Zoological Studies **37**(4): 302-308 (1998)

Zoological Studies

Sexual Size Dimorphism and Microhabitat Use of Two Sympatric Lizards, *Sphenomorphus taiwanensis* and *Takydromus hsuehshanensis*, from the Central Highlands of Taiwan

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(Accepted June 18, 1998)

Wen-San Huang (1998) Sexual size dimorphism and microhabitat use of two sympatric lizards, *Sphenomorphus taiwanensis* and *Takydromus hsuehshanensis*, from the central highlands of Taiwan. *Zoological Studies* **37**(4): 302-308. Sexual size dimorphism and microhabitat use of 2 syntopic lizards, *Sphenomorphus taiwanensis* and *Takydromus hsuehshanensis*, from the central highlands of Taiwan are examined. Adult *S. taiwanensis* females attain a larger body size than do males, but in *T. hsuehshanensis*, body size shows no significant difference between sexes. Head sizes of males are larger than those of females in both species. All morphological traits of *T. hsuehshanensis* are larger than those of *S. taiwanensis*. The 2 species differ considerably in microhabitat use horizontally. *T. hsuehshanensis* was collected predominantly in cultivated land of *Brassica oleracea capitata*, while *S. taiwanensis* was found mainly in a saxicolous area. Neither *T. hsuehshanensis* nor *S. taiwanensis* shows significant differences in microhabitat utilization between sexes. Morphological differences were observed between the 2 species, and these are presumably associated with their differential microhabitat preferences. The longer forehand of *T. hsuehshanensis* allows a greater degree of locomotor activity. Causality of snout-vent length dimorphism of 5 sympatric lizards are also discussed.

Key words: Syntopic, Lizards, Sexual size difference, Squamata, Taiwan.

The processes by which male and female lizards attain different adult body sizes are highly complicated and may involve an interplay between adaptive, exaptive, and nonadaptive genetic (i.e., phylogenetic) or environmental variables (Shine 1990). Several authors have tried to recognize and discuss the operative pattern and evolution of sexual dimorphism in reptiles (Berry and Shine 1980, Fitch 1981, Schoener et al. 1982, Carothers 1984, Vitt and Cooper 1985, Shine 1986 1989, Vial and Stewart 1989, Woolbright 1989, Anderson and Vitt 1990, Andrews and Stamps 1994, Dearing and Schall 1994, Preest 1994). However, a sexual difference in body size of lizards has rarely been noted in Taiwan, except for sexual dimorphism in *Sphenomorphus indicus* (Huang 1996a), *Japalura swinhonis* (Lin and Cheng 1986), and *Eumeces elegans* (Huang 1996b).

Comparative and experimental studies have dominated attempts to understand patterns within lizard assemblages (Tinkle 1982). Earlier studies have demonstrated that sympatric species partition resources primarily in 3 dimensions: space, time, and food (Pianka 1973, Smith 1981, Vitt et al. 1981, Colli et al. 1992). The latter studies have provided insights into mechanisms causing differences in habitat utilization (e.g., Dunham 1980, Vitt and Carvalho 1995, Vacibradic and Rocha 1996). Recent studies of morphology may provide useful interpretations of fundamental causes of community patterns (Vitt and Carvalho 1995). Several ecological studies on lizards have been conducted on temperate (e.g., Pianka 1986, Vitt 1991) and tropical species (e.g., Howland et al. 1990, Vitt and Carvalho 1995). Few ecological studies exist on the lizards in Taiwan. The area chosen for the present study contains only 2 lizard species. They are both predominantly active on the ground and are insectivorous, suggesting a potential for competitive interaction. The present study examines 1)

sexual dimorphism in the body and head size of 2 syntopic lizards, *Sphenomorphus taiwanensis* and *Takydromus hsuehshanensis* in the central highlands and 2) microhabitat use by these lizards.

