The Zebra-tailed Lizard, *Callisaurus draconoides*, has a broad distribution in arid habitats of western North America, occurring from northwestern Nevada and southeastern California to southwestern New Mexico, in the United States, and in Mexico southward to the tip of Baja California and southern Sinaloa. Reproduction is an important part of the natural history of a species, and the following article contributes to our knowledge of the reproduction of this species by reporting on its reproductive cycle in Baja California Sur, Mexico. Pictured here is an adult male *C. draconoides* from Cabo San Lucas, Baja California Sur, Mexico. © Matt Cage (www.cages.smugmug.com)

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Reproduction of the Zebra-tailed Lizard, *Callisaurus draconoides* (Squamata: Phrynosomatidae), from Baja California Sur, Mexico

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Abstract: I studied the reproductive cycle of *Callisaurus draconoides* from Baja California Sur, Mexico, by performing a histological examination of the gonads. The smallest reproductively active male and female of this species measured 49 mm and 48 mm in snout–vent length (SVL), respectively. Individuals from Baja California Sur reached reproductive maturity at a smaller size than those reported from populations in the United States. Males began sperm production and females commenced ovarian activity in March. Females can produce multiple egg clutches in the same year. The mean clutch size (*n* = 26) was 3.23 ± 0.76 SD, range = 2–4, which is smaller than what has been reported for *C. draconoides* populations from the United States.

Key Words: Clutch sizes, oviductal eggs, reproduction, spermiogenesis, yolk deposition

Resumen: Estudié el ciclo reproductivo de *Callisaurus draconoides* de Baja California Sur, México, a través de una examinación histológica de las gónadas. El macho y la hembra más pequeños y reproductivamente activos midieron 49 mm y 48 mm en longitud hocico–cloaca (LHC), respectivamente. Los individuos de Baja California Sur alcanzaron la madurez reproductiva a una talla más chica que las reportadas para las poblaciones de Estados Unidos. Los machos iniciaron la producción de esperma y las hembras la actividad ovárica en marzo. Las hembras pueden producir múltiples camadas en el mismo año. La media del tamaño de la camada (*n* = 26) fue de 3.23 ± 0.76 SD, rango = 2–4, la cual es menor a lo que se ha reportado para las poblaciones de *C. draconoides* en los Estados Unidos.

Palabras Claves: Deposición de yema, espermiogénesis, huevos oviductales, reproducción, tamaños de camada

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INTRODUCTION

Callisaurus draconoides ranges from northwestern Nevada and southeastern California eastward to southwestern New Mexico, in the United States, and in Mexico southward to the tip of Baja California and southern Sinaloa (Stebbins, 2003). Although the reproduction of *C. draconoides* has been well studied in North America (Pianka and Parker, 1972; Tanner and Krogh, 1975; Vitt and Ohmart, 1977; Goldberg, 2013a), reproduction in *C. draconioides* in Mexico consists of reports from Baja California (Asplund, 1967; Fitch, 1970; Grismer, 2002) and Sinaloa (Goldberg, *This issue*). In this paper I provide additional information on the reproductive cycle of *C. draconoides* from Baja California Sur, Mexico, based on a histological examination of museum specimens. I compared my findings with those of other studies on the reproduction of *C. draconoides*.

MATERIALS AND METHODS

I examined a sample of 111 *Callisaurus draconoides* consisting of 66 adult males (mean snout–vent length [SVL] = 63.0 mm ± 6.7 SD, range = 49–86), 40 adult females (mean SVL = 53.32 mm ± 4.1 SD, range = 46–63 mm) and 5 juveniles (mean SVL = 33.2 ± 7.1 SD, range = 25–43 mm) from Baja California Sur, Mexico, from the herpetology collection of the Natural History Museum of Los Angeles County (LACM), Los Angeles, California, United States. The specimens of *C. draconoides* were collected from 1936 to 1978. I measured the SVL (in mm) of each specimen from the tip of the snout to the anterior margin of the vent. I removed the left gonad and embedded it in paraffin, and cut histological sections at 5µm and stained them with hematoxylin followed by eosin counterstain (Presnell and Schreibman, 1997). I examined the slides of testes to determine the stage of the testicular cycle, and those of ovaries to ascertain the presence of yolk deposition. I counted enlarged follicles (> 4 mm length) and oviductal eggs, but performed no histology; I deposited the histology slides at LACM. I used an unpaired *t*- test to compare the mean body size (SVL) of males and females, and investigated the relationship between female body size and clutch size by linear regression using Instat (vers. 3.0b, Graphpad Software, San Diego, California, United States).

