



Additional Notes on the Reproduction of the Formosan Grass Lizard, *Takydromus formosanus* (Boulenger 1894) (Squamata: Lacertidae), from Southwestern Taiwan

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Photographs by the senior author.

Abstract.—We collected 13 (male = 2; female = 10; juvenile = 1) *Takydromus formosanus* on an *ad hoc* basis from a Betelnut Palm (*Areca catechu*) plantation in Santzepu, Sheishan District, Chiayi County, as part of a herpetofaunal survey of the area. The smallest reproductively active female had a snout-vent length (SVL) of 44 mm, and the smallest male with an enlarged tail base had a SVL of 41 mm. A histological examination and oviposition indicated that the female reproductive cycle commences in April and lasts until at least June. We recorded no clutch sizes greater than two eggs. *Takydromus formosanus* is a poorly studied species, and many aspects of the reproductive biology of this species merit further research.

Information on the reproductive patterns of reptiles and amphibians is critical to species conservation efforts (Gibbons 1994), so understanding, for example, the period of sperm production, timing of yolk deposition, and number and sizes of clutches produced is important. Even chance observations and studies generating limited data can provide important information, can be helpful in generating questions leading to comprehensive studies, or highlight aspects that warrant in-depth research. For that reason, the publication of such data should be encouraged.

The Formosan Grass Lizard (*Takydromus formosanus* [Boulenger 1894]; Fig. 1) is endemic to the main island of Taiwan, where it was formerly believed to be the most widely distributed *Takydromus* species in Taiwan (Lue et al. 2002; Shang and Lin 2001). As for many other species, some confusion exists regarding the taxonomic history of *T. formosanus*. Until it was validated as a legitimate species, Stejneger's Grass Lizard (*T. stejnegeri* Van Denburgh 1912) was considered a synonym of *T. formosanus* (Boulenger 1917). More recently, a study (Lin 2003; Lin et al. 2002) using molecular markers indicated that the *T. formosanus* complex contained two other cryptic species from northern and eastern Taiwan; sub-

sequently, Lue and Lin (2008) described *T. viridipunctatus* (the northern clade) and *T. lueyanus* (the eastern clade).

In a previous report, we described three clutches of *Takydromus formosanus* from southwestern Taiwan (Norval et al. 2007). In this report, we incorporate additional information concerning reproduction with our previous observations to provide a more comprehensive description of reproduction in *T. formosanus* from southwestern Taiwan. We also highlight those aspects that merit further research.

Methods

From early January 2004 to late October 2006, we collected *T. formosanus* on an *ad hoc* basis by hand or pitfall traps inside enclosures erected in a Betelnut Palm (*Areca catechu*) plantation in Santzepu, Sheishan District, Chiayi County (N23°25'41", E120°28'11"; WGS84; Norval et al. 2007).

For all collected lizards, we measured snout-vent length (SVL) and tail length (TL) with a transparent plastic ruler to the nearest mm, scored the tail as complete or broken, and weighed the lizard to the nearest 0.1 g with a digital scale. If the lizard had suffered tail-loss in the past, the regenerated portion of the tail was also measured with a transparent plas-



Fig. 1. The Formosan Grass Lizard (*Takydromus formosanus*) is a small diurnal species that lives on and among herbaceous vegetation at altitudes below 1,500 m on the main island of Taiwan.

tic ruler to the nearest mm. In order to avoid injury to live lizards or induce tail-loss, no attempts were made to determine the sex of the lizards, other than visually examining the tail bases for the presence of enlarged hemipenial pouches.

