Zoological Studies **35**(1): 55-61 (1996)

Zoological Studies

Reproductive Cycles and Sexual Dimorphism in the Viviparous Skink, *Sphenomorphus indicus* (Sauria: Scincidae), from Wushe, Central Taiwan

Wen-San Huang

Department of Zoology, National Museum of Natural Science, 1, Kuan Chien Rd., Taichung, Taiwan 404, R.O.C.

(Accepted November 9, 1995)

Wen-San Huang (1996) Reproductive cycles and sexual dimorphism in the viviparous skink, *Spenomorphus indicus* (Sauria: Scincidae), from Wushe, central Taiwan. *Zoological Studies* **35**(1): 55-61. Seasonal variation in the male and female reproductive cycles of the viviparous scincid *Sphenomorphus indicus* is described in this study. Mean snout vent length (SVL) of adult females (n = 50) (range: 76 to 94, mean = 81.6 mm) was significantly larger than that of the adult males (n = 29) (range: 63 to 85, mean = 73.6 mm). However, the mean values of head length (HL) and head width (HW) showed no significant differences between sexes. Females exhibited a spring vitellogenic period with parturition occurring in June and July. The onset of vitellogenesis coincided with increasing rainfall and showed a negative correlation with the female liver somatic index (FLSI). Females produced 4 to 11 embryos and the clutch size was positively correlated with body size. Males exhibited a spermatogenic cycle with spermatogenesis commencing during late summer and autumn. Peak spermiogenesis occurred during spring at which time testis somatic indices were maximum. Peak spermiogenesis in males coincided with vitellogenesis in females. Testicular regression occurred during summer, with seminiferous tubule diameters at their minimum values. Male seminiferous tubule diameter (MSTD) and testis somatic index (MTSI) had a negative correlation with temperature.

Key words: *Sphenomorphus indicus*, Reproduction, Sexual size difference, Viviparous lizards.

The genus *Sphenomorphus* is widespread in southeastern Asia, India, Malaysia, the Philippines, Taiwan, and New Guinea (Lin and Cheng 1990). Reproductive cycles of 2 species of this genus have already been described (*S. incognitus* and *S. indicus*, Okada et al. 1992). However, the investigation of the reproductive traits of *S. indicus* in Taiwan was based on specimens spreading from several localities. A long-term study of *S. indicus* in Taiwan has not yet been performed.

The viviparous lizard, *S. indicus*, was described as an oviparous species (Lin and Cheng 1990). A short note on the delivery process of the female has been reported (Lin et al. 1993). The complete reproductive cycle of this species has apparently not been studied at any single locality. This study examined the male and female reproductive cycles of a montane population in Wushe, central Taiwan. Sexual dimorphism in morphological characteristics and size are also described.

MATERIALS AND METHODS

The study was conducted in a montane area in Wushe, Nantou County, about 87 km east of Taichung in central Taiwan (23° 30' N, 121° 08 'E). The elevation of this area is approximately 1 100 m. Because the lizards were sensitive to intruders, samples were only collected in a small dry drainage area that was covered with dried leaves.

Average annual rainfall for Wushe is about 2 500 mm, most of which falls in the spring and summer, from February to September. The dry period lasts from October to January. Maximum air temperatures in the summer (June-August) range from 24 to 26 °C and minimums range from 14 to 18 °C in the winter (November to January) (Fig. 1A).

Lizards were hand collected each month from June 1992 to August 1993. Some samples were incomplete due to the difficultly in finding lizards during rainy weather, however attempts were made to collect 5 males and 5 females each month. Each specimen was: 1) weighed to the nearest 0.01 g; 2) measured for snout-vent length (SVL) to the nearest 0.1 mm; and 3) dissected to remove the liver and testes which were weighed to the nearest 0.01 g. Stage of maturity for males was assessed by the appearance of the testes and epididymides, which were small and without obvious convolutions in immature specimens. Females with follicles larger than 3 mm were considered to be mature.

