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Sexual Size Dimorphism in the Five-striped Blue-tailed Skink, *Eumeces elegans*, with Notes on Its Life History in Taiwan

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Wen-San Huang (1996) Sexual size dimorphism in the five-striped blue-tailed skink, *Eumeces elegans*, with notes on its life history in Taiwan. *Zoological Studies* **35**(3): 188-194. Sexual size dimorphism in the five-striped blue-tailed skink, *Eumeces elegans*, is presented. Adults are sexually dimorphic in coloration, body size, and in head sizes. Males attain a larger size than females in snout vent length (SVL), head length (HL), head width (HW), head depth (HD), and 3rd toe length (TTL). Annual activity begins in March, peaks in August-September; lizards are inactive from December to February. Mean growth rates in SVL of juveniles were greater than those of adults.

Key words: Sexual size difference, Population structure, *Eumeces elegans*, Taiwan.

Sexual dimorphism can occur in the morphology, coloration, and behavior of organisms (Carothers 1984). Several authors have discussed the evolution of sexual size 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). Although studies of sexual size dimorphism often emphasize sexual selection as a causal factor, dimorphism may result from three primary selective forces (Carothers 1984). The first of these, natural selection for reduction of food competition, is related to different body and trophic apparatus sizes, whereby larger individuals may exploit larger food items (Shine 1977, Camilleri and Shine 1990, Perez-Mellado and Riva 1993). The second selective force acts on clutch size in females (Tinkle et al. 1970, Okada et al. 1992, Sinervo et al. 1992). The third factor promotes sexual dimorphism through mate competition, mate choice, and territorial combat in males (Fitch 1981, Vitt and Cooper 1985, Woolbright 1989). The factors contributing to the various expressions of sexual dimorphism are undoubtedly complex and probably include both natural and sexual selection (Koening and Albano 1986, Vial and Stewart 1989).

In addition to the species listed by Shine (1989), a sexual difference in body size has been noted for *Sphennomorphus indicus* (Huang 1996), *Japalura mitsukurri formosensis* (Cheng and Lin 1977), and *J. m. mitsukurii* (Lin and Cheng 1986), but it does not appear in *J. brevipes* (Huang, unpublished data) in Taiwan. Sexual dichromatism has been described for many lizards, e.g., the gerrhonotine species, *Gerrhonotus kingii* (Knight and Duerre 1987), and *Barisia monticola* (Vial and Stewart 1989). However, sexual dichromatism in lizards has rarely been reported in Taiwan.

Studies on lizard populations have become increasingly frequent in recent years, and their focus has been to test and refine current theories on life history evolution (Henle 1990b, James 1991a). Most studies concentrate on animals in the temperate and tropical regions (Tinkle and Ballinger 1972, Barbault 1976, Henle 1989, James 1991a, Mushinsky 1992); however, information concerning subtropical species is still rudimentary. There has only 1 report on the population ecology of *Japalura mitsukurii* in subtropical Taiwan by Lin and Lu (1982).

Eumeces elegans is a medium-sized skink common throughout southeastern continental China to the Ryukyu Islands of Japan. In Taiwan, it is widely distributed from the plains to 2 400 m elevation

(Lin and Cheng 1990). Short notes about nesting *E. elegans* have been reported by Lue and Chen (1989) and Kato and Ota (1994), but no other studies have addressed aspects of this species' life history.

MATERIALS AND METHODS

The study was carried out at the Montane Horticultural Station of National Taiwan University at Meifong, Nantou County, Taiwan (24°05'N, 121°10'E; at ca. 2 120 m elevation) from March 1991 to February 1992. Maximum air temperatures were found from June to August, and ranged from 16 °C to 21 °C, while minimum temperatures ranged from 7 °C to 12 °C (November to January). Average annual precipitation was about 2 500 mm, falling mostly in the spring and summer (from February to September). The period between October and January is the dry season.

