

SEXUAL DIMORPHISM AND REPRODUCTION IN THE GRASS LIZARD *Takydromus septentrionalis*

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Sexual dimorphism and reproduction in a population of *Takydromus septentrionalis* on Xiushan Island of Zhoushan Islands group were investigated during the breeding seasons of 1989–1992. Most males and females, approximately two years after hatching, reached sexual maturity at 54 and 57 mm SVL, respectively. Adult male and female *T. septentrionalis* were similar in SVL but quite different in the head size characteristics, males having larger heads than females of similar SVL except near the size of sexual maturity. Mating success in males was apparently not related to increased SVL. Males can copulate with females in several hours before or after oviposition. The duration of intromission averaged 227 min. Females can lay 1–3 clutches with 2–6 eggs each per season. Clutch size or clutch mass was significantly correlated with SVL and was not correlated with the clutch size. Relative clutch weight (RCW) averaged 0.149. Oviposition frequency averaged 16.7 days.

Key Words: Lacertidae, *Takydromus septentrionalis*, sexual dimorphism, mating behavior, clutch weight, oviposition frequency.

INTRODUCTION

During the past 20 years, a great number of detailed data in reproduction and sexual dimorphism of reptiles, particularly lizards, have been reported by the authors outside China. In contrast, there are relatively few data on these aspects of lizard ecology in the mainland of China. Among lizards living in China, *T. septentrionalis* is one of the best known species. It is a widely foraging diurnal lizard. It is commonly called as “grass lizard” reflecting its habit of spending a lot of its daily active time on grasses and shrubs. Prey items mostly belong to arthropods, mostly insects and spiders, found in leafy vegetation. *T. septentrionalis* is one of the most common lizard species in Zhejiang Province, in particular in Zhoushan Islands group.

Previous studies of *T. septentrionalis* have been focused on spatial distribution, food habit, reproduction in the field, seasonal metabolic characteristics, embryonic metabolism, and egg components (Wang, 1964, 1966; Wang and Xu, 1987; Wang et al., 1989; Ji et al., 1989; Ji, 1992). Problems of sexual dimorphism and reproduction of the species, however, remain poorly studied. Liu (1939) and Wang (1966) ex-

amined many individuals and they present only descriptive results.

Here we present the new data on sexual dimorphism and reproduction in *T. septentrionalis*. In particular, we study the mating behavior, clutch size, relative egg size and relative clutch weight, oviposition frequency and sexual dimorphism in head size.

MATERIAL AND METHODS

Our field observations were made during the breeding seasons of 1989–1992 on Xiushan Island (30°11' N, 122°9' E), Zhoushan Islands group, Zhejiang Province. The habitat consists primarily on woody saplings of *Pinus thunbergii*, *Camellia sinensis*, *Albizia juibrissin*, *Quercus fabris*, and *Sympocos pampulata*, and grasses of Agrostidoideae and *Pteridium*.

Lizards were captured by hand in a field on Xiushan Island. In the laboratory each lizards was sexed, weighed (nearest 0.01 g) and its snout-vent length (SVL) was measured to the nearest 0.1 mm). All the captured lizards were numbered temporarily with a radiograph pen and were marked permanently by toe-clipping in unique combinations. Lizards were then placed in two plastic boxes (80 × 50 × 50 cm) with a microhabitat similar to the natural habitats. Lizards in captivity were allowed to feed freely on larvae of *Tenebrio molitor*. Morphological comparisons among lizards were made from following data set: body

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mass, SVL, head length (from the snout to the posterior edge of tympanum), head width (taken at the posterior end of the mandible) and head height (the deepest point on the head).

We recorded the mating behavior of lizards with a camera and descriptive notes both in the field and in the laboratory. Those were recorded as the behavior of lizards before intromission, the duration of intromission, and the individual peculiarities of the mating lizards. The latter were estimated by using of special conditional index that was expressed as a wet weight (g)/SVL (cm) \times 100%.

Females either with enlarged yolk ovarian eggs or with eggs in their oviducts were used to determine their clutch size. New-laid eggs were collected within 6 hours of being laid. Each egg was numbered; its size (nearest 0.02 mm) and wet mass (nearest 0.01 g) were noted. Relative clutch weight (RCW) was calculated by using the ratio of wet clutch weight of the newly laid eggs to total female body mass (including clutch weight) (Vitt and Congdon, 1978; Vitt, 1981; Vitt and Price, 1982).