The reproductive state of females was determined on the basis of the presence and the number of vitellogenic follicles and uterine embryos (if present). Follicles were considered vitellogenic when they were longer than 3 mm. A reproductive active state was defined as a female with vitellogenic follicles, or with embryos as contrasted with a female in a nonreproductive state with no vitellogenic follicles or embryos. The estimation of clutch size was based on the number of vitellogenic follicles and uterine embryos. Relative clutch mass (RCM) was determined by dividing clutch mass by body mass. RCM was determined for 10 lizards that were collected in June, i.e., the last month of the young-bearing period. The time necessary for producing a clutch of eggs was assessed from the dates when the first females were found with small vitellogenic follicles and when the last females with embryos in utero were collected.

Reproductive states of males were estimated by testicular weights and spermatogenetic activity. The right testis from each adult male was fixed in Bouin's solution, embedded in paraffin, serially-sectioned at 6 μm, and stained with hematoxylin and eosin. Spermatogenetic activity was assessed qualitatively by using the classification system of Licht (1967).

To minimize body weight differences, weights of liver and testis were expressed as an organosomatic index: (gram organ weight/gram body weight) × 100%. Voucher specimens are deposited at the National Museum of Natural Science, Taichung, Taiwan.

The relationship between clutch size and female body size was examined using a Pearson's correlation analysis. Statistical differences were assessed using ANOVA. A probability of 0.05 or less was used to indicate significance.

RESULTS

Of the 79 specimens, 50 were females. Mean snout vent length (SVL) of adult females (range: 76 to 94 mm, mean = 81.6 mm) was significantly larger than that of adult males (range: 63 to 85 mm, mean = 73.6 mm) ($F_{1,77}$ = 6.6; $p < 0.05$). The mean values of head lenght (HL) and head width (HW) showed no significant differences between sexes ($F_{1,77}$ = 1.12; p = 0.29 for HL; $F_{1,77}$ = 0.30; p = 0.59 for HW; Table 1).

Female reproductive cycle

The SVL of the samllest reproductive *Sphenomorphus indicus* female measured 76 mm; therefore, only females with a SVL $\geq$ 76 mm were used in this study. All females larger than this size were reproductively active between April and June when rainfall in the area is high (Fig. 1A), and non-reproductive from July to March when the amount of rainfall is low (Fig. 1A). The rainfall amounts of these two periods show a significant difference ($F_{1,13}$ = 8.7; p = 0.01).

At Wushe, vitellogenesis began in spring to early summer (April-June): the first females initiating vitellogenesis were found in April and the last females having embryos were found in June. The interval between the time females with vitellogenic follicles were initially found and the time when the last females with embryos were found indicated that 3 months were required to produce a clutch of eggs. Vitellogenesis is associated with a rapid and significant increase in follicular diameter

Table 1. Mean values of snout vent length (SVL, ± SE), head length (HL, ± SE), and head width (HW, ± SE) of male and female *Sphenomorphus indicus* in central Taiwan

		SVL (mm)		HL (mm)		HW (mm)	
Sex	*n*	mean ± SE	range	mean ± SE	range	mean ± SE	range
Male	29	73.6 ± 5.4	63-85	15.0 ± 1.8	12-21	8.9 ± 0.8	7-10
Female	50	81.6 ± 6.2	76-94	14.6 ± 1.2	11-17	9.0 ± 0.8	7-11

(Fig. 2A). Female follicular diameter (FFD) was negatively correlated with female liver somatic index (FLSI) ($r = -0.82$; $p < 0.005$; Table 2), but had no correlation with air temperature ($r = -0.12$; $p = 0.75$; Table 2). The RCM values ranged from 0.212 to 0.333 (mean = 0.288).

Adult females ranged in SVL from 76 mm to 94 mm. Clutch size averaged 7.27 ± 1.62 (range 4 to 11) and the number of in-utero embryos was positively correlated with female body size ($r = 0.584$; $p < 0.005$; Fig. 3). Births occurred during late June and in early July.

Female FLSI had no monthly variation ($F_{1,8} = 9.23$; $p > 0.05$), and showed no correlation with air temperature ($r = 0.22$; $p > 0.05$) (Table 2). However, the FLSI values were higher between July and September than in other months.