A 5.5-ha study site was selected at the station. The main vegetation of the study area was comprised of *Actinidia chinensis setosa*, *Aralia decaisneana*, *Alnus formosana*, *Stellaria media*, *Trifolium repens*, *Oxalis corniculata*, *Polygonum chinensis*, *Rumex japonicus*, *Clematis gouriana*, *Digitalis purpurea*, and *Brassica oleracea capitata*. The study area was investigated 3 days per month.

Snout-vent length (SVL), head width (HW), head length (HL), head depth (HD), tail length (TL), and 3rd toe length (TTL) of each skink caught in the study area was measured using dial calipers. All individuals were weighed with a Galaxy 400 D electric balance. Sexes and ages were determined according to the classification of Lin and Cheng (1990). These classifications are: adult male, red spots on cheeks and 5 stripes absent from back; young male: 5 stripes on back absent or light; adult female: body brown with 5 stripes on back; juveniles: body blue and black with 5 stripes on back. All skinks were marked by clipping toes with scissors for permanent identification. After taking measurements, skinks were released at the same place where they were captured.

Data were analyzed separately for individual sexes and ages using the analysis of covariance (ANCOVA) with SVL as the covariate in order to factor out the effect of body size. Regressions were calculated for each sex and age, by comparing HL, HW, HD, and TTL, respectively, against SVL. Log body mass was regressed against log SVL, and the analysis of covariance was used with log SVL as the covariate to search for sexual and age differences in mass independent of SVL. Comparisons of means of the morphological variables were made with ANOVA followed by Duncan's multiple range tests.

RESULTS

In total, 222 skinks, *Eumeces elegans*, (representing 210 individuals) were captured (Fig. 1).
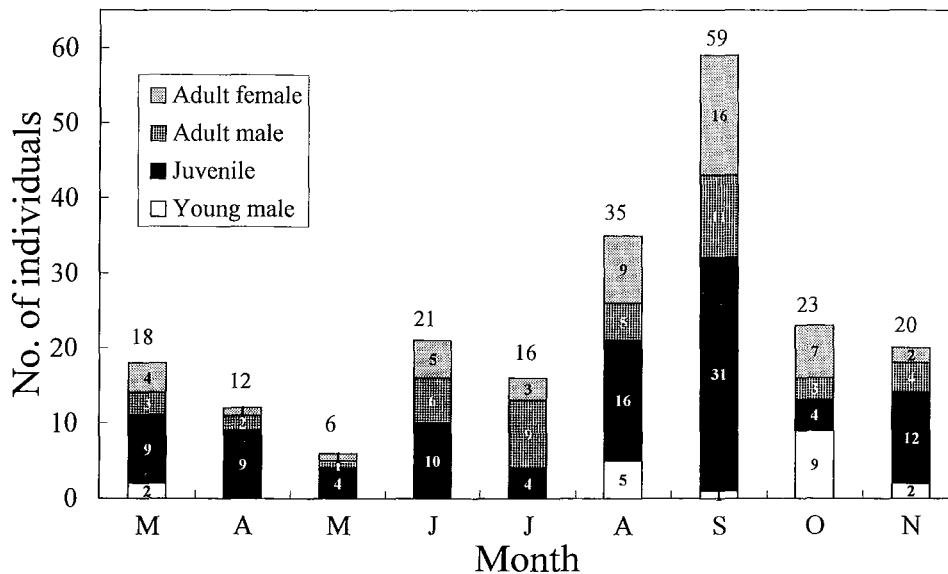

Fig. 1. Monthly sampling distribution of *Eumeces elegans* in Meifong, Nantou County. Numbers within the bar represent the monthly capture of each age class. Numbers above bars indicate total monthly capture of 4 age classes.

Rank analysis of covariance indicated that the distributions of HW, HL, HD, and TTL relative to SVL, and log body mass relative to log SVL were significantly different among adult males, adult females, young males, and juveniles. Parametric covariance analysis of head size variables and TTL, with SVL as the covariate demonstrated that regression slopes for adult males were significantly different from those of adult females, young males, and juveniles for all variables except 3rd toe length (Table 1). Larger males had relatively longer, wider, and deeper heads.