RESULTS

The mean body size of *Callisaurus draconoides* from Baja California Sur, Mexico, was significantly larger in males than females ($t = 8.3$, $df = 104$, $P = < 0.0001$). The following two stages were noted in the testicular cycle (Table 1): (1) recrudescence, a proliferation of germ cells for the next period of sperm production (spermiogenesis) is underway, primary spermatocytes typically predominate in early stages, secondary spermatocytes predominate in late recrudescence; and (2) spermiogenesis, lumina of the seminiferous tubules are lined by clusters of sperm or metamorphosing spermatids. Spermiogenesis for some males started in March and continued through August (Table 1). The smallest reproductively active male (spermiogenesis) measured 49 mm SVL (LACM 14162), and was collected in August.

Table 1. Stages in the monthly testicular cycle of 66 adult *Callisaurus draconoides* from Baja California Sur, Mexico.

Month	*n*	Recrudescence	Spermiogenesis
March	8	6	2
April	4	0	4
May	13	1	12
June	8	0	8
July	2	0	2
August	31	0	31

Four stages were noted in the ovarian cycle of *C. draconoides* (Table 2): (1) quiescent; no yolk deposition was observed; (2) early yolk deposition, basophilic vitellogenic granules were observed in the ooplasm; (3) enlarged oocytes > 4 mm; and (4) oviductal eggs present. Reproductive activity began in March and continued into August. Mean clutch size (n = 26) was 3.23 ± 0.76 SD, range = 2–4. Linear regression analysis revealed that the correlation between female body size (SVL) and clutch size (n = 26) was not significant (r = –0.23, P = 0.26). One female collected in August (LACM 14063) contained three oviductal eggs, and also was undergoing concurrent yolk deposition (enlarging yellow 3 mm follicles) indicating that more than one clutch can be produced in the same year. The smallest reproductively active female (3 follicles > 4 mm) was collected in July and measured 48 mm SVL (LACM 94417). One slightly smaller female (SVL = 46 mm, LACM 94407) collected in June contained quiescent ovaries, and I arbitrarily considered it an adult. Another slightly smaller reproductively inactive female collected in May (LACM 127918) measured 43 mm SVL, and I arbitrarily considered it a subadult. Four other four subadults (SVLs = 25, 28, 36, 43) might not have reached adult size. The two smallest specimens were collected in November, and likely were born earlier that year.

Table 2. Stages in the monthly ovarian cycle of 40 adult female *Callisaurus draconoides* from Baja California Sur, Mexico. *indicates one female contained oviductal eggs and concurrent yolk deposition for a subsequent clutch, and two other clutches of oviductal eggs were damaged and could not be counted.

Month	*n*	Quiescent	Yolk Deposition	Enlarged Follicles > 4 mm	Oviductal Eggs
March	3	2	0	1	0
May	4	2	2	0	0
June	5	4	0	1	0
July	5	0	2	2	1
August	23	0	0	9	14*

DISCUSSION

The minimum sizes for mature *Callisaurus draconoides* from Baja California Sur (males = 49 mm SVL, females = 48 mm SVL) are smaller than those previously reported for this species in the United States (males = 67 mm SVL, females = 63 mm SVL) by Pianka and Parker (1972). Similarly, Goldberg (2013b) reported that *Dipsosaurus dorsalis* from Baja California Sur reached maturity at a smaller size (males = 106 mm SVL, females = 93 mm SVL) than reported by Mayhew (1971) from California, United States (males = 115 mm SVL, females = 110 mm SVL). I have no explanation for these observations.

The *C. draconoides* female reproductive season commenced in March in Baja California Sur, Mexico (one female with enlarged follicles > 4 mm), and in southern California (one female exhibited yolk deposition; Goldberg, 2013a). Fitch (1970) reported a gravid female *C. draconoides* collected in Baja California (no location given) on 14 March.