Four *T. formosanus* died in pitfall traps and were subsequently deposited in the herpetological collection of the Natural History Museum of Los Angeles County (LACM), Los Angeles, California. These specimens were examined histologically to determine their reproductive state. The right gonad of each lizard was removed, dehydrated in an ascending series of ethanol, embedded in paraffin, sectioned at 5 μ , mounted on glass slides, and stained with Harris' hematoxylin followed by an eosin counterstain. We examined the left ovaries of the four LACM specimens visually *in situ* or microscopically, and assigned them to one of four stages of the ovarian cycle: (1) inactive (no yolk deposition); (2) yolk deposition in one or more ovarian follicles; (3) oviductal eggs present and yolk deposition in one or more ovarian follicles; or (4) oviductal eggs present, and no yolk deposition in ovarian follicles.

Results

During the study period, we collected 13 *T. formosanus*. Two of the collected lizards were positively sexed as males by the presence of enlarged tail bases (Fig. 2). One had SVL, TL, and body mass of 43 mm, 71 mm, and 1.4 g, the other 41 mm, 119 mm, and 1.5 g, respectively. Since a male with a SVL of 41 mm was found with an enlarged tail base, any lizard with a SVL \geq 41 mm without an enlarged tail base was regarded as female. For females ($n = 10$) SVL, TL, and body mass were 41–47 mm (mean \pm SD = 45.3 \pm 1.5 mm), 75–137 mm (118.4 \pm 16.7 mm), and 1.2–1.8 g (1.5 \pm 0.2 g), respectively. The smallest reproductively active female measured 44 mm SVL, and for reproducing females ($n = 5$), SVL, TL, and body mass were 44–47 mm (45.5 \pm 1.3 mm), 96–137 mm (115.5 \pm 21.5 mm), and 1.3–1.8 g (1.6 \pm 0.2 g), respectively. The remaining lizard had a SVL, TL, and body mass of 30 mm, 55 mm, and 0.5 g, and was thus regarded as a juvenile that could not be accurately sexed.

Of the four specimens that were examined histologically, only two were reproductively active. A female collected in

Table 1. A summary of the morphological data of gravid female Formosan Grass Lizards (*Takydromus formosanus*) from Santzepeu and their eggs. ¹ = current study; ² = Norval et al. 2007; SVL = snout-vent length in mm; BM = body mass in g; CS = clutch size; MEL = mean egg length in mm (SD); MEW = mean egg width in mm (SD); MEM = mean egg mass in g (SD); RCM = relative clutch mass; * = post-oviposition body mass; ** = oviposition date; *** = collection date.

Date	SVL	BM	CS	MEL	MEW	MEM	RCM
Mar 2004*** ¹	45	1.8	2	–	–	–	–
Mar 2006*** ¹	44	1.6	2	–	–	–	–
22 Apr 2006** ²	44	1.3*	2	8.2 (0.04)	5.15 (0.14)	0.1 (0)	15.39
15 May 2006** ²	46	1.5*	2	8.7 (0.28)	5.58 (0.67)	0.1 (0)	13.33
26 Jun 2006** ²	47	1.5*	2	8.73 (0.11)	5.43 (0.04)	0.1 (0)	13.33

March 2004 (LACM 180394; SVL = 45 mm; TL = 131 mm; mass = 1.8 g) had two enlarged ovarian follicles, 3 mm each, but no oviductal eggs. Another female, collected in March 2006 (LACM 180393; SVL = 44 mm; TL = 75 mm; mass = 1.6 g), had two oviductal eggs, and no yolk deposition in any ovarian follicles.

Discussion

Although Shang and Lin (2001) and Lue et al. (2002) made some references to reproduction in *T. formosanus*, no descriptions of sexually mature sizes were given, so no comparisons can be made. The smallest reproducing females (n = 2) recorded in this study had a SVL of 44 mm (Table 1), and since a fairly large female (SVL = 41 mm) from our study was still non-reproductive even though she was collected in July, female *T. formosanus* apparently become sexually mature at a SVL of ca. 44 mm. In studies of *T. hsuehshanensis* and *T. sauteri*, Huang (1998, 2006) found that males become sexually mature at a slightly lesser SVL than females. Consequently, the sexes of *T. formosanus* become sexually mature at the sizes reported herein. Still, due to the very small sample sizes, additional research is needed for confirmation.

