SEXUAL SIZE DIMORPHISM OF SEA SNAKES IN TAIWAN

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ABSTRACT—A total of 140 museum specimens of 7 different species of sea snakes, *Emydocephalus ijimae*, *Hydrophis cyanocintus*, *H. melanocephalus*, *Laticauda colubrina*, *L. laticaudata*, *L. semifasciata*, and *Pelamis platurus*, were examined. Snout-vent length (SVL), head length, head width, head depth, and tail length were measured. Females had larger SVLs than males in *H. cyanocinctus* and *P. platurus*. All head variables of females were larger than those of males in *L. semifasciata*. Female head lengths were larger than those of males in *P. platurus*, whereas males' head widths and depths were larger than those of females in *H. melanocephalus*. Tail lengths of male *H. cyanocinctus*, *H. melanocephalus*, and *L. semifasciata* were greater than those of the respective females.

KEY WORDS: Head sizes, Body sizes, Hydrophiidae, Taiwan

INTRODUCTION

Since Darwin (1871) proposed the process of sexual selection, interest in this area has led to an examination of sexual dimorphism in a variety of reptiles (e.g., Shine, 1978; Fitch, 1981; King, 1989; Huang, 1996a). Sexual dimorphism may result from inter-sexual selection, e.g., female choice, especially in frogs and toads; Halliday (1983) and intra-sexual selection e.g., male-male competition (Madsen and Shine, 1994; Huang, 1996b). Ecological divergence (Shine, 1989), adult survival rates (Howard, 1981) and energy allocation to reproduction (Woodbright, 1983) also have important effects on the evolution of body sizes of each sex of snakes and have been discussed extensively. However, sexual dimorphism in sea snakes has received little attention, and its basis is open to discussion (Pernetta, 1977).

Sexual dimorphism in snakes has been described and discussed by Shine (1978) and in light of sexual selection theory by Trivers (1972). Male-male competition can act to increase the size of males (Shine, 1978), whereas natural selection can favor large size in females through production of more offspring (Semlitsch and Gibbons, 1982). Snakes are well suited for analyses of ecological causes for the evolution of sexual dimorphism because head sizes in this group are important for feeding but not for reproductive behavior (Shine, 1991). Although several studies have reported excellent descriptions of the morphologies, color in life, skeletal characters, musculature of the venom gland, heart and lungs, hemipenis, immunologies and aggressiveness in Taiwanese sea snakes, however, they have exclude discussion of sexual dimorphism (Mao *et al*., 1977, 1978; Mao and Chen, 1980; Tu, 1987; Tu and Su, 1991), except

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for Tu and Lue (1990) who reported a short description of the sexual dimorphism of *Latcauda semifasciata*. The present study records the sexual size differences of sea snake in the collections of the National Museum of Natural Science in Taiwan with the aim of providing extensive data on the degree of sexual size dimorphism in relative bodysize of sea snakes in Taiwan.

