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SEXUAL SIZE DIMORPHISM AND FEEDING ECOLOGY OF *EUTROPIS MULTIFASCIATA* (REPTILIA: SQUAMATA: SCINCIDAE) IN THE CENTRAL HIGHLANDS OF VIETNAM

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Abstract*.—Little is known about many aspects of the ecology of the Common Sun Skink, *Eutropis multifasciata* (Kuhl, 1820), a terrestrial viviparous lizard found in the Central Highlands of Vietnam. We measured males and females to determine whether this species exhibits sexual size dimorphism and whether there was a correlation between feeding ecology and body size. We also examined spatiotemporal and sexual variations in dietary composition and prey diversity index. We used these data to examine whether the foraging pattern of these skinks corresponded to the pattern of a sit-and-wait predator or a widely foraging predator. The average snout-vent length (SVL) was significantly larger in adult males than in adult females. When SVL was taken into account as a covariate, head length and width and mouth width were larger in adult males than in adult females. The mean tail length and relative tail length were not significantly different between the sexes. We identified 489 prey items belonging to 22 unique animal categories. These mainly included invertebrates, but also included some vertebrates, such as scincid lizards, gekkonid geckos, and small frogs. The total dietary breadth of skinks was 9.91; the most important prey categories were grasshoppers, termites, spiders, and insect larvae (56.18% of occurrence frequency, 62.37% of prey items, and 40.55% of total volume, with a combined importance index of 53.04%). The foraging behavior of *E. multifasciata* best fits a widely foraging model. Results indicated that temperature and relative humidity, but not precipitation, were associated positively with prey volume.

Key Words.—Common Sun Skink; diet; food; lizards; skinks

INTRODUCTION

The Common Sun Skink, *Eutropis multifasciata* (formerly *Mabuya multifasciata*), is a widely distributed species in India, southern China (Yunnan, Guangdong, and Hainan), Taiwan, Myanmar, Thailand, Indochina, Philippines, Indonesia, Singapore, Malaysia, and New Guinea (Zhao and Adler 1995; Nguyen et al. 2009). About 470 species of reptiles are known from Vietnam (Uetz, P., and L. Hošek. 2014. The Reptile Database, Available at: http://www.reptile-database.org. [Accessed 8 January 2014]), and five of these are in the genus *Eutropis* (Fitzinger 1843; Nguyen et al. 2009). Previous studies indicate that *E. multifasciata* is commonly distributed in open regions, villages, and occasionally in secondary forest at various temperature and humidity regimes (Ji et al. 2006; Lin et al. 2008; Nguyen et al. 2009; Li et al. 2010). In winter, this species becomes inactive in burrows at depths of 25–40 cm (Binh Ngo, pers. obs.).

The Central Highlands of Indochina are a region of high biodiversity (Nguyen et al. 2009) and are considered to be one of the biodiversity hotspots in the world (Myers et al. 2000). This region is affected strongly by habitat fragmentation or loss and climate change (Truong 2013). Studies of the ecology, sexual dimorphism and reproduction, and feeding performances of skinks from southern China including Hainan Island (Ji et al. 2006; Lin et al. 2008; Sun et al. 2012), Taiwan (Huang 2006; Kuo et al. 2013), and Malaysia (Goldberg 2013) have been published, representing important progress towards the understanding of these reptile species. Information on the feeding ecology of *E. multifasciata* skinks is lacking and little information is available on most aspects of their ecology. Thus, studies of sexual dimorphism and feeding ecology, including an assessment of diversity in the dietary composition of *E. multifasciata* skinks, can be valuable to gain insight into their ecology and population status and to inform management and conservation plans for this species in Vietnam.

Sexual dimorphism in morphological measurements as well as in overall body size is widespread among lizard species (Andersson 1994; Brana 1996; Clemann et al. 2004; Ji et al. 2006). Sexual dimorphism may be selected for directly or indirectly through natural or sexual selection (Schwarzkopf 2005; Ji et al. 2006; Clutton-Brock 2007; Reilly et al. 2007). Sexual selection through male choice or female contest competition is the most frequently cited explanation for the evolution of sexual size dimorphism (Anderson and Vitt 1990; Ji et al. 2006; Clutton-Brock 2007). Previous studies indicate that male skinks are the larger sex because of male contest competition for diet and copulation (Zhang and Ji 2004; Huang 2006). As a result, larger male individuals may eat larger prey categories (Du and Ji 2001; Zhang and Ji 2004; Huang 2006). However, action of natural selection often to reduce intersexual resource competition, differential mortality between the sexes, and fecundity selection, are increasingly reported as alternative causes of sexual size dimorphism (Slatkin 1984; Shine 1989; Brana 1996; Shine et al. 2002; Ji et al. 2006). Thus, whether or not variation in sexual dimorphism is often associated with the feeding ecology of scincid skinks is useful to our understanding of the ecology of *E. multifasciata*.