Male reproductive cycle

Mean SVL of males used in this study was 73.6 ± 5.4 mm ($n = 29$). Because of the small sample size of captured male lizards, and because the male liver somatic index (MLSI), male testis somatic index (MTSI), and male seminiferous tubule diameters (MSTD) showed no significant differences between 1992 and 1993 (MLSI: $F_{1,8} = 0.63$, $p = 0.45$; MTSI: $F_{1,8} = 1.08$, $p = 0.33$; MSTD: $F_{1,8} = 0.25$; $p = 0.63$), these specimens were pooled into 1 year. MTSI showed a significant monthly variation ($F_{1,5} = 16.4$, $p < 0.05$; Fig. 4A), with an increase commencing in late summer (August) and a peak reached in spring (March). A significant negative correlation with air temperature ($r = -0.78$; $p < 0.01$; Table 2) was ob-

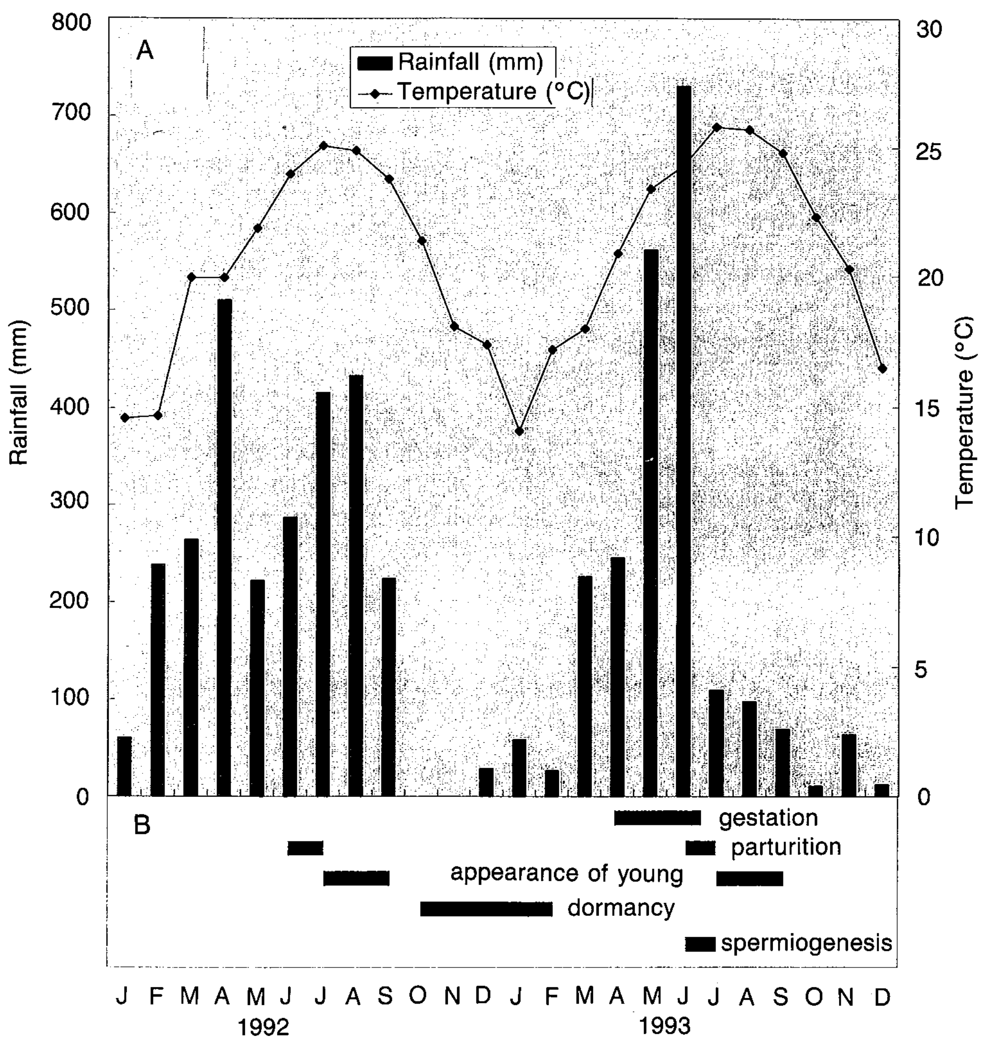

Fig. 1. Mean monthly temperature and total monthly rainfall at Wushe, Nantou County in 1992 and 1993 (A). Reproductive cycles of *Sphenomorphus indicus* at Wushe, Taiwan (B).

