

## EFFECT OF DROUGHT ON BLUNT-NOSED LEOPARD LIZARDS (*GAMBELIA SILA*)

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**ABSTRACT**—We studied a population of blunt-nosed leopard lizard (*Gambelia sila*) on the Elkhorn Plain, California from 1988–1991. Sufficient precipitation fell during the winters of 1987–1988 and 1990–1991 to produce abundant herbaceous ground cover the following springs. Winter rains in 1988–1989 produced low amounts of ground cover, and rains in 1989–1990 did not cause any appreciable number of annual plants to germinate. Counts of grasshoppers differed significantly between 1990 and 1991, with 10–60 times more grasshoppers counted in 1991 than 1990. In 1988, 1989, and 1991, adult leopard lizards, together with yearlings that hatched the preceding year, emerged from winter torpor in the spring and remained active through June. A few adults remained active into August, and in 1991 into September. In these same years, hatchlings appeared aboveground in August, and stayed active into September or October. However, in 1990, only yearling lizards were found active aboveground, and no reproduction occurred. Adult *Gambelia sila* have the ability to remain belowground > 21 mo during periods of low prey abundance.

One of the density-independent factors of the environment that can affect populations of lizards is drought. Periods of below-average rainfall will decrease growth of plants, particularly herbaceous annuals, which in turn can depress populations of arthropods. Blunt-nosed leopard lizards (*Gambelia sila*) are mainly insectivorous (Montanucci 1965; Tollestrup 1979; Kato et al. 1987). Years with below-average precipitation can directly affect this species by lowering abundance of its prey.

*Gambelia sila* is listed as an endangered species throughout its range in the San Joaquin Valley of California, and approximately 15% of its habitat remains (Germano and Williams 1993a). Understanding the response of populations of *G. sila* to environmental fluctuations is necessary for planning its recovery. In this paper, we discuss the ecology of a population of *G. sila* during a period of drought. We monitored changes in activity and reproduction of this species over four years, and correlated these changes with variation in environmental conditions. We discuss our results in light of possible responses that a long-lived lizard could make to a variable environment.

### METHODS

#### *Study Site*

We conducted studies on populations of *G. sila* on the Elkhorn Plain, San Luis Obispo County, California. The Elkhorn Plain is a high elevation bench (685–765 m) on the western side of the Temblor Range, with the lower elevation Carrizo Plain to the west. The Elkhorn Plain represents a foothill habitat of *G. sila*, although the greatest portion of the original range of this species occurred in the floor of the San Joaquin Valley (Montanucci, 1965). Much of the Elkhorn Plain is covered by non-native herbaceous annual plants, such as filaree (*Erodium cicutarium*), Arabian grass (*Schismus arabicus*), and red brome (*Bromus rubens*). Our study plots also contained the native shrubs California ephedra (*Ephedra californica*) and snakeweed (*Gutierrezia californica*), along with lesser numbers of eastwoodia (*Eastwoodia elegans*) and desert boxthorn (*Lycium andersonii*).

The Elkhorn Plain has a Mediterranean climate and receives less than 254 mm of precipitation annually, based on long-term records from the nearby Carrizo Plain. Most precipitation comes in the winter, and the summer is dry. Herbaceous annual plants usually germinate in response to late fall and winter precipitation. Between July 1986 and June 1991, annual precipitation averaged only 160 mm.

TABLE 1. Precipitation totals for the Elkhorn Plain for 1986-1991.

Year	Precipitation (mm)		
	Total (July-June)	Winter (Oct.-April)	Winter % of total
20-year mean <sup>a</sup>	224.4	204.5	91.1
1986-1987 <sup>b</sup>	160.8	114.4	71.1
1987-1988 <sup>b</sup>	258.5	257.6	99.7
1988-1989 <sup>b</sup>	107.1	100.6	94.0
1989-1990 <sup>c</sup>	85.6	63.2	73.8
1990-1991	185.9	160.6	86.3

<sup>a</sup> Mean of three ranch stations.

<sup>b</sup> Mean of Traver's and Washburn Ranch stations.