In this study, we investigated sexual size dimorphism and feeding ecology of *E. multifasciata* living in the Central Highlands of Vietnam. Specifically, we examined: (1) spatiotemporal (among localities and seasons) variation in feeding ecology; (2) variation between the sexes in prey composition; and (3) quality and quantity of prey consumption by this tropical insectivorous skink in different habitats. We tested the hypothesis that sexual differences in feeding by adult males and females resulted in different morphological measurements of head and body size. We predicted that head size is larger in adult males than in adult females. We also tested the hypothesis that individuals sampled in different geographic areas, among seasons, and between sexes differed in prey consumption. Because mouth sizes of skinks (width and gape) are positively correlated with prey sizes found in their stomach (Reilly et al. 2007), we tested the hypothesis that differences in mouth widths of skinks resulted in different sizes of prey consumed. We predicted that foraging strategies of *E. multifasciata* fit an active foraging predator model and that these skinks eat mainly small, sedentary, and clumped prey. We also examined the feeding ecology of *E. multifasciata* to estimate season-dependent dietary variation and to test the notion that the size of prey consumed and the dietary breadth of *E. multifasciata* are positively correlated with their body size.

Materials and Methods

Study site.—We conducted this study in the Buon Don District (12°40'31"–13°06'05"N, 107°28'25"–108°03'29"E), Dak Lak Province, Vietnam (Fig. 1). This area is characterized by a tropical climate and seasonal monsoons, with an annual average temperature of 24.04 ± 0.41 °C (ranging from 21.24 ± 0.98 °C in January and 25.97 ± 1.01 °C in May), an annual average rainfall of 1,676.1 ± 302.4 mm, and an annual average humidity of 82.8 ± 0.54% (data obtained from weather stations in Buon Don District, Dak Lak Province, unpubl. data). This region also has a relatively dry period (the dry season) that extends from November to April, with monthly rainfall ranging from 0.22 to 82.64 mm (33.16 ± 15.64 mm). Most rainfall is restricted to the wet season, which takes place between May and October (approximately 6 months) and has monthly rainfall amounts from 216.7 to 319.6 mm (246.2 ± 15.73 mm). The dominant vegetation in these regions is typical for the Central Highlands and ranges from dense grassland (usually with a sparse covering of shrubs and small trees), to rice fields, corn fields, sugar-cane fields, and marshes. These regions are tropical mountain areas

