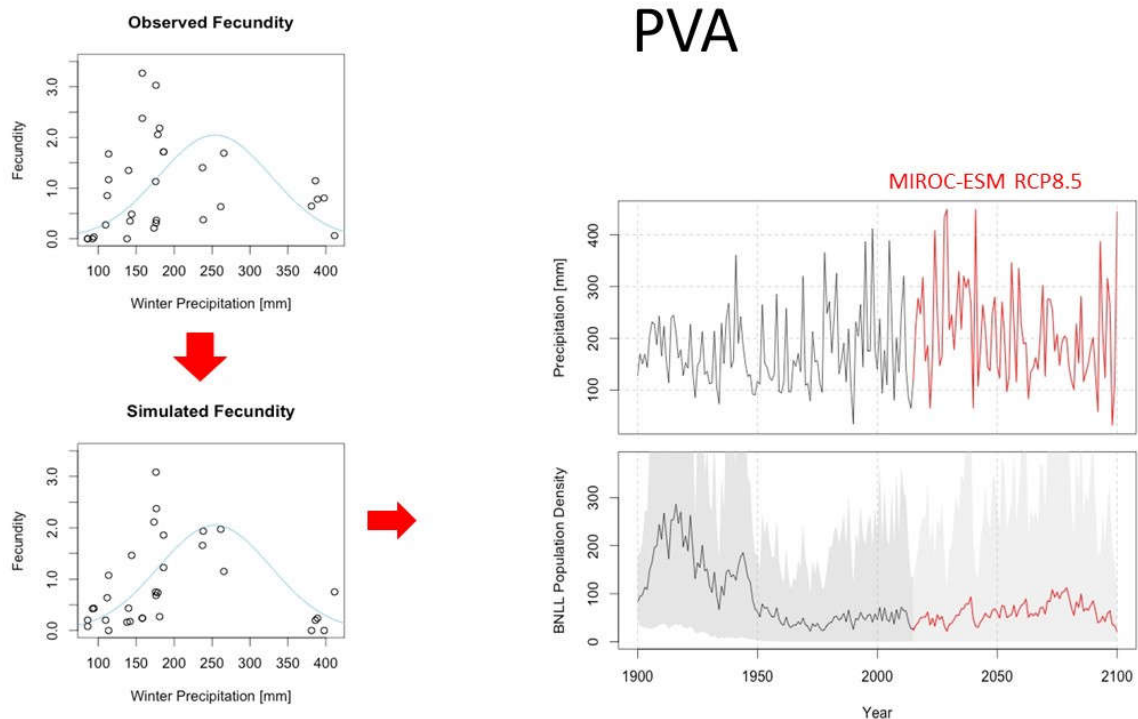
Figure 9. Initial work on a Population Viability Analysis (PVA) for *Gambelia sila* based on historic data collected on the Elkhorn Plain using fecundity and precipitation as predictor variables (Joseph Stewart, unpublished data).

4. USE OF GENETIC SAMPLING TECHNIQUES

We used census grids to estimate population abundance and density of lizards. However, a less intensive and possibly less invasive way to track populations on our study sites would be to use genetic sampling techniques to estimate effective population size. We

recommend experimenting with genetic sampling techniques on our monitoring plots in future years.

5. *DEVELOPMENT OF HABITAT RESTORATION AND TRANSLOCATION TECHNIQUES*

Habitat loss continues to be a factor affecting endangered species in the San Joaquin Desert (see Stewart et al. unpublished draft manuscript, Appendix A). However, after the passage of the Sustainable Groundwater Management Act in California in 2014, many researchers are predicting that vast portions of agricultural lands in the San Joaquin Desert may be retired. These retired lands may provide an important opportunity to contribute to endangered species recovery in the San Joaquin Desert (Kelsey et al. 2018). For BNLL conservation, it is crucial to develop habitat restoration and reintroduction/translocation techniques that are scientifically sound, and allow researchers to restore retired agriculture lands that will provide appropriate habitat for BNLL and work toward recovery goals.

6. *DEVELOPMENT OF SITE SPECIFIC HABITAT MANAGEMENT PRESCRIPTIONS*

In line with recommendations 3 and 5, it is important to develop best habitat management prescriptions for sites with BNLL. Continuing to refine modeling exercises that predict population variability will help land managers determine best management practices on protected sites, especially with regard to vegetation management and shrub revegetation.

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APPENDIX A. *GAMBELIA SILA* BIOGEOGRAPHY MANUSCRIPT

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Habitat restoration opportunities, climatic niche contraction, and conservation biogeography in California's San Joaquin Desert

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APPENDIX B. LINKS TO ADDITIONAL MANUSCRIPTS

Germano, D. J., E. N. Tennant, and L. R. Saslaw. 2015. Predation events on the endangered Blunt-nosed Leopard Lizard (*Gambelia sila*) including another by the Long-nosed Snake (*Rhinocheilus lecontei*). Western Wildlife 2:44-45. http://www.tws-west.org/westernwildlife/vol2/Germano_et_al_WW_2015-07.pdf

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