MATERIALS AND METHODS

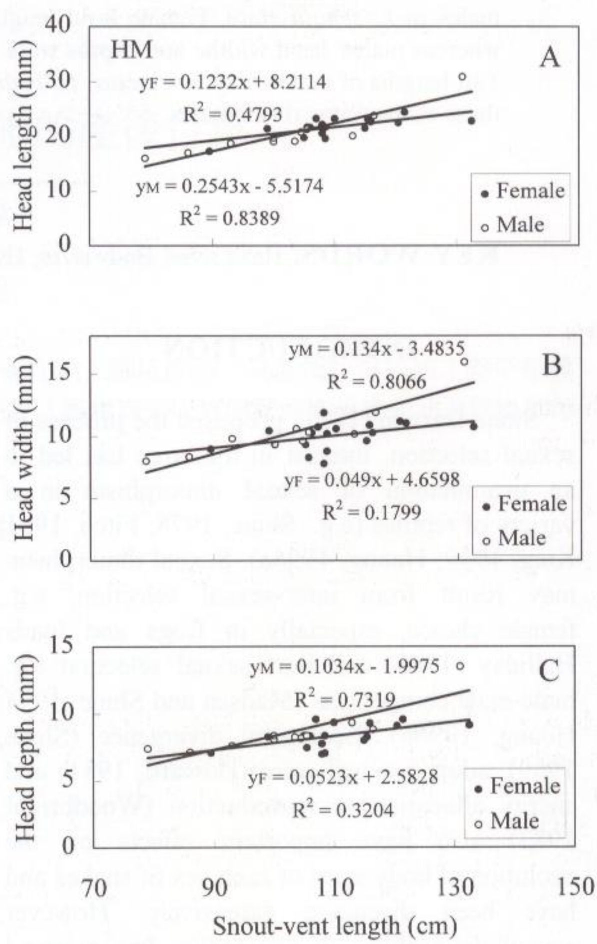
A total of 140 specimens of seven species of sea snakes which occur in Taiwan were examined in this study. All specimens are deposited at the National Museum of Natural Science, Taichung, Taiwan. For each specimen the snout-vent length (SVL) and the tail length (TL) were measured to the nearest centimeter. Head length (HL), head width (HW), and head depth (HD) were measured to the nearest millimeter. Gender was determined by examining everted hemipenes, the shape of the tail, or by using a midventral incision to examine the gonads. Juveniles or specimens in which the internal organs were missing or damaged were recorded as unsexed.

Data were analyzed separately for individual sexes using the analysis of covariance (ANCOVA) with SVL as the covariate to factor out the effect of body size. Regressions were calculated for each sex comparing HL, HW, and HD against SVL. Comparisons of means of the morphological variables were made with the General Linear Models Procedure Least Square Means. A value of probability less than 0.05 was taken to indicate significance in comparisons of means.

RESULTS

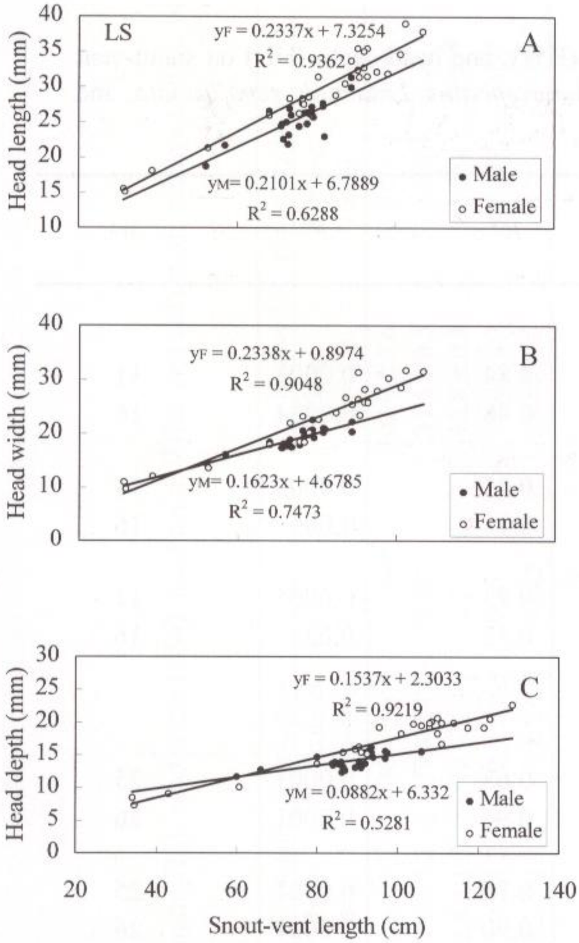
Because there were no male *Laticauda colubrina* or female *L. laticaudata* specimens in the present study, sexual dimorphism was not determined in these two sea snakes. Sample sizes smaller than that of *Pelamis platurus* ($n = 9$) were also ignored in regression analyses in the present study. Only three species, *Hydrophis melanocephalus*, *L. semifasciata*, and *P. platurus*, were used for statistical calculations herein. However, information from all specimens examined is included to facilitate further study. A total of 140 specimens of sea snakes were examined. Analysis of covariance indicated that the distributions of each head variable relative to SVL were significantly different between sexes in *Laticauda semifasciata*, as were head width and depth in *Hydrophis melanocephalus*, and head length in *Pelamis platurus* (text-fig. 1-3, table 1).