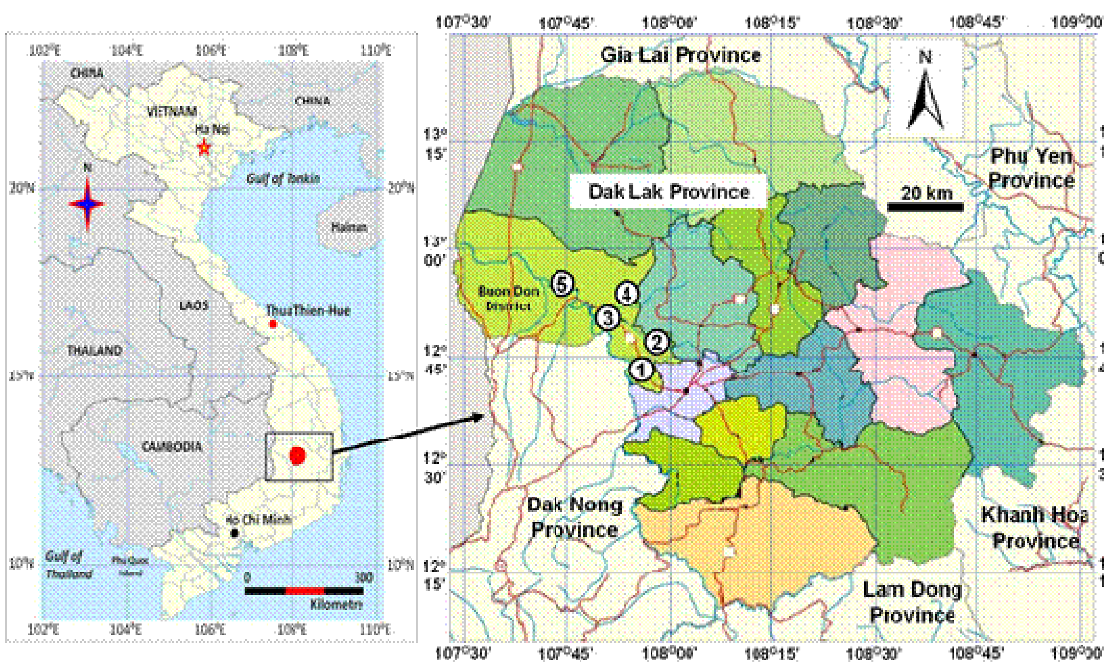

Figure 1. Map of Dak Lak Province in Vietnam showing the geographic location of Buon Don District and the five localities where we sampled (white circles) the Common Sun Skink, *Eutropis multifasciata*: (1) Ea Nuol, (2) Cuor Knia, (3) Ea Wer, (4) Ea Huar, and (5) Krong Na.

belonging to the Vietnamese Highlands with fragmented secondary forests, which consist of a mosaic of riparian forest, mesophytic forest, eucalyptus culture, rubber-trees, and open areas (tracks and glades).

Sample collection.—We collected specimens of *Eutropis multifasciata* at the following localities in Buon Don District, Dak Lak Province: (1) Ea Nuol (12°43'15"N, 107°56'27"E, at 295 m above sea level [asl]); (2) Cuor Knia (12°47'25"N, 107°58'31"E, at 349 m asl); (3) Ea Wer (12°50'05"N, 107°52'16"E, at 215 m asl); (4) Ea Huar (12°53'09"N, 107°54'06"E, at 236 m asl); and (5) Krong Na (12°55'15"N, 107°44'52"E, at 196 m asl). To determine foraging mode, two of us observed each scincid skink, one watching and describing the skink's activity and the other recording data. We generally watched skinks from a distance of ≥ 3 m, which was sufficient to avoid disturbing the skinks (Phong Truong, unpubl. data). We began recording data 5–10 min after finding a *E. multifasciata* to minimize observer effects associated with our arrival. For each minute of observation (total of 10 min for each individual observed), we noted the number of movements made and the behavior of an individual (including active hunting of prey, sit-and-wait behavior, basking, etc.). We limited observations obtained from 0930–1600 in the analyses for the widely foraging versus sit-and-wait pattern because these skinks usually bask before 0930 and are not active.

We collected lizards in approximately equal proportions from the different locations and seasons (81 during the dry season and 76 during the wet season). We conducted daytime surveys at each site (especially after sunny days with optimal weather for skink activity) from 0800–1600. At these sites, we collected samples along transects, approximately 2.5 to 3.5 km in length. We collected throughout the villages, open areas, riparian forest, forestry plantations, and fields. We visually searched for skinks and collected specimens by hand, using rods, and pitfall traps, then placed them into individually labeled bags. We recorded site, date, time, elevation, ambient temperature, and relative humidity for each individual we caught. For each sample site where skinks were found, we took coordinates with datum WGS 84 using a GPS unit (Garmin Colorado 400t, Garmin Corporation, Taipei County, Taiwan) to determine the distance among sites and the distribution of *E. multifasciata* in the Central Highlands.

Morphology and sexual dimorphism.—We measured individuals with standard calipers (Prokits, Taipei, Taiwan) to the nearest 0.1 mm for snout-vent length (SVL) and tail length (TL). We measured head length (HL, distance from the tip of the snout to the anterior edge of the ear aperture), head width (HW, horizontal line at posterior end of the mandible), and mouth width (MW, horizontal line at the posterior angle of the jaw) using digital calipers (Mitutoyo Corporation, Kawasaki, Japan) to the nearest 0.01 mm. To measure body mass (BM), we used an electronic balance (Prokits, Taipei, Taiwan) to the nearest 0.1 g. We used the ratio of TL/SVL to calculate relative tail length (RTL), and some measurements of head morphology relative to SVL such as HL/SVL, HW/SVL, and MW/SVL. When necessary to meet normality assumptions and homogeneity of variance, body size variables (exclusive of ratios) were log-transformed prior to the analyses (Clemann et al. 2004; Rosner 2010; Zar 2010). We also restricted all morphological analyses examining sexual size dimorphism to adult individuals (i.e., female SVL ≥ 75 mm and male SVL > 76 mm; Truong 2013).