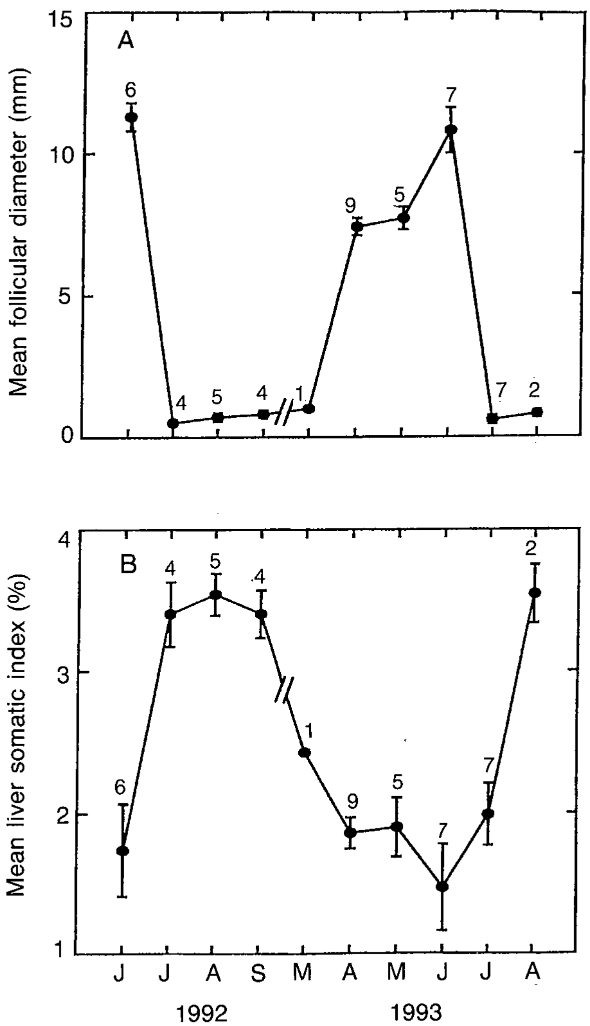

Fig. 2. Variation (mean ± SE) in mean follicular diameter (A) and mean liver somatic index (B) during the biennial reproductive cycle of *Sphenomorphus indicus* females. Numbers above data points indicate sample sizes.

served. During April to July, MTSI decreased to a low. The MSTD showed a significant monthly variation ($F_{1,5}$ = 85.20, $p < 0.005$; Fig. 4B), and showed a negative correlation with air temperature ($r = -0.74$; $p < 0.05$; Table 2).

Histological examinations indicated that peak spermiogenesis was evident during March and April when spermatids were abundant and spermatozoa were present (Fig. 5A). During this period MTSI and MSTD reached maximum values and a correlation existed between MTSI and MSTD (r = 0.67; $p < 0.05$; Table 2). Testes were in a regressed state from May through July and seminiferous tubules were mostly occupied by spermatogonia. MTSI and MSTD were lowest during this period (Fig. 5B). Proliferation of primary spermatocytes, with the appearance of secondary spermatocytes, commenced during August and September (Fig. 5C).

The MLSI showed a significant variation in monthly samples ($F_{1,5}$ = 13.4, $p < 0.05$; Fig. 4C). However, there were no correlations with MSTD, MTSI, air temperature, or rainfall (Table 2).

The testicular annual cycle and female reproductive cycle of *Sphenomorphus indicus* shown in Fig. 1B indicate that males and females reproduce synchronously. Larger follicles occurring in spring in female lizards were coincident with maximum spermiogenesis in male lizards (Fig. 1B).