MATERIALS AND METHODS

The study was carried out at Hsiulin near Hohuan Mountain (24°10'N, 121°20'E; ca. 2360 m elev.), Hualien County, Taiwan from January to December 1994. A 0.71-ha study area was selected at the locality. Vegetation of the area is composed predominantly of *Miscanthus*, *Trifolium repens*, and *Brassica oleracea capitata*. There are only 2 species of lizards, *Sphenomorphus taiwanensis* and *Takydromus hsuehshanensis*, in the study area, both of which are endemic to the highlands of Taiwan.

Lizards were collected monthly by hand. On some days only field observations were made. Both collections and field observations were made from 0800 to 1600 h on sunny days. The microhabitat of each captured lizard was recorded on the basis of the following: (1) cultivated land of *Brassica oleracea capitata* (CL); (2) smashed rocky area (SR); (3) *Trifolium repens* plantation (TRP); (4) saxicolous area (S); and (5) *Miscanthus* area (MA).

Snout-vent length (SVL), head length (HL), head width (HW), and forehand length (FH) were measured to the nearest 0.1 mm, and body weight (BW) was recorded to the nearest 0.1 g. Sexual maturity of each male was assessed by the appearance of sperm as observed from paraffin sections of testes and epididymides. Females containing vitellogenic follicles (diameter ≥ 3 mm) were considered to be mature (Huang 1997b). Differences between sexes and species were analyzed separately using analysis of covariance (ANCOVA) with log SVL as the covariate. Regressions were calculated for each sex of each species by comparing BW, HL, HW, and FH, against log SVL. Differences in microhabitat utilization between the sexes and the species were tested by constructing a log-linear model for categorical data. Because some cells had values of zero, I replaced these zeros with a very small number (0.00001) to compute all parameters in the model (Kleinbaum and Kupper 1978).

RESULTS

Morphology

Means of HW, HL, and FH were significantly higher for adult males compared with adult females in *S. taiwanensis*, whereas SVL showed the reverse (Table 1). Mean SVL of males showed no significant difference from that of females in *T. hsuehshanensis*, but the morphological variables BW, HW, HL, and FH of males were higher than those of females (Table 1). All morphological traits correlated significantly with Log SVL (all $R^2 > 0.36$, all $p < 0.0001$) based on analyses using all individuals of the 2 lizards (Figs. 1, 2).

The 2 species differed significantly in the 5 morphological traits tested (Table 1). *T. hsuehshanensis* had larger BW (ANCOVA; $F_{2, 169} = 229.5$; $p < 0.0001$) (Fig. 1A); HW (ANCOVA; $F_{2, 169} = 100.2$; $p < 0.0001$) (Fig. 1B); HL (ANCOVA; $F_{2, 169} = 273.3$; $p < 0.0001$) (Fig. 1C); FH (ANCOVA; $F_{2, 127} = 39.66$; $p < 0.0001$) (Fig. 2); and SVL (ANOVA;

Table 1. Comparisons of means of snout-vent length (SVL), body weight (BW), head width (HW), head length (HL), and forehand length (FH) of sexually mature *Sphenomorphus taiwanensis* (ST) and *Takydromus hsuehshanensis* (TH) in central Taiwan

Character	ST			TH		
	females (20)	males (19)	mean (39)	females (71)	males (65)	mean (136)
SVL (mm)	56.3 ± 1.1*	52.1 ± 1.0	54.5 ± 0.8#	61.2 ± 0.5	60.0 ± 0.6	60.7 ± 0.4
BW (g)	3.3 ± 0.2	3.1 ± 0.2	3.2 ± 0.1#	4.7 ± 0.1*	5.2 ± 0.1	4.7 ± 0.1
HW (mm)	6.0 ± 0.2*	7.2 ± 0.2	7.1 ± 0.2#	8.0 ± 0.1*	9.5 ± 0.1	8.6 ± 0.1
HL (mm)	10.2 ± 0.2*	11.0 ± 0.1	10.5 ± 0.2#	14.1 ± 0.1*	15.8 ± 0.1	14.7 ± 0.1
FH (mm)	15.7 ± 0.4*	16.3 ± 0.5	16.0 ± 0.5#	18.1 ± 0.6*	19.6 ± 0.5	19.1 ± 0.2

Notes: Means (± SE) of each size measurements were compared between adult females and males, using the ANCOVA, with log SVL as the covariate. An asterisk (*) or (#) indicates differences in means ($p < 0.05$) between females and males and between species, respectively. Numbers in the parentheses indicate sample sizes.