RESULTS

Body size and sexual dimorphism. *T. septentrionalis* in our sample ranged from 20.8 mm SVL at hatchling to 76.0 mm for female and 73.6 mm SVL for male. There was no significant difference in SVL between the sexes in adult individuals. Maximal body size for females was 9.8 and 8.2 g for males (Table 1). Most males and females, approximately two years after hatchlings, reached sexual maturity at 54 and 56 mm respectively. The sexual mature males with minimal SVL usually failed in gaining access to females. However, a majority of the second-year females were capable to lay their eggs for the first time.

Means and ranges of morphological data from our samples are given in Table 1. Juvenile males and females of similar SVL had similar head size (Mann-Whitney *U*-test, $p > 0.05$), but adult males and females were quite different in the head size. There were significant differences in the head length (HL) ($F(2.48) = 58.152$, $p < 0.01$), head width (HW)

TABLE 1. Data on Body and Head Size Characteristics for *T. septentrionalis*. Mean \pm SE and Ranges are Presented with Sample Sizes in Parentheses

Variable	Juvenile	Adult female	Adult male
SVL, mm	51.8 \pm 1.0 (8)	65.2 \pm 0.6 (65)	65.9 \pm 0.5 (59)
	45.6–54.1	55.0–76.0	56.0–73.6
Body weight, g	2.3 \pm 0.2 (8)	5.4 \pm 0.2 (43)	5.9 \pm 0.2 (40)
	1.7–3.3	2.9–9.8	3.9–8.2
Head length, mm	13.25 \pm 0.19 (9)	15.30 \pm 0.22 (23)	17.41 \pm 0.24 (19)
	12.06–13.92	13.12–16.40	14.89–18.86
Head width, mm	6.67 \pm 0.16 (9)	7.85 \pm 0.09 (23)	9.15 \pm 0.15 (19)
	5.96–7.36	6.94–8.50	7.76–10.06
Head height, mm	5.76 \pm 0.13 (9)	6.75 \pm 0.10 (23)	7.82 \pm 0.10 (19)
	5.14–6.20	5.68–7.66	6.86–8.40
HL/SVL	0.253 \pm 0.003 (9)	0.228 \pm 0.002 (23)	0.253 \pm 0.001 (19)
	0.239–0.264	0.214–0.252	0.240–0.266
HW/SVL	0.128 \pm 0.003 (9)	0.117 \pm 0.001 (23)	0.133 \pm 0.002 (19)
	0.117–0.140	0.107–0.128	0.124–0.147
HH/SVL	0.110 \pm 0.002 (9)	0.101 \pm 0.001 (23)	0.114 \pm 0.001 (19)
	0.099–0.116	0.091–0.111	0.110–0.124

$F(2.48) = 72.337$, $p < 0.01$) and head height (HH) ($F(2.48) = 66.791$, $p < 0.01$) among the lizards of different size and sex groups, with adult males having larger heads than juveniles (Duncan's new multiple range test: HL-ISR = 0.098; HW-LSR = 0.053; HH-LSR = 0.045; and adult females (HL-LSR = 0.094; HW-LSR = 0.050; HH-LSR = 0.043) whereas adult females having larger heads than juveniles (HL-LSR = 0.094; HW-LSR = 0.050; HH-LSR = 0.043). Because head size was positively correlated with SVL, values of HL/SVLL, HW/SVL, and HH/SVL are more useful in comparing head size characteristics between the sexes. Also, there were significant differences in HL/SVL ($F(2.48) = 60.750$, $p < 0.01$), HW/SVL ($F(2.48) = 31.200$, $p < 0.01$), and HH/SVL ($F(2.48) = 38.001$, $p < 0.01$) among lizards of different size and sexual groups, with adult males having greater values of HL/SVL (LSR = 0.008), HW/SVL (LSR = 0.006) and HH/SVL (LST = 0.005) than adult females. In a contrast, there were slight differences in these values between adult males and juveniles, although the differences in HW/SVL (LSR = 0.005) and HH/SVL (LSR = 0.004) were statistically significant. In all the cases the head size-SVL regression lines were higher in adult males than adult females (Table 2).