<sup>c</sup> Data for July-February from Traver's and Washburn Ranch stations.

### Field Methods

Two plots were established during April 1988; one within the fenced Elkhorn Plain Ecological Reserve, and the other approximately 2.4 km northwest of the reserve. Plots were 277 m by 293 m (8.1 ha), with 16 census lines spaced 18.3 m apart. Census lines were 277 m long and oriented north to south.

Plots were walked to visually census lizards during the morning or early afternoon during temperatures when lizards were most active (24-35°C air taken 1-2 cm above soil surface; 30-41°C soil taken 1-2 cm below soil surface). We tried to sample plots simultaneously during a census period with two researchers alternating plots censused each day. However, during the course of the four years, plots were sometimes censused by one person, who either alternated plots each day or censused both plots on the same day, when the temperature regime permitted.

We used a pole and noose to capture lizards, and we noted location, determined sex, and applied a numeral to the lizard's dorsal surface with a felt-tipped pen. Marked lizards were renumbered occasionally with a pen after the number was lost due to shedding. Captured lizards were placed in cloth bags and held until after the daily census. After the daily census, we took body measurements, including snout-vent length (SVL) and total length (TL) to the nearest mm, and mass to the nearest g. During 1989 and 1990, we noted whether females appeared to be gravid. During 1991, we also palpated females to determine how many eggs or yolk follicles they were carrying. Starting in August 1989, we injected a passive integrated transponder (PIT) subdermally to mark individuals permanently (Germano and Williams 1993b). After all lizards were processed for a day, lizards were brought back to their original points of capture and released.

For purposes of discussion, we have classified *G. sila* < 3 mo old (same yr as hatching) as either hatchlings (ca. 45-60 mm SVL) or juveniles (ca. 61-90 mm SVL) depending on size; 7-15 mo old (first yr after hatching; about 90-100 mm SVL) as yearlings (juveniles in Tollestrup 1982); and > 20 months (second yr after hatching) as adults (follows Montanucci 1965). Both yearlings and adults may breed, depending on the environmental circumstances. Sometimes the term adult was used when yearlings and adults were indistinguishable.

As a first approximation of prey abundance, we counted all grasshoppers (Acrididae) and side-blotched lizards (*Uta stansburiana*) found while walking census lines for *G. sila* in 1990 and 1991. We used counts of grasshoppers and *Uta* as an estimate of relative food abundance on each plot. Rainfall data for 1986 to February 1990 was estimated by determining the monthly means from two weather stations located at ranches on the Carrizo Plain (3-8 km from plots). Rainfall data from March 1990 through 1991 came from rain gauges on the leopard lizard plots. Plant productivity and mulch level were estimated each year using randomly placed (each session) 0.25 m<sup>2</sup> quadrats located in and out of the Reserve. Plant productivity was obtained in May by clipping all herbaceous vegetation at ground level within a quadrat and then drying the samples to a constant weight. Mulch levels were obtained in August or September by gathering all plant litter on the ground within newly placed quadrats and weighing these samples.

### Statistical Analyses

We combined data on leopard lizards from the two plots. We compared SVL and mass among years and between sexes using time periods of activity of different size classes (corresponding to