Means of SVL, body weight, HW, HL, and HD were significantly higher for adult males compared with adult females (Table 2). The heads of adult males were significantly larger than those of adult females for all head measurements (Table 2; Fig. 2).

Activity of the *E. elegans* population was esti-mated from the numbers of observations of active individuals within the study area. Yearly activity began in March, and peaked in August and September; activity was totally absent from December to February, coincident with lower temperatures during this period. A few individuals (mostly juveniles) were active until November (Fig. 1). Inactive *E. elegans* individuals were found seperately coiled into circles under rocks on the ground. Adult males, females, and juveniles were captured most frequently during September. However, no young males were captured from April to July. Based upon captures of individuals, the population was composed of 21% adult males, 9% young males, 23% adult females, and 47% juveniles.

Individual growth rates were estimated from recaptured animals, including 3 juveniles and 8 adults skinks (Table 3). The mean growth rate of

Table 1. Regression analyses of head width (HW), head length (HL), head depth (HD), and 3rd toe length (TTL) on snout vent length (SVL) and log body mass on log SVL for adult males, adult females, young males, and juveniles *Eumeces elegans*

Character regressed with SVL[+]	a (intercept)	b (slope)	R^2	p	N
HW					
adult male	-8.71	0.27 ± 0.03	0.67	< 0.0001	44
adult female*	-2.20	0.17 ± 0.03	0.36	< 0.0001	48
young male*	0.14	0.13 ± 0.04	0.36	0.0062	19
juvenile*	1.66	0.10 ± 0.01	0.82	< 0.0001	99
HL					
adult male	-4.19	0.28 ± 0.03	0.63	< 0.0001	44
adult female*	-2.75	0.25 ± 0.04	0.52	< 0.0001	48
young male*	4.64	0.14 ± 0.04	0.48	< 0.001	19
juvenile*	2.92	0.17 ± 0.01	0.92	< 0.0001	99
HD					
adult male	-1.87	0.12 ± 0.01	0.61	< 0.0001	44
adult female*	0.38	0.08 ± 0.03	0.16	0.0046	48
young male*	-1.66	0.12 ± 0.04	0.35	0.0072	19
juvenile*	0.90	0.07 ± 0.00	0.82	< 0.0001	99
TTL					
adult male	2.21	0.06 ± 0.02	0.15	< 0.01	44
adult female	0.45	0.08 ± 0.02	0.20	< 0.001	48
young male	2.41	0.05 ± 0.02	0.17	0.08	19
juvenile*	0.98	0.07 ± 0.01	0.68	< 0.0001	99
Log body mass					
adult male	-8.08[++]	2.44 ± 0.25[++]	0.69	< 0.0001	44
adult female*	-6.83[++]	2.08 ± 0.50[++]	0.27	0.0002	48
young male*	-10.31[++]	2.93 ± 0.44[++]	0.72	< 0.0001	19
juvenile*	-9.09[++]	2.58 ± 0.10[++]	0.86	< 0.0001	99

Where sexual and age differences exist (based on ANCOVA), regression models for each sex and age are present.
*indicates differences in slopes (p < 0.0001) of the regression due to sex and age based on ANCOVA, with SVL (or log SVL) as the covariate.
[+]The log of SVL was used for the log body mass regression.
[++]Values are logs.

body weight and SVL of juveniles was 0.27 g and 4.3 mm per month, respectively; those of adult skinks were 0.25 g and 0.64 mm, respectively.

Most recaptured individuals had not moved far from their initial capture site. Only one of the 12 recaptures was made more than 200 m, but less than 500 m, from the previous location.