$F_{1, 170} = 47.4$; $p < 0.0001$) (Table 1).

Temporal variation in capture success

Because the temperature decreased to between -0.3 and 2 °C, and the study site was covered with snow from January to mid-March, and was hit by a typhoon that closed the road in August 1994, specimen collection was severely limited during these months. The peaks of daily activity of both *S. taiwanensis* and *T. hsuehshanensis* were concentrated during the sunniest and warmest hours (0900-1200) during the day. The 2 lizard species differed in monthly activity. The peaks of activity for *S. taiwanensis* occurred in July and September, and that for *T. hsuehshanensis* in October (Fig. 3).

Microhabitat use

The 2 lizards showed significant differences in utilization of the 5 microhabitats (log-linear model, $df = 1$, $X^2 = 47.2$, $p = 0.000$) (Fig. 4). Neither sex nor species*sex of *T. hsuehshanensis* and *S. taiwanensis* showed significant differences among the 5 microhabitats (Table 2). *S. taiwanensis* were collected mostly in the saxicolous area (79.5%, $N = 31$), while *T. hsuehshanensis* was collected predominantly in the cultivated land (31.3%, $N = 42$) (Fig. 4). The former species did not occur on cultivated land, the *Miscanthus* area, or the smashed rocky area.

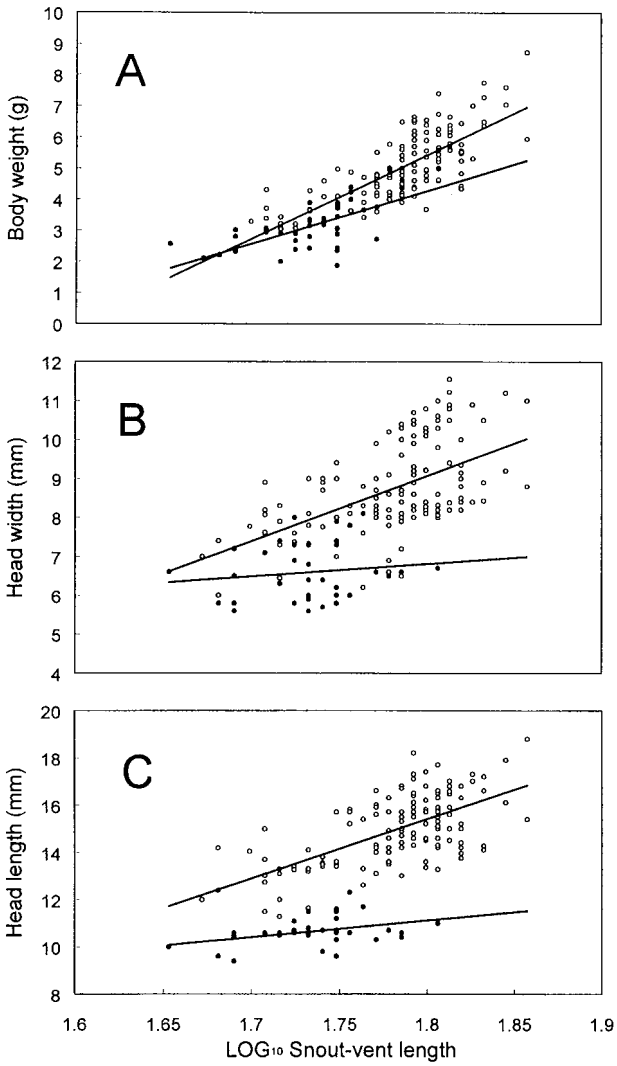

Fig. 1. Relationships between body weight (A), head width (B), head length (C), and snout-vent length (data log-tranformed) for *Takydromus hsuehshanensis* (white circles) and *Sphenomorphus taiwanensis* (black circles) in the central highlands of Taiwan.