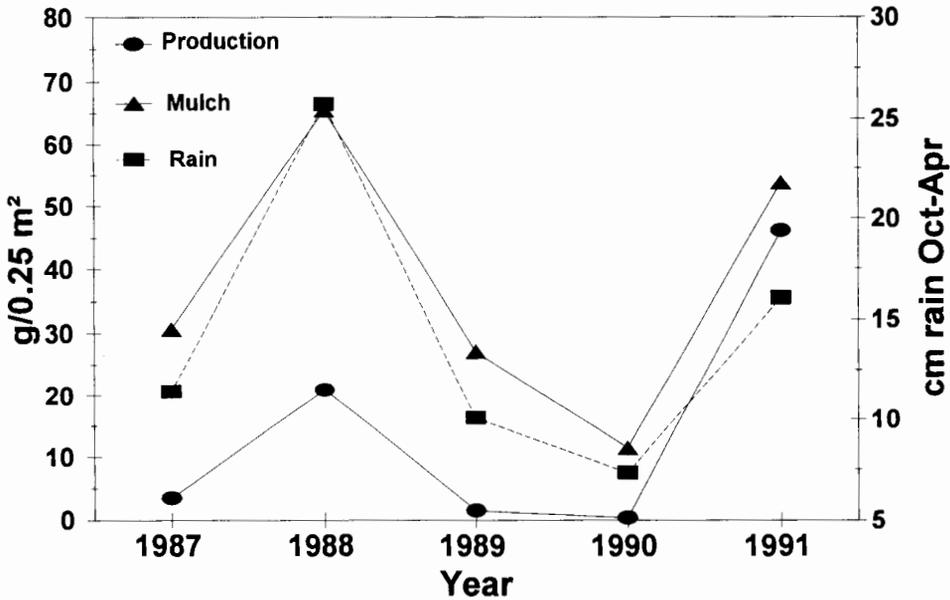


FIGURE 1. October to April precipitation, mean aboveground net productivity of herbaceous plants, and mulch measured each year on the Elkhorn Plain Ecological Reserve 1987–1991.

hatchling/juvenile and yearling/adult age classes). Adults and yearlings were most active from April through July, whereas hatchlings usually did not appear aboveground until late July and stay active through September or October. Therefore, we compared mean SVL and mass of lizards among years and sexes for lizards caught from April–July and from August–September using one-way analysis of variance (ANOVA) or, if variances were not homogeneous, using Kruskal-Wallis one-way nonparametric ANOVA. We compared pairs of means using the Scheffé test. Because of the lack of sightings of lizards July–September 1990, we compared mean SVL and mass of lizards caught August–September 1989 to those caught in the same time period in 1991 using the nonparametric median test. We tested for homogeneity of variances using Bartlett's test of equal variances and for normality using Wilk-Shapiro/Rankit plots. Indices of food abundance in 1990 and 1991 were compared between years using Wilcoxon two-sample test. Significance of all tests was  $p < 0.05$ . Statistical analyses were done using Statistix (Analytical Software 1992).

## RESULTS

### Climate and Plant Productivity

The winter of 1987–1988 was wet, but was followed by two drought years (Table 1). Only 33% of the 1987–1988 annual total fell in the 1989–1990 water year (July–June). Winter precipitation in 1989–1990 was 31% of the 20-yr mean (Table 1). Winter precipitation is critical to germination of herbaceous annuals, and few herbaceous plants grew in 1990 (Fig. 1). Mean plant productivity was  $130.4 \text{ g} \cdot \text{m}^{-2}$  ( $\text{SD} = 61.6$ ) in 1988,  $1.28 \text{ g} \cdot \text{m}^{-2}$  (1.16) in 1990, and  $236.8 \text{ g} \cdot \text{m}^{-2}$  (104.4) in 1991 (estimates in 1987 of  $14 \text{ g} \cdot \text{m}^{-2}$  and in 1989 of  $6 \text{ g} \cdot \text{m}^{-2}$  are based on photographic interpretation). Precipitation increased in 1990–1991, although 74% of the winter total fell in March, mainly from one storm. This late rain led to a dense growth of herbaceous annual plants (mostly *E. cicutarium*) and some grasses (Fig. 1).

### Population Comparisons

Mean SVL, irrespective of sex, for lizards caught in the May–July time period in 1990 was shorter than for the same time in 1989 or 1991 (Fig. 2;  $H = 55.18$ ,  $p < 0.0001$ ). The