Whereas Goldberg (2013a) reported limited female reproductive activity in *C. draconoides* collected in August and September in southern California, 100% of the 26 adult females and 100% of the 31 males from Baja California Sur were reproductively active (Tables 1, 2). This situation, however, might be associated with late summer precipitation and the resultant food increase in Baja California Sur (Asplund, 1967; Grismer, 2002). Some female *C. draconoides* reproduction likely persists into September in Baja California Sur, Mexico, but the exact duration will require an examination of female samples collected in the fall.

I include a summary of the clutch sizes of *C. draconoides* from the literature in Table 3. Fitch (1985) found no geographic variation in mean clutch sizes between populations from Nevada, California and Arizona, United States. The mean clutch size for *C. draconoides* from Baja California Sur is smaller than that previously reported (Table 3). Goldberg (1973, 1977) showed that clutch sizes in phrynosomatid lizards decrease late in the reproductive season.

Most (82.%) of the gravid female samples of *C. draconoides* from Baja California Sur (enlarged follicles > 4 mm, or oviductal eggs) were collected in August, late in the season (Table 2). Whether the small mean clutch size for female *C. draconoides* reported herein was influenced by collection late in the season (August) will require an examination of females collected earlier in the activity season.

Table 3. Clutch sizes of *Callisaurus draconoides* recorded in previous studies.

Mean Clutch Size	Range	*n*	Locality	Source
—	2–5	6	Nevada	Kay et al. (1970)
4.2	—	—	Northern Nevada	Pianka and Parker (1972)
4.3	—	—	Southern Nevada, California, Arizona	Pianka and Parker (1972)
4.5	—	—	Sonora, Mexico	Pianka and Parker (1972)
4.4	2–8	73	Above data combined	Pianka and Parker (1972)
4.5	3–7	12	Southwestern United States	Vitt (1977)
4.5	3–6	16	Nevada	Tanner and Krogh (1975)
4.6	1–8	34	Mohave, Yuma County, Arizona	Vitt and Ohmart, (1977)
3.6	4–8	55	Mohave County, Arizona	Smith et al. (1987)
4.5	3–8	28	Southern California	Goldberg (2013a)
3.0	2–5	5	Sinaloa, Mexico	Goldberg (2015)
3.2	2–4	25	Baja California Sur, Mexico	This paper

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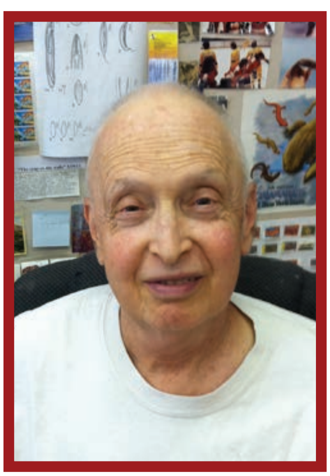
Appendix 1: *Callisaurus draconoides* (*n* = 111) from Baja California Sur, Mexico examined from the herpetology collection of the Natural History Museum of Los Angeles County (LACM), Los Angeles, California, United States.

LACM 3866, 3884, 3902-3905, 3913, 3918, 3919, 3946, 9817–9819, 9821–9824, 14042–14052, 14054–14057, 14059–14065, 14067–14077, 14079–14088, 14157–14159, 14162, 14277–14280, 62460, 62461, 74275, 94401–94408, 94410, 94411, 94416–94419, 94432–94437, 127897–127902, 127912, 127915–127918, 127921, 127922, 127927, 127930–127935.



Stephen R. Goldberg was born and raised in New York City. He was introduced to nature as a child while he attended summer camp near Peekskill, New York, and regularly visited the American Museum of Natural History where he was awed by the magnificent exhibitions of nature. Subsequently, he earned a B.A. from Boston University and an M.S. and Ph.D. in Zoology at the University of Arizona, Tucson, where he worked under Charles H. Lowe. Fellow graduate students in the same laboratory were well-known herpetologists Robert L. Bezy, Charles J. Cole, and John W. Wright. From 1970 to 2014 he taught herpetology and zoology at Whittier College, in California. Stephen has published widely on reptile reproduction, and his publications on parasitology of amphibians and reptiles with Charles R. Bursey (Penn State, Shenango) include the descriptions of numerous new species of Cestoda and Nematoda.