DISCUSSION

Three types of reproductive cycles are recognized among tropical lizards (Rocha 1992): (a) continuous; (b) continuous with variation in reproductive activity; and (c) non-continuous. *Spheno-*

Table 2. Correlation coefficients (r) of female liver somatic index (FLSI), female follicular diameter (FFD), male liver somatic index (MLSI), male seminiferous tubule diameter (MSTD), male testes somatic index (MTSI), temperature (TEM), and rainfall (RF) for *Sphenomorphus indicus* in central Taiwan

	FLSI	FFD	MLSI	MSTD	MTSI	TEM	RF
FLSI		−0.82***	0.62*	—	—	0.22	−0.29
FFD			—	—	—	−0.12	0.52^{+}
MLSI				0.34	0.09	−0.04	−0.12
MSTD					0.67*	−0.74*	−0.45
MTSI						−0.78**	−0.27

Correlation coefficients (r) were analyzed from the monthly means of these parameters.
$^{+}$, 0.1 < p < 0.05; *, p < 0.05; **, p < 0.01; ***, p < 0.005.

morphus indicus has a non-continuous reproductive cycle. All adult females were reproductively active during the reproductive season, suggesting that all adult females of this species reproduce annually but not continuously. Environmental factors known to be related to reproductive cycles in lizards are daylength, temperature, and rainfall (Licht 1971, Marion 1982, James and Shine 1985, Benabib 1994). The onset of vitellogenesis at a time of increasing rainfall and an increase of spermiogensis with decreasing temperatures suggest that different environmental factors are correlateed with the onset of reproductive activity in females and males *S. indicus*.

Fitch (1981) stated that the females of viviparous species tend to have a relatively large body in order to support the growth of embryos in oviducts for a much longer period than those of oviparous species. The larger body size of females of *S. indicus* suggests that, in this species, selection for larger females occurs strictly because of its live-bearing mode of reproduction. Shine (1986 1989) has demonstrated that widespread distribution of sexual dimorphism in trophic morphology among animals could be consistent with either sexual selection or trophic divergence. Head width is related to prey size in several reptilian taxa (Perez-Mellado and Riva 1993). However, there was no significant difference observed in head widths between males and females of *S. indicus*, indicating that there may not be differentiation of this feature between the sexes.

Dunham et al. (1988) examined the associations between the categorical variables of lizard species, such as annually single or multiple brood, temperate or tropical distribution, and early or late maturing, and derived three types of relationships: (a) viviparous species are more likely to be annually single brooded and late maturing than are oviparous species, (b) temperate species are more frequently annually single brooded than are tropical ones, and (c) early maturing species are more frequently multiple brooded than are late maturing species. According to the results presented here the viviparous lizard of *S. indicus* is single brooded and late maturing, which fits the points (a) and (c).

Dunham et al (1988), in their analysis of life history patterns in squamate reptiles, indicated that diverse strategies occur within the Scincidae.

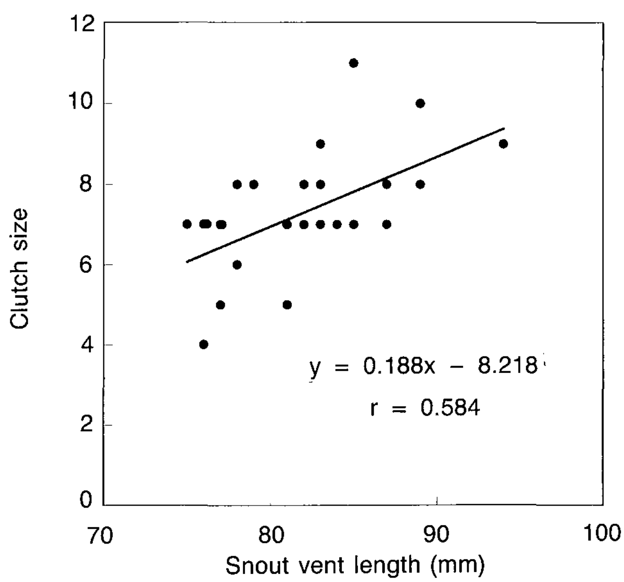

Fig. 3. Correlation between female body size (SVL) and the number of vitellogenic or uterine eggs in *Sphenomorphus indicus*.