DISCUSSION

Eumeces elegans exhibits strong sexual dimorphism, not only in SVL but also in head measurements. Head width is related to prey size in several reptilian taxa (Vitt 1983, Shine 1989). Perez-Mellado and Riva (1993) reported that sexual dimorphism of *Tropidurus melanopleůrus* in trophic structures corresponds to a strong sexual preference in the diets of males and females, with a diet based on small-sized ants in females, and a much more variable diet including several prey sizes in adult and subadult males. But large male head size

Table 2. Comparisons of means of morphological data on sexually mature *Eumeces elegans*

Character[a]	Adult males (n = 44)	Adult females (n = 48)	p
SVL (mm)	79.0 ± 6.5	66.8 ± 3.6	< 0.05
HW (mm)	12.8 ± 1.2	9.2 ± 0.7	< 0.05
HL (mm)	18.3 ± 1.3	14.2 ± 1.1	< 0.05
HD (mm)	7.8 ± 0.8	6.0 ± 0.3	< 0.05
BW (g)	13.4 ± 3.3	6.8 ± 1.6	< 0.05

[a]characters are as described in Table 1.

Table 3. Growth rate (SVL, BW) of recaptured skinks of *Eumeces elegans*

	Adult or Juvenile	Time of capture-recapture	Growth rate (BW g, SVL mm)[a]
1	A	March-June	(0.8, 2.0)
2	A	March-June	(0.6, 1.0)
3	J	March-June	(1.0, 9.0)
4	A	March-June	(−0.6, 0.0)
5	A	March-June	(2.0, 2.0)
6	A	June-July	(0.5, 0.2)
7	A	June-October	(1.4, 4.0)
8	J	March-October	(2.8, 17.0)
9	J	May-June	(0.1, 8.0)
10	A	August-September	(1.0, 4.0)
11	A	September-October	(−1.0, 0.0)
12	A	October-November	specimen found dead

[a]BW: body weight; SVL: snout vent length.

can be also interpreted in terms of competition between males, and, as Cooper and Vitt (1989) pointed out, sexual differences in morphological characters cannot be attributed to sexual selection unless independent data show that these characters determine differential reproductive success.

Hence, some morphometric characteristics of *E. elegans* may be due to natural selection. Larger male head size would confer an advantage in intraspecific combat in which biting is a part of the ritualistic behavior. It would also enhance success during copulation if males subdue females by grasping with their jaws (Vial and Stewart 1989). I have observed aggressive interactions between males in both the field and the laboratory. My
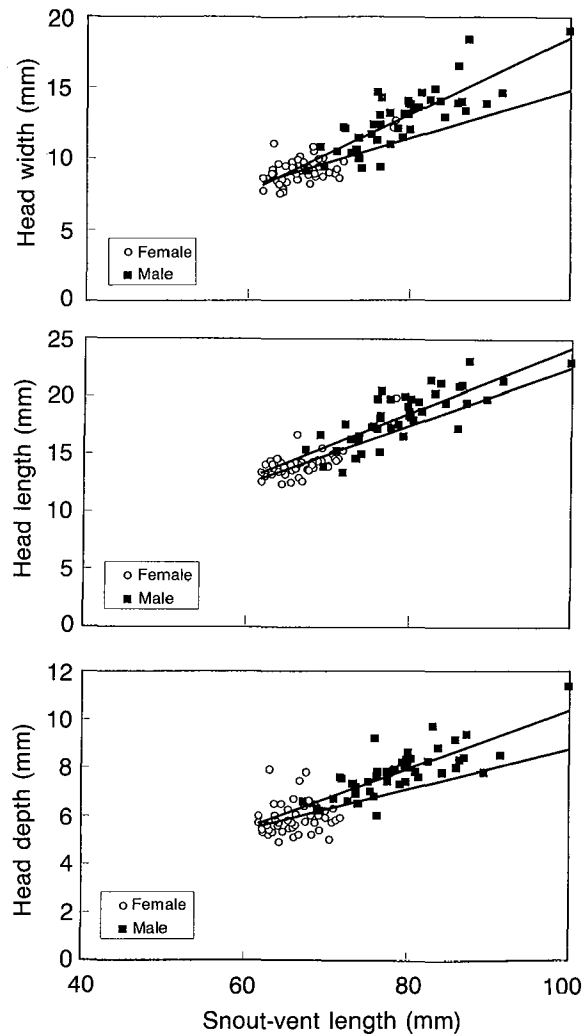