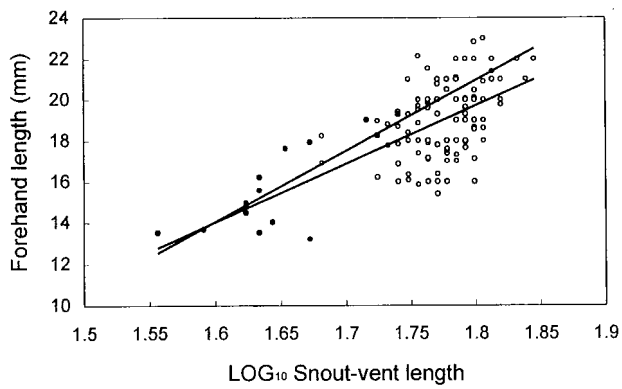

Fig. 2. Relationships between forehand length and snout-vent length (data log-transformed) for *Takydromus hsuehshanensis* (white circles) and *Sphenomorphus taiwanensis* (black circles).

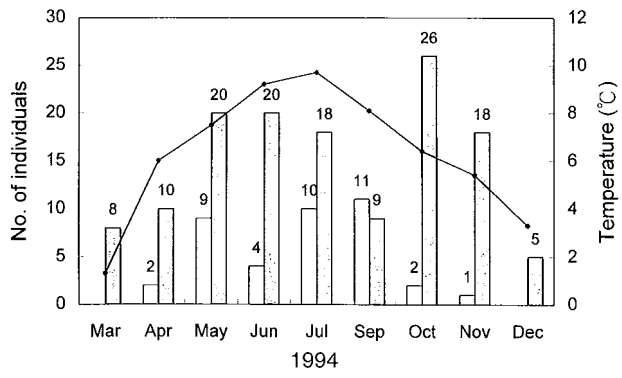

Fig. 3. Mean monthly temperature and total monthly number of individuals of *Takydromus hsuehshanensis* (gray bars) and *Sphenomorphus taiwanensis* (white bars) collected in 1994. Numbers above bars indicate total individuals collected each month. Data of mean temperature are from the Hohuan Weather Station, Central Weather Bureau, ROC.

DISCUSSION

Sexual size dimorphism

Two selective forces are recognized as causal factors of body dimorphism in lizards. The 1st selective force is the advantage of large body size in females when it is correlated with an increase in clutch size (e.g., Tinkle et al. 1970, Carothers 1984, Guyer 1988, Huang 1996a, 1997a,b). Second, males should be larger than females only in high-male-aggressive species (Carothers 1984). Huang (1996a; Table 3) showed that female body size of the Taiwanese viviparous skink, *Sphenomorphus indicus*, was associated positively with clutch size, and individuals experienced no male-male combat in which the SVLs of females were larger than those of males. In contrast, a report on the agamid lizard, *Japalura brevipes*, showed no significant relationship between maternal body size and clutch size (Huang 1997a), but males defended territories. SVLs of males and females of this species do not differ. Huang (1996b) also studied a population of *Eumeces elegans* in central Taiwan and suggested that adult males exhibited strong aggressive behavior in defending their territory against other males, and this caused a strong sexual size dimorphism in this species.

Body size of the grass lizard, *T. hsueh-shanensis*, of the present study shows no significant SVL dimorphism, which is consistent with field observations of no male-male combat behavior. However, there is a positive correlation between maternal SVL and clutch size. Curiously, the same phenomena are also observed in the sympatric lizard, *S. taiwanensis*, but SVL is sexually dimorphic. This result is consistent with the work of Huang (1996a) on the congener *S. indicus* (Table 3). He found that larger females lay more embryos, and male combat was not observed in the field. Tinkle et al. (1970) suggested that in the absence of other pressures, one might expect that females would be the larger sex. Fitch (1978), in surveys of 2 insectivorous lizard genera, found that female reproductive output has a strong effect on size dimorphism among members of the genus *Sceloporus*.