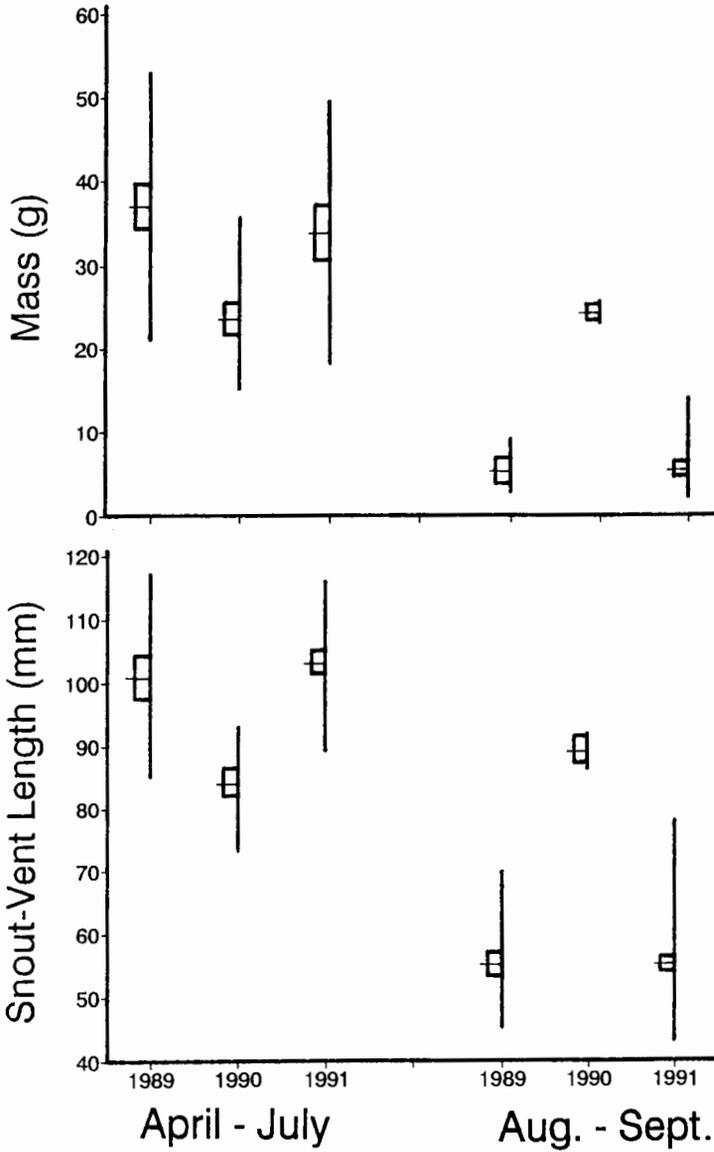


FIGURE 2. Mean (horizontal line), range (vertical line), and 95 % confidence intervals (box) of snout-vent length and mass of *Gambelia sila* found from April-July and August-September in 1989-1991 on the Elkhorn Plain.

mean mass of lizards caught April-July 1990 was lighter than in 1989 and 1991 (Fig. 2;  $H = 43.30, p < 0.0001$ ). We found only three *G. sila* from August-October 1990, and they were similar in mass and length to those seen during April-June 1990 (Fig. 2). They also were longer and heavier than hatchlings caught in August-October 1989 and 1991. *Gambelia sila* caught in the August-September time period in 1989 and 1991 did not differ significantly in SVL ( $\chi^2$  approximation = 0.001,  $df = 1, p = 0.966$ ) or mass ( $\chi^2$  approximation = 0.11,  $df = 1, p = 0.736$ ; Fig. 2). Three lizards caught in 1990 had PIT-tags that had been inserted when they were hatchlings in August and September 1989. Unmarked lizards