Stomach contents.—In the laboratory, we euthanized skinks with a solution of MS-222 (Tricaine Methanesulfonate) the same day that they were collected. We separated and fixed in 10% formalin stomach contents within two days (to preserve the stomach contents, fixation was usually carried out within 2 h after collecting). We determined the sex of specimens by examining gonads. We preserved all stomach contents in 95% ethanol for later laboratory analyses. After examination, we transferred specimens and stomach contents to 70% ethanol and deposited material in the herpetological collection of the Faculty of Biology, College of Education, Hue University, Vietnam, and the Faculty of Natural Sciences and Technology, Tay Nguyen University, Vietnam.

We sorted and identified prey items in each stomach sample to the lowest possible taxonomic level (mostly order, but identifications were made to family when possible). We consulted and followed keys and descriptions in Thai (2001) and nomenclature follows that of Johnson and Triplehorn (2005). We measured the length (head to thorax) and width (at widest centrally located section of body) of the body of each prey item with digital calipers to the nearest of 0.01 mm, or made a best estimation for incomplete items. We considered plant matter food. We considered other materials, such as sand, stones, and plastic parts, as accidental ingestions and excluded them from the analyses.

Data analysis.—We considered all unidentified materials (e.g., digested items that could not be identified) in the diet of *E. multifasciata* (such as unidentified insects) in the analyses. We calculated the percentage volume of each prey item and unidentified material, and estimated the volume (V) by the formula for a prolate spheroid (with π = 3.14159; Biavati et al. 2004; Valderrama-Vernaza et al. 2009; Caldart et al. 2012; Ngo and Ngo 2013):

$$V = \frac{4\pi}{3} \times \left(\frac{\text{length}}{2}\right) \times \left(\frac{\text{width}}{2}\right)^2$$

We adopted the reciprocal Simpson's index to calculate the dietary breadth of *E. multifasciata* from the Central Highlands:

$$B = 1 / \sum_{i=1}^{n} p_i^2$$

where *i* is the prey category and *p* is the proportion of prey in category *i*, and *n* is the total number of prey categories (Krebs 1999; Magurran 2004; Pérez-Crespo et al. 2013). We also calculated the percentage frequency of occurrence (F), which is the percentage of stomachs containing each prey category, and the numeric percentages (N) of each prey item in relation to all the prey items. We used the index of relative importance (IRI) to determine the importance of each prey category in the feeding ecology of *E. multifasciata*. This quotient (IRI) provides a more informed estimation of prey consumption than any of the three components alone by using the following formula (Biavati et al. 2004; Leavitt and Fitzgerald 2009):

$$IRI = \frac{\%F + \%N + \%V}{3}$$

where IRI is relative importance index for each prey category, %F is occurrence percentage, %N is numeric percentage, and %V is volumetric percentage.

To estimate the effects of sex, female reproductive condition, and season on the feeding ecology of *E. multifasciata*, we calculated an index of relative importance for prey types based on each individual stomach and the importance value (I) of prey categories as: I = (%N + %V)/2; where %N = numeric percentage and %V = volumetric percentage. We only used the most important prey categories in this analysis (i.e., those with IRI ≥ 5%).

To statistically analyze lizard and prey morphometric data, we used SPSS 14.0 software (SPSS Inc., Chicago, Illinois, USA) and STATISTICA 10.0 (StatSoft Inc., Tulsa, Oklahoma, USA) for Windows 7 and set the significance level to $P \leq 0.05$ for all analyses. To determine if the sexes were size dimorphic, we used a two-way analysis of variance (ANOVA) to compare SVL between sexes, among localities, and to determine if there was an interaction between sex and locality. If sexes were dimorphic, we used analysis of covariance (ANCOVA) to test morphological measurements of the head, BM, TL, and RTL with SVL as a covariate at locations where sexes differed (Rosner 2010; Zar 2010).