General linear model analysis of mean values



TEXT-FIGURE 1

Regression of head length (A), head width (B), and head depth (C) versus snout-vent length (SVL) for adult *Hydrophis melanocephalus* (HM).

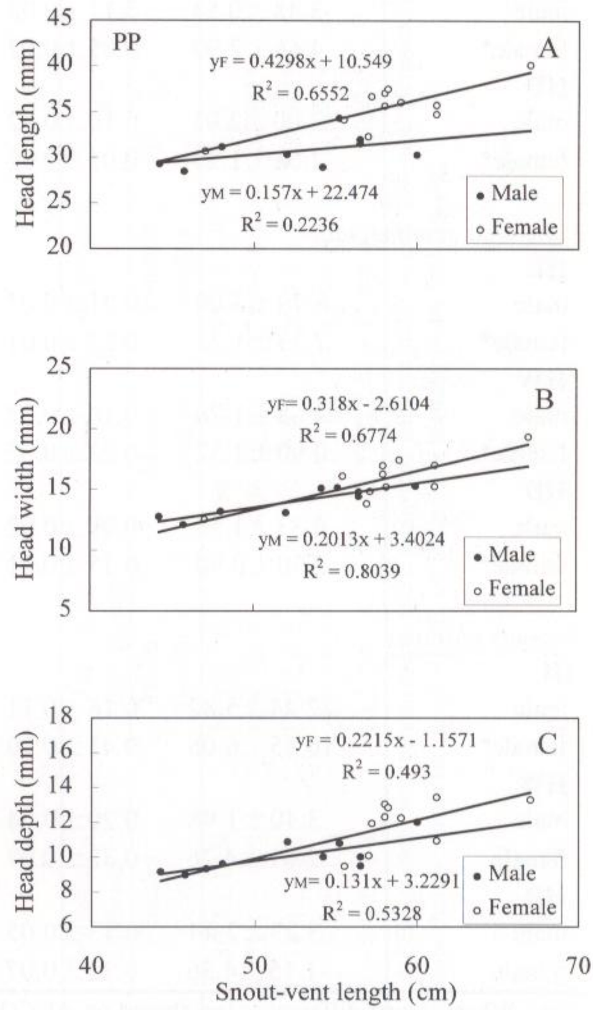


TEXT-FIGURE 2
Regression of head length (A), head width (B), and head depth (C) versus snout-vent length (SVL) for adult *Laticauda semifasciata* (LS).

indicated that the distributions of each head variable relative to SVL were significantly different between males and females in *L. semifasciata* (table 2). Head lengths of *P. platurus* females were larger than those of males, as were head widths and depth of female relative to male *H. melanocephalus*. The mean SVLs of females exceeded those of males in *H. cyanocinctus*, *P. platurus*, *H. melanocephalus*, and *L. semifasciata*, however, in only the first two species were differences significant (table 2). The tail lengths of males of *H. cyanocinctus*, *H. melanocephalus*, *L. semifasciata*, *E. ijimae*, and *P. platurus* were larger than those of females, however, in only the first three species were differences significant (table 2).

DISCUSSION

Sexual dimorphism in body size is common in snakes, the female usually being larger than the male (Shine, 1978; Fitch, 1981). Larger adult female size may be due to faster growth related to the necessity for females to carry large eggs (Pernetta, 1977) and/or has been attributed to



TEXT-FIGURE 3
Regression of head length (A), head width (B), and head depth (C) versus snout-vent length (SVL) for adult *Pelamis platurus* (PP).