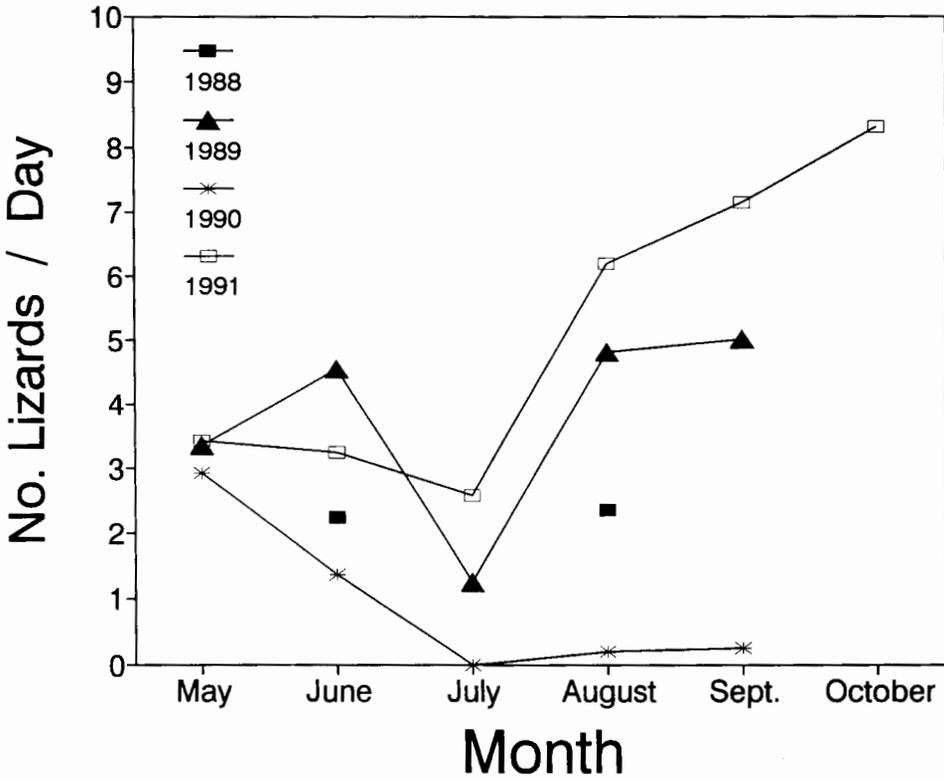


FIGURE 3. Index of monthly activity of *Gambelia sila* for 1988–1991 shown by the mean number of lizards found per day on the Elkhorn Plain.

caught in 1990 were similar in SVL and mass to these marked lizards, indicating that they also hatched in 1989. Lizards caught in August and September 1990 were the length and mass of yearling lizards, not hatchlings, indicating no reproduction took place.

Numbers of *G. sila* active aboveground differed among years. The mean number of lizards seen per day was similar among years in May, but in 1990, numbers decreased in June and none were seen in July (Fig. 3). In comparison, the mean number of lizards seen in June in 1989 and 1991 either was the same as seen in May or increased, and lizards were still active in July (Fig. 3). We saw few *G. sila* in August or September in 1990, whereas large numbers of lizards were seen in 1989 and 1991 (Fig. 3). Three adult lizards (108, 110, and 113 mm SVL) active in 1991 were first marked in June or July 1989 as adults (106, 106, and 111 mm SVL), but no lizards marked as adults in 1989 were found in 1990.

The production of eggs by *G. sila* was evident in 1989 and 1991, but not in 1990. In June 1989, 29% of females ( $N = 24$ ) were gravid, and no females ( $N = 2$ ) were gravid in July. In 1991, 16.7% of females ( $N = 12$ ) were gravid in April and May, 70.6% ( $N = 17$ ) were gravid in June, and 16.7% ( $N = 12$ ) were gravid in July. Most females were gravid from mid to late June in 1991. However, in 1990, no females were gravid in April and May ( $N = 11$ ) or June ( $N = 6$ ), and no lizards were active in July.

*Prey Abundance*

Although counts of prey are only relative abundances, numbers of grasshoppers and *U. stansburiana* were markedly different between 1990 and 1991 on both plots (Fig. 4).