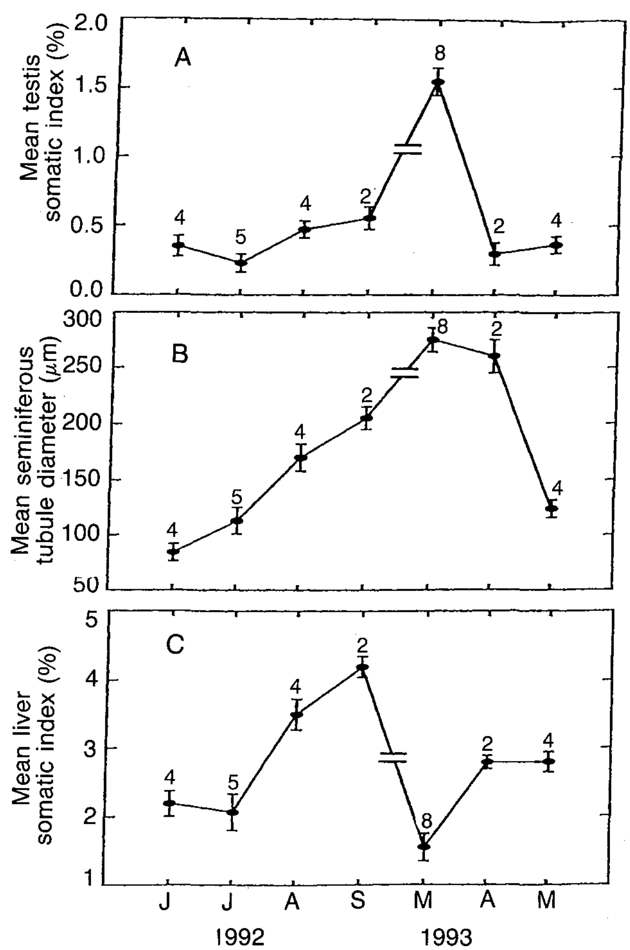

Fig. 4. Variation (mean ± SE) in mean testis somatic index (A), mean seminiferous tubule diameter (B), and mean liver somatic index (C) during the biennial reproductive cycle (pooled for one year) of *Sphenomorphus indicus* males. Numbers above data points indicate sample sizes.

Snout-vent length at maturity, average SVL of reproducing females, and clutch size were 62.5 mm, 70.7 mm, and 4.8, respectively, in the scincids analyzed by Dunham et al. (1988). In *S. indicus*, the values of SVL at maturity, average SVL of reproducing females, and clutch size were higher than in other species, indicating that, relative to other scincids (Dunham et al. 1988), *S. indicus* is a large, late-maturing, viviparous lizard, producing one large clutch per annum.