Fig. 2. Relationship of head width (HW), head length (HL), and head depth (HD) to snout vent length (SVL) in male (open circles) and female (solid squares) *Eumeces elegans*. Regression lines are based on data from sexually mature skinks only.

field observations suggest that larger males most often win aggressive encounters with smaller males. This is consistent with encounters those for other lizard species (i.e., Trivers 1976, Ruby 1984, Vitt and Cqoper 1985).

Coloration varied strikingly among adult males, adult females, young males, and juveniles of *Eumeces elegans*. This sexual dichromatism may be explained following Vial and Stewart's (1989) descriptions: (1) If sex ratios are equivalent, competition for females may be intensified by the fact that only half of the female population will be available reproductively at any given time. If male color distinctiveness confers an advantage in competition for females, it will come under strong selective pressure and thus be accentuated. (2) The lack of sexual dichromatism among juveniles indicated that the development of red spots on cheeks of adult skinks may correspond to gonadal maturation and is likely to be under control by sexual hormones (Vial and Stewart 1989).

Slow growth rates of species of *Ctenotus*, and year-to-year variations in reproductive output may result from adaptation to the variable and unpredictable demographic environment (James 1991b). Bull (1987) and Henle (1990a) observed very rapid growth in young *Trachydosaurus rugosus*. High growth rates in juveniles of *E. elegans* were also observed in the present study. Many studies of lizards have reported a positive correlation between environmental factors, such as rainfall, temperature, and/or food resources, and growth rates of individuals (e.g., Henle 1989, James 1991b). Because the food habits of skinks in the present study were not determined, further investigations are needed to elucidate factors affecting growth rates of *E. elegans*.

Higher population densities in insectivorous iguanids often result in a reduction in home range size, presumably because of the rising costs of defense (Alberts 1993). Other factors influencing population size of lizards are climate (directly affecting mortality and clutch size), predator pressure (Barbault 1976) and food supply (Bustard 1970). In Meifong, food supply could be a factor influening population size of *E. elegans*. Especially in September, decaying *Brassica oleracea capitata* in the fields attracted insects. During this period, skinks were found frequently in cultivated land. Studies have identified rainfall (Whitford and Creusere 1977), solar radiation (van Damme et al. 1987), supplemental water (Jones et al. 1987), and prey availability following rain (Reynolds 1982) as cues for activity in reptiles. On the Meifong

study site, heavy rainfall in autumn probably promotes an increase in the activity of *E. elegans*. This condition is in contrast with previous reports by James, studying species of *Ctenotus* (1991a), but it is consistent with Reynolds' study (1982) of many species of snakes. Mean temperatures decrease in winter, rendering the poikilothermic skinks inactive during this period.

A favorable environment for skinks usually includes shelter from predators, some amelioration of extremes of weather, a readily available food supply, and suitable oviposition sites (Bustard 1970). This study shows that the small active range of *E. elegans* may result from intraspecific competition for the requisites provided by the home site. The same results have also been found in insectivorous iguanids (Rand 1967, Schoener and Schoener 1980).

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臺灣麗紋石龍子雌雄異型及生活史之研究

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　　本研究描述臺灣麗紋石龍子雌雄異型及其生活史。成蜥的體色、體型和頭部大小皆呈雌雄異型。雄蜥的吻肛長、頭長、頭寬、頭高和第三趾長皆比雌蜥大。麗紋石龍子於三月開始活動，八至九月達到高峰；十二月至隔年二月冬眠。幼蜥的平均生長速度比成蜥快。

關鍵詞：雌雄異型, 族群結構, 麗紋石龍子, 臺灣。

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