TABLE 1
Regression analyses of head length (HL), head width (HW), and head depth (HD) on snout-vent length (SVL) for males and females of *Hydrophis melanocephalus*, *Laticauda semifasciata*, and *Pelamis platurus*

Species and character with SVL	a (intercept)	b (slope)	R^2	*P*	*n*
Hydrophis melanocephalus					
HL					
male	-5.5 ±0.32	0.25±0.04	0.84	0.0001	11
female	8.3 ±2.1	0.12±0.03	0.48	0.0034	16
HW					
male	-3.48±0.54	0.13±0.02	0.81	0.0003	11
female*	4.66±2.99	0.05±0.02	0.18	0.089	16
HD					
male	-2.00±2.05	0.10±0.02	0.73	0.0005	11
female*	2.58±1.23	0.05±0.02	0.32	0.02	16
Laticauda semifasciata					
HL					
male	6.79±3.00	0.21±0.03	0.63	0.0001	25
female*	7.33±1.22	0.23±0.01	0.94	0.0001	26
HW					
male	4.68±1.76	0.16±0.02	0.75	0.0001	25
female*	0.90±1.52	0.23±0.02	0.90	0.0001	26
HD					
male	6.33±1.55	0.09±0.02	0.53	0.0001	25
female*	2.30±0.90	0.15±0.01	0.92	0.0001	26
Pelamis platurus					
HL					
male	22.44±5.82	0.16±0.11	0.22	0.20	9
female*	10.55±6.06	0.43±0.10	0.66	0.0025	11
HW					
male	3.40±1.98	0.20±0.04	0.80	0.0011	9
female	-2.61±4.26	0.32±0.07	0.68	0.0019	11
HD					
male	3.23±2.44	0.13±0.05	0.53	0.0256	9
female	-1.15±4.36	0.22±0.07	0.49	0.016	11

Note: Where sexual differences test (based on ANCOVA), regression models for both sexes are present. An asterisk (*) indicates differences in slopes (*p*) of the regressions due to sex based on ANCOVA, with SVL as the covariate.

TABLE 2
Sexual dimorphism in snout vent length (SVL), and head length (HL), head width (HW), head depth (HD), and tail length, relative to SVL of seven species of sea snakes in Taiwan

Character	*Emydocephalus ijimae*			*Hydrophis cyanocinctus*			*Hydrophis melanocephalus*		
	Males (*n*=8)	Females (*n*=4)	*p*	Males (*n*=3)	Females (*n*=9)	*p*	Males (*n*=11)	Females (*n*=16)	*p*
SVL (cm)	57.5±3.9	47.3±5.5	0.16	110.6±6.3	136.4±3.5	0.004*	102.9±3.6	110.0±3.0	0.14
HL (mm)	17.8±0.5	19.9±0.8	0.06	27.0±2.2	29.8±1.1	0.34	21.5±0.5	21.2±0.4	0.63
HW (mm)	12.4±0.4	11.8±0.6	0.44	12.8±1.7	15.6±0.7	0.20	10.8±0.4	9.8±0.3	0.05*
HD (mm)	10.6±0.3	10.0±0.4	0.29	11.2±1.2	12.9±0.5	0.25	9.0±0.3	8.1±0.2	0.02*
TL (cm)	8.6±0.4	8.4±0.6	0.83	13.2±1.2	9.2±0.5	0.02*	9.8±0.2	8.9±0.2	0.005*

Continued

Character	*Laticauda colubrina*	*Laticauda laticaudata*	*Laticauda semifasciata*			*Pelamis platurus*		
	Females (*n*=6)	Males (*n*=12)	Males (*n*=25)	Females (*n*=26)	*p*	Males (*n*=9)	Females (*n*=11)	*p*
SVL (cm)	80.7±10.9	78.9±2.6	88.9±4.0	95.4±3.9	0.25	52.5±1.7	58.1±1.5	0.02*
HL (mm)	23.1± 1.3	18.8±0.7	26.3±0.3	28.9±0.3	0.0001*	31.6±0.7	34.8±0.6	0.005*
HW (mm)	14.4± 1.3	11.7±0.2	19.9±0.3	22.4±0.3	0.0001*	14.9±1.0	15.2±0.3	0.54
HD (mm)	9.8± 0.8	8.7±0.3	14.7±1.1	16.5±0.2	0.0001*	10.9±0.9	11.2±0.3	0.48
TL (cm)	8.9± 1.8	10.2±0.2	12.7±0.2	11.8±0.2	0.0004*	6.8±0.6	6.2±0.5	0.46

Note: Means (± SE) of each size measurement were compared between adult males and adult females, testing with an unpaired two-tailed t-test. An asterisk (*) indicates that the character shows significant differences between males and females.