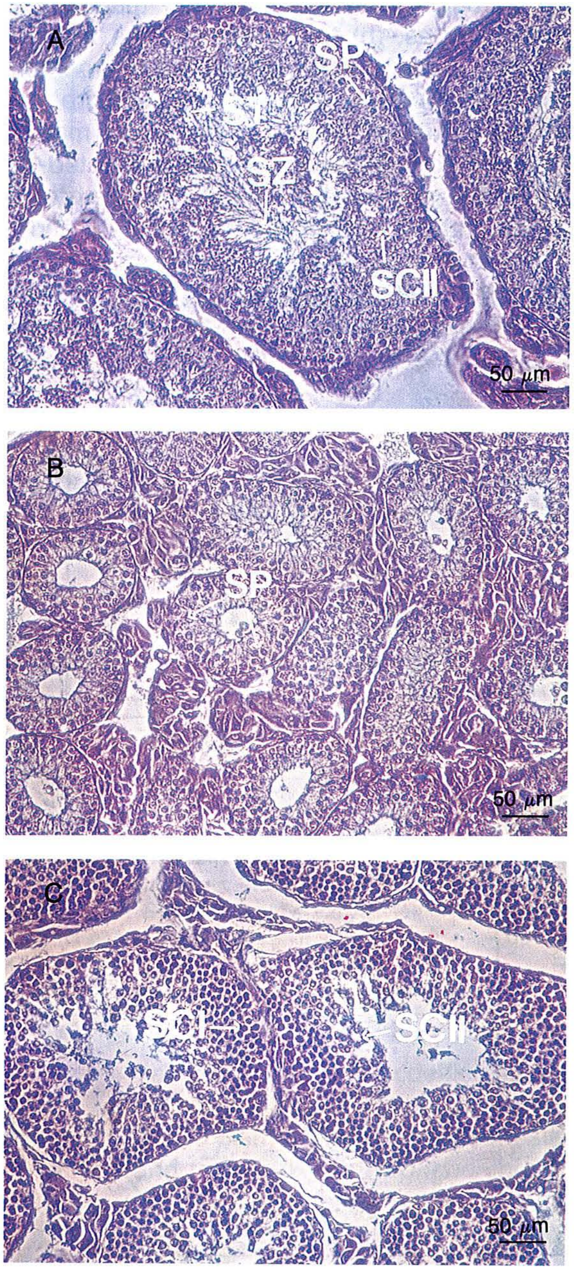

Fig. 5. Seasonal changes in the spermatogenetic cycle of *Sphenomorphus indicus*. SP, spermatogonia; SCI, primary spermatocytes; SCII, secondary spermatocytes; ST, spermatids; SZ, spermatozoa. (A), Breeding period (March-April), when maximum spermiogenesis and massive spermatozoa were found. (B), Regression period (May-July), when only spermatogonia were found. (C), Spermatogenesis recrudescent period, when primary and secondary spermatocytes were found.

It has been contended that relative clutch mass RCM is subject to different selective pressures than characteristics such as egg size, clutch size, and clutch frequency (Benabib 1994). Foraging and predator escape strategies may determine the RCM of lizards (Vitt and Congdon 1978, Vitt 1981, Vitt and Price 1982). RCM may be important in determining the probability of escape from a predator because it affects the agility of females (Benabib 1994). Lizards that employ the ambush or sit-and-wait foraging strategy exhibit high RCMs, whereas wide foragers have low RCMs (Dunham et al. 1988).

Similar to other scincid lizards, *S. indicus* is a wide-foraging predator (Cheng 1987). The mean RCM calculated from 10 pre-parturition female lizards was 0.288 (SE = 0.08), higher than the mean RCM of teiids (0.148; SE = 0.006), a typical wide-foraging family of lizards (Benabib 1994). However, the RCM of *S. indicus* is higher than, or close to, the sit-and-wait forager (0.25) (Vitt and Congdon 1978). The RCM value of *S. indicus* does not correlate with the report of Dunham et al. (1988). Further investigations to describe the RCM pattern in Taiwanese lizards are necessary.

Lizards living in seasonally temperate regions are generally considered to be in a periodically fluctuating energy environment, so seasonal variations should be observed in the amount of lipids in lizards in such an environment, whereas lipid masses of lizards living in tropical and subtropical regions, are thought to be consistent (Derickson 1976). The decrease of FLSI in female *Sphenomorphus indicus* corresponds to the onset of vitellogenesis, indicating that female lizards begin vitellogenesis during the reproductive season and rely heavily on the stored energy in the liver.

The timing of reproductive activity in males and females is an important aspect of a species' reproductive strategy (Guillette and Cruz 1993). Synchrony in reproductive timing between sexes has several apparent advantages, e.g., no need for sperm storage by either male or female, or timing of reproductive behavior when one or both sexes exhibit gonadal quiescence. Females of the viviparous skink, *S. indicus*, reproduce in spring, ensuring that young lizards are born at the onset of the spring or summer growing season when food is abundant, thus increasing the survivorship of juveniles.

Acknowledgements: Special thanks go to Dr. J. Y. L. Yu and three anonymous reviewers who provided valuable comments and revisions. I thank Mr. C. S. Chang for his enormous assistance during my field work in central Taiwan. I am indebted to Mr. K. C. Lue, Montane Horticultural Station, National Taiwan University, for assistance on the farm. Sincere thanks also go to Mr. K. J. Wang, Mr. Y. B. Huang, and Miss C. I. Shan for assistance with statistics. Financial support was provided by the National Museum of Natural Science, Taichung, Taiwan, R.O.C.

REFERENCES

Benabib M. 1994. Reproduction and lipid utilization of tropical populations of *Sceloporus variabilis*. Herpetol. Monogr. **8:** 160-180

Cheng HY. 1987. Ecology and conservation of Taiwan's lizards. Thunghai J. **28:** 763-790. (in Chinese, English abstract).

Derickson WK. 1976. Lipid storage and utilization in reptiles. Amer. Zool. **16:** 711-723.

Dunham AE, DB Miles, DN Reznick. 1988. Life history patterns in squamate reptiles. *In* C Gans, ed. Biology of the Reptila. New York: Alan R. Liss, pp. 441-522.