Adult lizards exhibit relatively bright coloration during period of reproduction in comparison with

TABLE 2. Regression Statistics for Head Characteristics on SVL and log Body Weight on log SVL for Adult *T. septentrionalis*

Variable	Regression model				Comparing slopes and elevations	
	<i>r</i>	significance	slope	intercept	equal slopes	equal elevations
Head length × SVL						
Females	0.859	$F(1.21) = 59.296, p < 0.01$	0.162	4.364	$t = 1.570, p > 0.05$	$t = 10.262, p < 0.01$
Males	0.813	$F(1.17) = 33.188, p < 0.01$	0.230	1.658	$df = 38$	$df = 39$
Head width × SVL						
Females	0.805	$F(1.21) = 38.521, p < 0.01$	0.067	3.359	$t = 0.330, p > 0.05$	$t = 9.062, p < 0.01$
Males	0.544	$F(1.17) = 7.156, p < 0.05$	0.093	2.785	$df = 38$	$df = 39$
Head height × SVL						
Females	0.763	$F(1.21) = 29.306, p < 0.01$	0.070	2.064	$t = 0.739, p > 0.05$	$t = 9.299, p < 0.01$
Males	0.746	$F(1.17) = 21.320, p < 0.01$	0.087	1.847	$df = 38$	$df = 39$
Log body weight × log SVL						
Females	0.303	$F(1.41) = 74.275, p < 0.01$	2.301	-4.351	$t = 1.532, p > 0.05$	$t = 2.908, p < 0.05$
Males	0.794	$F(1.38) = 64.823, p < 0.01$	3.676	-5.896	$df = 79$	$df = 80$

non-breeding period. Three adult color patterns were observed: 1) back brown, flanks green; 2) back brown with narrow white, yellow or green stripes on the periphery; 3) the same coloration pattern as the number 2 with additional dense black dots on the lateral surfaces. Interesting to note that pattern 1 was recorded only in females and pattern 3 was noted only in males. Coloration of the pattern 2 was found in females and males both.

Mating Behavior. We observed 15 cases of copulation in captivity (3 of them were observed at night). Males usually attempted to catch foraging females without preliminary displays. Females did not immediately mate with males and tried to escape. A male caught an escaping female by biting the left side of her body just anterior to hind legs. Mating success in males was apparently not correlated with the length of body (SVL). As shown in Table 3, the mating males have significantly more high conditional index than non-mating ones (Mann-Whitney *U*-test, $p < 0.05$). Males were capable for copulation with females even several hours (1–12) before or after oviposition. The duration of intromission averaged 227.6 ± 13.3 min ($n = 7$; range 180–280 min).

Female Reproduction. Oviposition began in the middle of May and finished in late of July. It depends on climatic characteristics of different years. During one season 1–3 clutches were deposited on moist ground and grass clumps. In the sample of 47 females with SVL 55.8–76.0 mm (65.0 ± 0.7 in average) with oviductal eggs or just after deposited clutch the clutch size varies from 2 to 6 (3.1 ± 0.1). The clutch size

($r = 0.701, F(1.45) = 43.574, p < 0.01$) or clutch weight ($r = 0.709, F(1.45) = 29.487, p < 0.01$) are positively correlated with SVL (Fig. 1). Mass of individual egg is not correlated with SVL ($r = 0.239, F(1.44) = 2.655, p > 0.05$) and clutch size ($r = 0.022, F(1.44) = 0.021, p > 0.05$). The mean value of relative clutch weight was 0.149 ± 0.007 ($n = 23$, range 0.096–0.220). Mean oviposition frequency was recorded in 16.7 ± 1.2 days ($n = 7$, range 12–20 days).

DISCUSSION

Sexual dimorphism in body size or other morphological characteristics has been noted in many lizard species. Powell and Russell (1985) categorized three types of sexual dimorphism: male+ with the males as the larger sex at adulthood; female+ with the females as the larger sex at adulthood; monomorphic where there are no significant difference in the size between males and females at their adulthood. According to available information, monomorphic reptiles species are very uncommon (Schoener, 1977; Fitch, 1981). In the terms of the sexual selection theory, the sexual selection can act on either males or females (Trivers, 1972, 1976). If the intrasexual competition or male combat is partially determined by body size, selection should favor large body size in males (Trivers, 1972; Cooper, 1977; Vitt, 1983; Carothers, 1984; Vitt and Cooper, 1985, 1986; Anderson and Vitt, 1990). If a female can increase reproductive success through production of more offsprings by increasing of body size, the selection should favor large body size in fe-