All of the reproductively active *T. formosanus* females described herein had a clutch size of two eggs, which is similar to the mean clutch size reported by Huang (2006). So, our data could not confirm the clutch sizes of two to six eggs reported by Lue et al. (1987) and Lue et al. (2002). Interestingly, *T. viridipunctatus* and *T. lueyanus*, which were formerly confused with *T. formosanus*, also have mean clutch sizes of two eggs, although a few females produce three eggs per clutch (Lue and Lin 2008). Consequently, we believe that clutches of at least three eggs are possible in some very large *T. formosanus* females, and the four to six eggs per clutch reported by Lue et al. (1987) could in fact be the result of counting oviductal eggs and enlarged ovarian follicles as a single clutch.

Studies involving *T. septentrionalis* (Ji et al. 2007; Luo et al. 2010), *T. stejnegeri* (Cheng and Lin 1987; Lin et al.

2004), and *T. tachydromoides* (Telford 1969) have indicated that these lizards are income breeders (i.e., they expend some acquired energy for reproduction soon after that energy is obtained; Jönsson 1997). Also, since multiple clutches of eggs in the same year have been reported for *T. hsuehshanensis* (Huang 1998), *T. kuehnei* (Norval and Mao 2008), *T. lueyanus* (Lue and Lin 2008), *T. sauteri* (Huang, 2006), *T. septentrionalis* (Ji et al. 2007; Luo et al. 2010), *T. stejnegeri* (Cheng and Lin 1987; Lin et al. 2004), *T. tachydromoides* (Telford 1969), and *T. viridipunctatus* (Lue and Lin 2008), this trait appears very common in the genus *Takydromus*. So,



Fig. 2. Scanned images of the venters of a female *Takydromus formosanus* (SVL = 46 mm; top) and a male (SVL = 41 mm; bottom) from this study to illustrate the enlarged tail base of the male.

even though we found no evidence that *T. formosanus* females produce multiple clutches in the same year, we suggest that producing more than one clutch of eggs per year is likely under suitable conditions.

Apart from the hatchlings described by Norval et al. (2007), we found no other descriptions. Since inter-population offspring size variations can exist within the same species (e.g., Du et al. 2010), we suggest that attempts should be made to obtain additional descriptions of hatchling *T. formosanus* as well as of all other species in the genus *Takydromus*.

Temperature during incubation can affect the fitness of hatchlings (Du and Ji 2006) and the incubation period (Birchard 2004; Chen et al. 2010). As with hatchling descriptions, the only record of an incubation period that we could find was that of Norval et al. (2007). Again, we advocate additional research on the incubation period of *T. formosanus* under natural conditions.

Due to the very small number of *T. formosanus* used in this study, we were unable to provide a complete description of the reproductive cycle of these lizards. However, Huang (2006) found that female *T. sauteri* become reproductively active as early as February, females with oviductal eggs are first apparent in April, and reproduction ceased in August. Similarly, Cheng and Lin (1987) determined that female *T. stejnegeri* commenced reproduction in March and ceased in August, whereas female *T. hsuehsbanensis* are reproductive from April to August (Huang 1998). As for *T. lueyanus* and *T. viridipunctatus*, which were formerly confused with *T. formosanus*, Lue and Lin (2008) stated that gravid females of the former can be found from May to August, while gravid females of the latter can be found from April to August. Based on the findings of this study, we conclude that the reproductive season of female *T. formosanus* is most likely very similar to that of congeners in Taiwan (i.e., spring and summer; Table 1). We suggest that a detailed empirical study be implemented to determine the exact extent of the reproductive cycle of *T. formosanus* of both sexes in Taiwan. Because of conservation concerns, we discourage the collection of animals from the wild for such a study, and suggest that existing museum specimens be utilized when possible.

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