We used one-way ANOVAs to examine the number of stomachs collected among localities and seasons. We tested correlations between body size (SVL, BM, and MW) and prey size (length, width, and volume) to determine if prey size was correlated with skink size. We used one-way ANOVAs to determine if prey length, prey width, or prey volume significantly differed between males and females. If these measures differed between sexes, we used one-way ANOVAs for each sex to test for differences between seasons and separately among localities. We tested the possible effects of climatic factors on feeding ecology and prey volume with multiple linear regressions between the monthly scores of precipitation (mm), mean temperature (°C), relative humidity (%), and prey volume. Multiple regressions between prey size (length, width, and volume) and body size (SVL, BM, and MW) were also used to examine significant effects of the relationships among localities and seasons. All data are presented as mean ± 1 SD (unless otherwise noted).

RESULTS

We made at least four visits per month from March to December 2013 (10 months) and collected 157 specimens (87 males and 70 females) of *E. multifasciata* from five localities. We did not find any juveniles during the study period. The number of *E. multifasciata* we found did not differ significantly between seasons ($F_{1,9} = 0.263$, $P = 0.625$) or among localities ($F_{4,49} = 0.562$, $P = 0.694$). On average, head ratios compared to SVL of adult males (n = 84) were significantly larger than adult females (n = 66) in this study area (Table 1).

TABLE 1. Summary of morphological traits in the Common Sun Skink, *Eutropis multifasciata*, from the Central Highlands, Vietnam. Morphological measurements are in millimeters (body mass, BM, is in grams). SVL = snout-vent length; HL = head length; HW = head width; MW = mouth width; TL = tail length; RTL = relative tail length.

	Adult male (n = 84)		Adult female (n = 66)	
Trait	**Mean ± SE**	**Range**	**Mean ± SE**	**Range**
SVL	100.9 ± 1.096	76.1–124.2	97.26 ± 1.374	75.2–120.1
HW/SVL	0.151 ± 0.001	0.121–0.186	0.142 ± 0.002	0.109–0.165
HL/SVL	0.204 ± 0.002	0.169–0.244	0.193 ± 0.002	0.161–0.222
MW/SVL	0.127 ± 0.001	0.099–0.163	0.118 ± 0.002	0.089–0.143
HL	20.54 ± 0.262	15.02–26.03	18.67 ± 0.254	14.1–25.0
HW	15.12 ± 0.194	10.11–18.21	13.71 ± 0.213	9.18–18.0
MW	12.82 ± 0.184	8.04–16.24	11.42 ± 0.207	7.02–15.6
TL	148.3 ± 3.079	60.4–222.1	139.1 ± 2.913	22.1–193.2
RTL	1.473 ± 0.028	0.569–2.067	1.443 ± 0.033	0.259–1.92
BM	30.88 ± 0.968	12.68–51.02	26.66 ± 0.996	11.8–53.2

The largest male was 124.2 mm SVL and the largest female 120.1 mm SVL (Table 1; Fig. 2). The average SVL of adults was significantly different between sexes ($F_{1,149}$ = 5.492, P = 0.021); whereas SVL did not differ significantly among localities nor was the interaction between sex and locality significantly different (locality: $F_{4,149}$ = 2.181, P = 0.075; interaction: $F_{4,149}$ = 0.873, P = 0.485). When SVL was taken into account as a covariate, the rate at which head length and width and mouth width increased with SVL were greater in adult males than in adult females (HL: $F_{1,147}$ = 223.37, P < 0.001, Fig. 3A; HW: $F_{1,147}$ = 126.46, P < 0.001, Fig. 3B; MW: $F_{1,147}$ = 124.34, P < 0.001, Fig. 3C). Adult male TL and RTL were also significantly greater than that of adult females with $\log_{10}$ (SVL) as a covariate (TL: $F_{1,147}$ = 14.17, P < 0.001; RTL: $F_{1,147}$ = 11.41, P = 0.001). Adult male BM with SVL as a covariate also was significantly greater than adult females ($F_{1,147}$ = 520.74, P < 0.001).