TABLE 3. Conditional Index of *T. septentrionalis* Measured in the Breeding Seasons of 1991–1992

Variable	N	Mean	SE	Range
Nonmating females	50	1.96	0.03	1.57–2.56
Mating females	9	1.85	0.11	1.42–2.42
Nonmating males	47	1.99	0.04	1.37–2.38
Mating males	8	2.17	0.08	1.70–2.42
Juveniles	31	1.98	0.04	1.37–2.44

males. However, factors other than sexual selection may also influence the body size: 1) differential mortality of the individual of different sexes (Dunham, 1981); 2) different influence of temperature factor and predators on the males and females (Hedrick and Temeles, 19989; Sandell, 1989) and 3) intersexual food resource partitioning (Schoener, 1967, 1969, 1971, 1977; Roughgarden, 1974; Powell and Russell, 1985; Best and Pfaffenberger, 1987). In a contrast to the majority of the reported species of lacertid lizards which are male+ (Fitch, 1981), *T. septentrionalis* is a monomorphic species. Because both males and females *T. septentrionalis* are not territorial (Ji et al., 1989) and not aggressive (Ji et al., in press) it is reasonable to assume that the male of *T. septentrionalis* are under the low rate of the sexual selection.

The adult males with minimal SVL usually fail to mate. There is no correlation between the increasing of SVL and mating success in larger males. Males do actively search out the females during the breeding season since the larger home ranges of adult males are determined not by their food necessities but rather by the size of the area where they can find more females (Ji et al., 1989).

In a contrast the larger females of *T. septentrionalis* can increase their reproductive success by increasing of SVL since the clutch size or clutch weight is positively correlated with SVL. Larger females can usually lay more than two clutches per breeding season.

Similar to many other lizard species (Vitt, 1982, 1983; Carothers, 1984; Vitt and Cooper, 1985; Congdon and Vitt, 1989; Anderson and Vitt, 1990) adult males of *T. septentrionalis* have larger heads than the females of similar SVL. Larger heads in adult males may be associated with niche partitioning and/or male-male combat (Carothers, 1984). We can conclude that large head size in male of *T. septentrionalis* may be indirectly correlated with the mating success because 1) it increases the prey-handling capability

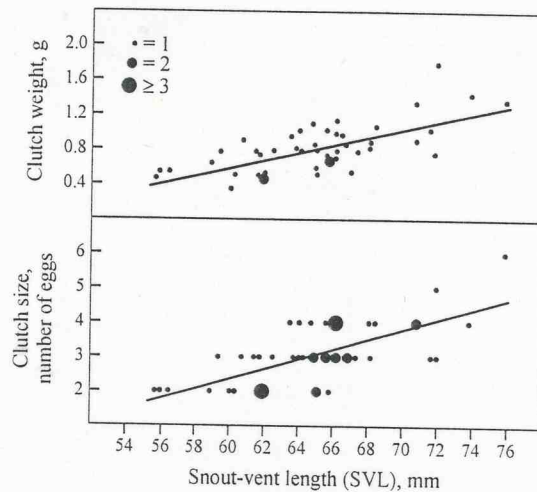


Fig. 1. Relationships of clutch size and clutch weight to body size (SVL). Size of point indicates number of data points at a given $x-y$ coordinate.

ties that are important for the good condition of the male to the breeding season and 2) it increases the advantages in the mating success. Our observations strongly suggest that female of *T. septentrionalis* allocate relatively more energy to SVL growth after the sexual maturity to realize the potential greater clutch size or clutch weight at the greater SVL.

Liu (1939) and Wang (1966) show no correlation between the individual egg size and female's SVL and negative correlation between individual egg size and clutch size. We found no correlation between the individual egg size and female SVL and also clutch size.

RCW in *T. septentrionalis* is similar to those reported for other lacertid lizards (0.137–0.400) (Avery, 1975; Goldberg and Robinson, 1979; Telford, 1969). Similar to many other widely foraging lizards, this species has lower RCW in comparison with sit-and-wait foraging lizards. Females may actually increase their reproductive potential by increasing of their running speed for escape through decreasing of reproductive output as in a model proposed by Vitt and Congdon (1978).

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