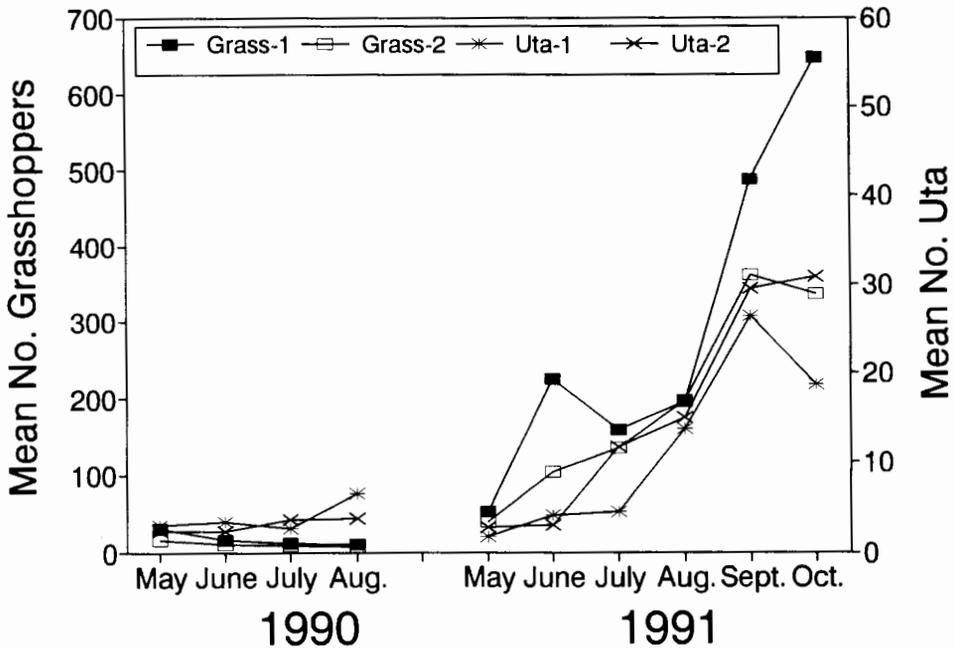


FIGURE 4. Mean number of grasshoppers (Grass) and side-blotched lizards (Uta) counted each month in 1990 and 1991 during surveys for *Gambelia sila* on the Elkhorn Plain. Means are shown for both plot 1 (Grass-1, Uta-1) and plot 2 (Grass-2, Uta-2).

Abundance of grasshoppers was highest in the spring on both plots in 1990, and steadily decreased through August (Fig. 4). Abundance of grasshoppers in 1991 generally increased through October (Fig. 4). Mean number of grasshoppers found on both plots were only slightly greater in the spring in 1991 compared to 1990, but reached 10–60 times greater abundance in later months of 1991 (Fig. 4).

A similar pattern between years was seen in counts of *U. stansburiana*. Counts were 2–4 times larger in 1991 than 1990 by August (Fig. 4). In both years, the increase in daily counts of *U. stansburiana* in July–October was due to the appearance of hatchlings.

#### DISCUSSION

Significant changes in a foothill population of *G. sila* occurred over a four-year period due to the effects of drought. In years with near average or greater winter precipitation, adult *G. sila* were active from April or May until July or August. Eggs were laid in May and June, and hatchlings appeared in August and were active into September or October. During the driest year (1990), major differences occurred in the lizard population compared to the three wetter years. The lack of appreciable winter rains in 1990 limited production of herbaceous annual plants in the spring of 1990 to about 1% of the production in 1988 and 0.5% of production in 1991. Correlated with this lack of plant production were low abundances of grasshoppers and *Uta*, main prey for *G. sila*. Adult *G. sila* (> 100 mm SVL) did not emerge from below ground in 1990. Yearlings (about 85–99 mm SVL) emerged but did not breed, as evidenced by the lack of hatchling lizards in August and September 1990. We are confident that we did not miss either adult or hatchling *G. sila* in 1990 because the lack of herbaceous ground cover on the plots in this year gave the greatest visibility of lizards compared to the other three years.