Approximately 5% (eight stomachs) of the 157 stomachs of *E. multifasciata* were empty, suggesting that many individuals were preserved soon enough after collection to successfully examine stomach contents. We identified 489 prey items in the diet of *E. multifasciata*. The number of prey items consumed by males (296 items) and females (193 items) was not significantly different ($F_{1,155}$ = 3.331, P = 0.071). The number of prey items in the wet season (277 items) was significantly larger than in the dry season (212 items; $F_{1,155}$ = 8.642, P = 0.004). Prey items of *E. multifasciata* represented 22 unique animal categories, five plant items, and 15 unidentified types. A total of 22 prey categories determined that diet mainly included invertebrates, but also some vertebrates (e.g., skinks, geckos, and small frogs; Table 2). The mean number of prey items per individual was 3.11 ± 0.177 (ranging from 0–20). Mean prey length was 15.46 ± 10.94 mm (ranging from 2.18–85.23 mm), mean prey width was 4.18 ± 1.58 mm (ranging from 1.01–9.78 mm), and average prey volume was 282.24 ± 187.97 mm^3 (ranging from 1.17–2419.5 mm^3).

We found 22 prey categories, unidentified materials (mainly insects), and plant types in stomachs, excluding plastic materials, sands, and stones (Table 3). The total dietary breadth of *E. multifasciata* from the Central Highlands in Vietnam was 9.91. The broadest dietary breadth was from the Ea Wer location (11.55); whereas the narrowest dietary breadth was found at the Ea Nuol location (6.77). Two populations with intermediate dietary breadths were at the Cuor Knia (9.67) and Ea Huar (9.64) localities; while the dietary breadth of the Krong Na location (9.93) was similar to the total dietary breadth (9.91). Individuals of two populations at the two Ea Wer and Krong Na localities consumed prey in 21 food categories; while two populations at two Cuor Knia and Ea Nuol localities consumed prey in 13 and 16 prey categories, respectively. All five populations of *E. multifasciata* consumed grasshoppers, termites, spiders, insect larvae, small crustacean species, and ants, with a total dietary breadth of approximately 68% (Table 3).

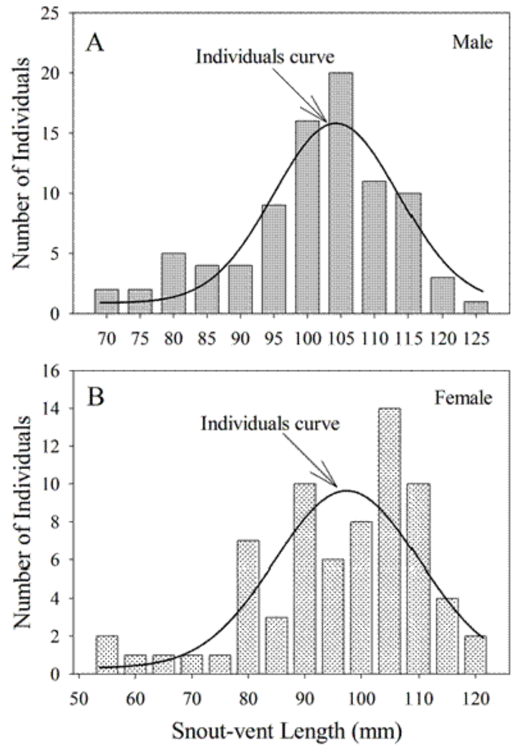

FIGURE 2. The normal distribution of snout-vent length (SVL, mm) for male (A) and female (B) Common Sun Skink, *Eutropis multifasciata* individuals showing the distribution of individuals among classes and sexual size dimorphism. For clarity, the upper bounds of the classes are shown. The curves in the figure are generated from a fit of the normal distribution for the data.

The most abundant prey of *E. multifasciata* skinks were grasshoppers, termites, spiders, insect larvae, and small crustacean species, accounting for 56.18% of occurrence frequency, 62.37% of the number of prey items, and 40.55% of the total volume, with an index of relative importance of 53.04% (Table 2; Fig. 4). Based on the index of relative importance, Araneae, Hymenoptera, Isoptera, Orthoptera, Isopoda, and insect larvae were the most important prey; while Diptera, Odonata, Haemadipsidae, Achatinidae, Dicroglossidae, and Gekkonidae were the less important prey items, comprising 3.07% of the total number of prey items with an index of relative importance of 6.04% (Table 2). Remaining prey items such as Coleoptera, Hemiptera, Lumbriculida, Scincidae, and unidentified items were intermediate importance items, with an index of relative importance of 22.11% (Table 2). In addition, we found five plant items in stomachs giving an index of relative importance of 1.31% (Table 2). Some sand, several plastic items, and several stones were also found in the stomachs but were likely swallowed accidentally with prey items. Thus they were excluded from the analysis.