Fitch HS. 1981. Sexual size differences in reptiles. Univ. Kansas Mus. Nat. Hist. Mis. Publ. **70:** 1-72.

Guillette LJ, FRMDL Cruz. 1993. The reproductive cycle of the viviparous Mexican lizard *Sceloporus torquatus*. J. Herpetol. **27:** 168-174.

James CD, R Shine. 1895. The seasonal timing of reproduction: a tropical-temperate comparision in Australian lizards. Oecologia (Berlin) **67:** 464-474.

Licht P. 1967. Environmental control of annual testicular cycles in the lizard *Anolis carolinensis*. I. Interaction of light and temperature in the initiation of testicular recrudescence. J. Exp. Zool. **165:** 505-516.

Licht P. 1971. Regulation of the annual testis cycle by photoperiod and temperature in the lizard *Anolis carolinensis*. Ecology **52:** 240-252.

Lin CY, WS Huang, KY Lue. 1993. Note on the reproduction of *Sphenomorphus indicus* Schmidt in Taiwan. Bull. Nat. Mus. Nat. Sci. **4:** 191-192.

Lin JY, HY Cheng. 1990. A synopsis of Taiwan lizards. Taipei, Taiwan: Taiwan Provincial Museum, pp. 123-129. (in Chinese).

Marion KR. 1982. Reproductive cues for gonadal development in temperate reptiles: temperature and photoperiod effects on the testicular cycle of the lizard *Sceloporus undulatus*. Herpetologica **38:** 26-39.

Okada S, H Ota, M Hasegawa, T Hikida, H Miyaguni, J Kato. 1992. Reproductive traits of seven species of lygosomine skinks (Squamata: Reptilia) from east Asia. Nat. Hist. Res. **2:** 43-52.

Perez-Mellado V, IDL Riva. 1993. Sexual size dimorphism and ecology: the case of a tropical lizard, *Tropidurus melanopleurus* (Sauria: Tropiduridae). Copeia **1993:** 969-976.

Rocha CFD. 1992. Reproductive and fat body cycles of the tropical sand lizard (*Liolaemus lutzae*) of southeastern Brazil. J. Herpetol. **26:** 17-23.

Shine R. 1986. Sexual differences in morphology and niche utilization in an aquatic snake, *Acrochordus arafurae*. Oecologia **69:** 260-269.

Shine R. 1989. Ecological causes for the evolution of sexual dimorphism: a review of the evidence. Quart. Rev. Biol. **64:** 419-461.

Vitt LJ. 1981. Lizard reproduction: habitat specificity and constraints on relative clutch mass. Am. Nat. **117:** 506-514.

Vitt LJ, JD Congdon. 1978. Body shape, reproductive effort, and relative clutch mass in lizards: resolution of a paradox. Am. Nat. **112:** 595-608.

Vitt LJ, HJ Price. 1982. Ecological and evolutionary determinants of relative clutch mass in lizards. Herpetologica **38:** 237-255.

臺灣中部霧社胎生印度蜓蜥雌雄異型及生殖週期之研究

黃 文 山[1]

本研究描述霧社地區胎生印度蜓蜥雌雄異型及生殖週期之季節性變化。成熟雌蜥(50隻)的吻肛長(snout vent length; SVL)(平均值=81.6 mm)與成熟雄蜥(29隻)(平均值=73.6 mm)呈顯著差異。然而兩者的頭長和頭寬平均值並無顯著差異。雌蜥於春天排卵，六至七月生幼蜥。生卵於雨季開始並與肝臟重量指數成反比。雌蜥每次可生4−11隻幼蜥，窩卵數與吻肛長呈正相關。雄蜥的生精作用始於夏末至初秋。春天時，精子生成最旺盛，此時睪丸的重量指數達到最高，並與雌蜥的生卵作用時間一致。夏天，睪丸活性降至最低，細精管直徑亦縮至最小值。雄蜥的細精管直徑和睪丸重量指數和溫度成負相關。

關鍵詞：印度蜓蜥, 生殖, 雌雄異型, 胎生蜥蜴。

[1] 國立自然科學博物館蒐藏研究組