sexual selection for increased fecundity (Triver, 1972; Shine, 1994). The present results indicate that body sizes of females of *Hydrophis cyanocinctus* and *Pelamis platurus* are larger than those of males. The body size of the former species was reported by Fitch (1981) with mean SVL values in males and females of 137 cm and 175 cm, respectively, which are larger than those of the present study. The body sizes of the latter species were described by Kropach (1975) and Shine (1994). SVLs of males and females of Kropach (1975) were 45.2 mm and 48.1 mm, respectively, which are smaller than those of the present study, whereas in Shine's (1994) reported that SVLs of males were 56.3 mm and of females were 66.4 mm, which are larger than those of the present study. Although three reports showed SVL differences between males and females, female SVLs were usually longer than males'. This deduction is coincide with Shine (1986, 1994) who reported that larger body size in aquatic snakes does not necessarily confer an advantage in combat, because agility may be more important than strength. Thus, SVL selection may be directed toward females. Studies of the water snakes, *Enhydris chinensis* and *E. plumbea*, by Pope (1935) and Huang (unpublished manuscript) in which SVLs of females are larger than those of males agree with such an opinion. Thus, further study is needed to clarify sexual size dimorphism of sea snakes.

Significant differences between the sexes in head size relative to body length are common among snakes (Camilleri and Shine, 1990). Male snakes which attain larger head sizes seldom engage in male-male combat, and it seems unlikely that larger head sizes in females of many snake species have envolved primarily because of advantages conferred by social interaction (Camilleri and Shine, 1990). In other words, sexual selection has not been important for the development of differences in head sizes between sexes. Shine (1991) comparing the head length of two species of sea snakes, *H. elegans* and *P. platurus* supports above description. Camilleri and Shine (1990) also mention two hypotheses to explain sexual dimorphism in head size among snakes. 1) Adaptation. Modifications due to sexual differences in diets (e.g., Voris and Voris, 1983) studying food habits of 39 species of sea snakes, such as enlargement of the head in one sex, serve as visual stimuli, perhaps in intraspecific or anti-predator display, and head enlargement reflects selection for larger sensory organs or brains in one sex. 2) Non-adaptation. Dimorphism may be an accidential consequence of hormonal effects during ontogeny (e.g., Shine and Crews, 1988) studying the garter snake *Thanmnophis sirtalis*), or a reflection of sexual differences in diets, growth rates or thermal history during juvenile life. Although Mao and Chen (1980) described several food habits of Taiwanese sea snakes, the differences between males and females can not be determined from either their report or the present study. The food items of these sea snakes need to be further studied.

Male snakes typically have longer tails than females (King, 1989). King (1989) advanced three hypotheses to explain tail length differences between sexes. 1) The morphological constraint hypothesis: males have relatively longer tails to contain hemipenes and retractor muscles. 2) The female reproductive output hypothesis: females have relatively shorter tails as a secondary result of natural selection for increased reproductive capacity. 3) The male mating ability hypothesis: males have longer tails to favor courtship. Although only *Hydrophis cyanocinctus*, *H. melanocephalus*, and *Laticaudata semifasciata* showed SVLs with significant differences between sexes, the tail length of all males of species examined herein were longer than those of females of the same species. Thus, the present study seems to agree with King's. (1989) predictions.

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台灣海蛇雌雄異型之研究

黃文山

摘 要

本研究檢視保存於國立自然科學博物館的飯島式海蛇、青環海蛇、黑頭海蛇、黃唇青斑海蛇、黑唇青斑海蛇、闊帶青斑海蛇和黑背海蛇等七種共 140 條標本。測量每條海蛇的吻肛長、頭長、頭寬、頭高和尾長。雌性青環海蛇和黑背海蛇的吻肛長比雄蛇大。雌性闊帶青斑海蛇的所有頭部測量值皆比雄蛇大。雌性黑背海蛇的頭長比雄蛇大，然而雄性黑頭海蛇的頭高和頭寬皆比雌蛇大。雄性青環海蛇、黑頭海蛇和闊帶青斑海蛇的尾長比各自的雌蛇長。

關鍵詞：頭部型質、身體大小、海蛇科、台灣