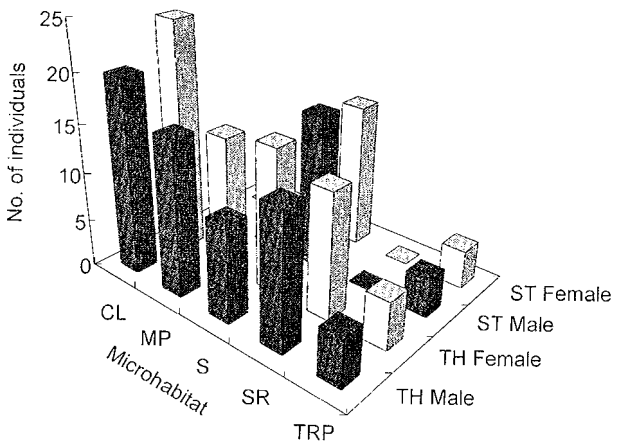

Fig. 4. Frequency of utilization of different microhabitat types by males (black bars) and females (white bars) of *Takydromus hsuehshanensis* (TH) and *Sphenomorphus taiwanensis* (ST) in the central highlands of Taiwan.

Table 2. Log-linear model for categorical data to compare differences in utilization of 5 microhabitats by species, sex, and species*sex of *Takydromus hsuehshanensis* (TH) and *Sphenomorphus taiwanensis* (ST)

Source	*df*	X^2	*p*
Species	1	47.20	0.0000***
Sex	1	0.01	0.92
Species* Sex	1	0.15	0.70

***$p < 0.005$.

Table 3. Comparison of snout-vent length between male and female, correlation of female snout-vent length (FSVL) and clutch size (CS), and male aggressive behavior (MAB) of 5 sympatric lizards from the central high-elevation area in Taiwan

Species	FSVL vs. CS	MAB	SVL	Resource
Sphenomorphus indicus	positive	no	F > M	Huang 1996a
S. taiwanensis	positive	no	F > M	Huang 1997b, Present study
Takydromus hsuehshanensis	positive	no	NS	Present study, Huang 1998
Japalura brevipes	none	yes	NS	Huang 1997a
Eumeces elegans	ND	yes	M > F	Huang 1996b

NS: indicated none significant difference between male and female SVL.
ND: indicates no data available.

Accordingly, neither the fecundity nor male-male combat hypothesis can explain sexual dimorphism in body size of the 2 sympatric lizards in the present study. An analysis of dimorphism of body size within the present study suggests that dimorphism in body size is a highly variable condition. However, the present data suggest sexual size dimorphism may be phylogenetic (e.g., *Sphenomorphus taiwanensis* and *S. indicus*), rather than environmental factors (e.g., *S. taiwanensis* and *Takydromus hsuehshanensis*).

Field observations of the 2 sympatric lizards recorded no male-male combat, which contrasts with Anderson and Vitt's (1990) study in which they assert that the head may be important in determining the outcome of assessment and aggressive interactions among males. They also examined the skink, *Eumeces laticeps*, and suggested that males with large heads and jaws may have an increased ability to hold large females during copulation attempts.

Microhabitat use

Both *S. taiwanensis* and *T. hsuehshanensis* in high elevations of central Taiwan are diurnal, actively foraging lizards that are most common in areas exposed to direct sunlight. Although the 2 species tend to overlap considerably in time of activity, no aggressive interactions were observed between the species in the present study. My observations are consistent with those of Huey and Pianka (1977) in their study of sympatric *Mabuya* and suggest that overlap is not necessarily proportional to intensity of competition, nor does high niche overlap necessarily imply strong competition.

Activities of *S. taiwanensis* and *T. hsuehshanensis* are associated with the timing of cycling daily air temperatures which appear necessary for attainment of a high-activity body temperature. These 2 species were active during sunlight hours from 0900-1200 h and were frequently observed basking in warm, open saxicolous areas where local temperatures considerably exceeded the air temperature (e.g., Fig. 5 for *T. hsuehshanensis*). The grass lizard, *T. hsuehshanensis*, has an active peak in the colder months of October and November, and it is likely that this may be caused by population dynamics or by the longer forehand of *T. hsuehshanensis* allowing a greater degree of locomotive activity. This increased activity may facilitate achieving a high, active body temperature by this species, thus allowing it to be active at lower temperatures from October to December as compared with *S. taiwanensis*. This relationship between a higher degree of mobility and body temperature of *T. hsuehshanensis* is similar to that of other lizards, which also tend to maintain higher-than-ambient body temperatures when active (Grant 1990, Grover 1996). However, when temperatures decreased to the minimum, ranging from -0.7 to 0.3 °C, during January and February, both species were inactive and were not observed in the study area.