The response of populations of iteroparous lizards, such as *G. sila*, to extended periods of lowered prey abundance could vary based on circumstances. Responses of lizards to drought could include: 1) being active aboveground to compete for scarce resources and to breed, but facing predation and the possibility of not being able to regain energy (fat reserves) needed to overwinter; 2) being active aboveground to compete for scarce resources and increase fat reserves for the following winter, but forgoing breeding; or 3) remaining underground to avoid predation and to conserve fat reserves, but forgoing breeding and any increase of fat reserves for the following winter. The first option may not be advantageous to relatively long-lived lizards that can breed the following year if conditions improve. In addition, hatchlings may not be able to grow and accumulate energy reserves in years of very low prey abundance. Obligatory activity regardless of prey abundance is characteristic of short-lived lizards, such as *U. stansburiana* (Tinkle 1966). The second option results in individuals aboveground increasing their chances of being killed by predators, but survivors could gain stored energy by consuming prey. Individuals entering winter torpor with low fat reserves may be required to become active the next spring to survive, even if prey resources are poor. Options one and two are not mutually exclusive, and may be used by different individuals within a population depending on their physiological state at the time of emergence. Remaining underground throughout a "bad" year could be a suitable strategy for an ectotherm having lower per-mass energy requirements than endotherms (McFarland et al. 1985), but could be a poor strategy if prey abundance is low two or more consecutive years.

The response of *G. sila* to drought on the Elkhorn Plain is consistent with the second and third options that we hypothesize for iteroparous lizards. It may be possible for *G. sila* to physiologically evaluate the environmental conditions during their period of torpor in winter. The humidity of the burrows in which they reside may provide a clue to the aboveground conditions, although this has not been tested in this or other species of lizards. At least in this case, adult *G. sila* did not come aboveground during drought. Adult males are territorial (Montanucci 1965; Tollestrup 1983), and coming aboveground and investing energy in territoriality could deplete fat reserves. In addition, females and hatchlings would not have the resources needed for reproduction and growth, and their energetic requirements probably select for staying underground in severe drought years. Breeding and production of eggs in these years may require more energy than females have available from body reserves and reduced prey abundance. Also there may be, on average, insufficient prey for hatchlings to grow and accumulate enough energy reserves to overwinter successfully. Either or both situations would favor postponement of emergence and breeding if energetic costs of continued inactivity were sufficiently low to remain underground until the next spring.

Drought has been correlated with less or delayed reproduction in the insectivorous fringe-toed lizards, *Uma*, (Mayhew 1965, 1966a, 1966b), *U. stansburiana* (Hoddenbach and Turner 1968), tree lizard, *Urosaurus ornatus*, (Martin 1973, 1976; Ballinger 1977), and striped plateau lizard, *Sceloporus virgatus*, (Vinegar 1975), and with no reproduction in the omnivorous long-nosed leopard lizard, *G. wislizenii*, (Turner et al. 1969) and the herbivorous chuckwalla, *Sauromalus obesus*, (Nagy 1973). However, in none of these cases did the adult population stay underground during the drought, although fewer adult female *G. wislizenii* were found above ground than were believed to be inside three fenced plots (Turner et al. 1969). Similar to these other species, adults of a valley floor population of *G. sila* did come aboveground and breed during a drought year, but reproduction was later and shorter than normal (Tollestrup 1982). This case may not be directly comparable to what we found, though, because of differences in timing and amounts of rainfall and subsequent plant productivity. Plant growth at the sites studied during the drought year in 1977 was not quantified, and production of plants was simply listed as sparse (Tol-

lestrup 1979). Also, no estimate of prey availability was made. These findings do suggest, however, that aboveground activity following winter dormancy is complex and many options may be available to iteroparous lizards.

Yearling *G. sila* that hatched in 1989 were active in the spring and early summer of 1990, and a few remained active into fall. Why did yearling lizards respond differently than adults? Yearling leopard lizards probably cannot afford energetically to remain underground. Even in drought years when prey abundances are low, yearlings may need to be out and foraging in order to store energy and increase size enough to breed the following year. Although prey abundance was low in 1990, yearling lizards did grow larger and gain weight during their limited time of activity.

We found a marked response by a population of *G. sila* to one year of drought on the Elkhorn Plain. High variance in yearly rainfall totals and drought years are often found in the San Joaquin Valley desert region (Tollestrup 1982), and is a common phenomenon in arid lands throughout the world (Thomas 1965). Populations of arid-adapted species, especially ectotherms, may not be adversely affected by one year of low rainfall. This seems to be true of *G. sila*.

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