The large numbers of *T. hsuehshanensis* collected in October and of *S. taiwanensis* in September may be due to the need for a foraging period of energy preservation for overwinter utilization. Huang (1998) found that the high peak of energy preservation was coincident with the highest emergence months of these 2 lizards. In these months, lizards actively forage and preserve chemical energy in the liver or in the abdomen of *S. taiwanensis* and *T. hsuehshanensis*, respectively, for metabolic use over winter.

Microhabitat segregation between the 2 sympatric lizards of *S. taiwanensis* and *T. hsuehshanensis* was observed in the present study. The former species did not occur in cultivated land, smashed rocky areas, or the *Miscanthus* area. Such differences in microhabitat utilization between the 2 lizards are probably related to such morphological traits as forehand and body sizes. The longer hand of *T. hsuehshanensis* probably allows more locomotive activity in the 5 microhabitats and greater vertical use of space compared to *S. taiwanensis*; the latter species was found mainly in the saxicolous area. Similarly, the smaller body

Fig. 5. A photograph showing 8 *Takydromus hsuehshanensis* basking together on a rock during the breeding season (The photo was taken on 31 May 1994 in Hsiulin near Hohuan Mountain, Hualien County, Taiwan.).

size of *S. taiwanensis* may allow easier movement among small holes between contiguous rocks. Vitt (1981) suggested that the flattened body plan of the lizard *Platynotus semitaeniatus* allowed activity in rock crevices as its preferred microhabitat. Although 25 (18.7%) individuals of *T. hsuehshanensis* were captured in the saxicolous area, most of these were basking and departed under cloudy conditions.

The larger species, *T. hsuehshanensis*, utilizes microhabitats with more vegetative cover than does the smaller skink, *S. taiwanensis*, which occurs in the *Trifolium repens* plantation. This pattern has been well established in numerous studies of sympatric lizards (e.g., Pianka 1986, Adolph 1990, Grover 1996). Scheibe (1987) studied the structure of temperate zone lizard communities and suggested that larger lizards spend more time in the shade than do smaller lizards with the same thermal preferences. They attributed this pattern to the effect of size on the rate of heat exchange with the environment.

Acknowledgments: Special thanks go to H. Ota for critical reading of an early draft manuscript. I am indebted to C. S. Chang for his enormous assistance with field work; and to H. W. Chen, G. H. Adler, and Y. B. Huang for assistance with statistics and graphics. I am grateful to the Taroko National Park for permission to sample within the park. Financial support was provided by the National Museum of Natural Science, Taichung, Taiwan, ROC.

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臺灣中部高海拔區同域分布之臺灣蜓蜥和雪山草蜥雌雄異型與微棲地利用之研究

黃文山[1]

本研究描述臺灣中部高海拔區同域分佈之臺灣蜓蜥和雪山草蜥雌雄異型及其微棲地利用。臺灣蜓蜥成熟雌性之體長大於雄性。而雪山草蜥雌雄體長卻無顯著差異。兩種蜥蜴的雄性頭部形值皆比雌性大。而雪山草蜥的體長或頭部形值都比臺灣蜓蜥大。兩種蜥蜴重疊使用微棲地。雪山草蜥主要出現於高麗菜田；而臺灣蜓蜥出現於岩石區。兩種蜥蜴各自之雌雄微棲地利用並無顯著差異。雪山草蜥和臺灣蜓蜥對微棲地的喜好可能與體型有關；前者的前腳較長可允許較大的運動能力。造成五種同域分布的蜥蜴體長雌雄異型的因子在此一併討論。

關鍵詞：同域分布，蜥蜴，雌雄異型，有鱗目，臺灣。

[1]國立自然科學博物館動物組