TABLE 2. Diet composition of the Common Sun Skink, *Eutropis multifasciata* (n = 149 stomach contents), in percentage frequency of occurrence (F), number of items (N), and volume (V, mm³), and the index of relative importance (IRI) of each prey, sampled in the Central Highlands of Dak Lak Province, Vietnam. *Number of stomachs containing prey item; IRI = (%F + %N + %V)/3.

Prey category	Frequency (F)		Number (N)		Volume (V)		IRI
	F*	%F	N	%N	V(mm³)	%V	
Arachnida: Araneae	41	11.52	58	11.86	5,494.43	6.00	9.79
Insecta:							
Blattodea	9	2.53	10	2.04	2,472.99	2.70	2.42
Coleoptera	18	5.06	20	4.09	4,539.51	4.96	4.70
Dermaptera (Anisolabididae)	10	2.81	11	2.25	1,556.44	1.70	2.25
Diptera	2	0.56	2	0.41	180.02	0.20	0.39
Hemiptera	19	5.34	19	3.89	4,521.18	4.94	4.72
Hymenoptera (Formicidae)	20	5.62	27	5.52	282.71	0.31	3.82
Hymenoptera (Others)	9	2.53	15	3.07	680.01	0.74	2.11
Insect Larvae	22	6.18	36	7.36	7,630.95	8.33	7.29
Isoptera	37	10.39	87	17.79	7,623.39	8.32	12.17
Lepidoptera	7	1.97	8	1.64	3,451.09	3.77	2.46
Mantodea	3	0.84	4	0.82	3,974.08	4.34	2.00
Odonata	1	0.28	1	0.20	1,127.71	1.23	0.57
Orthoptera	75	21.07	92	18.81	12,995.62	14.19	18.02
Malacostraca: Isopoda	25	7.02	32	6.54	3,403.21	3.72	5.76
Clitellata:							
Lumbriculida	15	4.21	17	3.48	3,918.76	4.28	3.99
Haemadipsidae	3	0.84	3	0.61	314.21	0.34	0.60
Diplopoda: Julidae	7	1.97	8	1.64	3,397.41	3.71	2.44
Gastropoda: Achatinidae	5	1.40	5	1.02	1,978.64	2.16	1.53
Amphibia: Dicroglossidae	2	0.56	2	0.41	4,208.38	4.59	1.85
Reptilia:							
Scincidae	4	1.12	5	1.02	9,362.58	10.22	4.12
Gekkonidae	2	0.56	2	0.41	2,132.98	2.33	1.10
Plant materials	5	1.40	5	1.02	1,385.14	1.51	1.31
Unidentified	15	4.21	20	4.09	4,971.08	5.43	4.58

TABLE 3. Comparison of the occurrence of prey items, plant materials, and unidentified items in the Common Sun Skink, *Eutropis multifasciata*, and dietary breadth from locations in Buon Don District, the Central Highlands, Vietnam. (1) Ea Nuol (n = 24), (2) Cuor Knia (n = 17), (3) Ea Wer (n = 39), (4) Ea Huar (n = 35), and (5) Krong Na (n = 34).

	Location					
C	(1)	(2)	(3)	(4)	(5)	Total (n = 149)
Araneae	8.55	10.0	11.6	10.1	20.2	11.9
Blattodea	2.56	–	3.88	1.01	1.19	2.04
Coleoptera	3.42	5.00	3.88	4.04	4.76	4.09
Dermaptera (Anisolabididae)	5.98	–	0.78	–	3.57	2.25
Diptera	–	–	1.55	–	–	0.41
Hemiptera	4.27	3.33	3.88	3.03	4.76	3.89
Hymenoptera (Formicidae)	3.42	8.33	5.43	6.06	5.95	5.52
Hymenoptera (Others)	2.56	5.00	3.10	2.02	3.57	3.07
Insect Larvae	7.69	1.67	10.9	8.08	4.76	7.36
Isoptera	31.6	20.0	14.8	14.1	5.95	17.8
Lepidoptera	2.56	–	2.33	1.01	1.19	1.64
Mantodea	–	–	1.55	2.02	–	0.82
Odonata	–	–	–	–	1.19	0.20
Orthoptera	17.1	13.3	17.1	24.2	21.4	18.8
Isopoda	4.27	16.7	6.98	4.04	4.76	6.54
Lumbriculida	1.71	1.67	3.88	5.05	4.76	3.48
Haemadipsidae	–	–	0.78	1.01	1.19	0.61
Julidae	0.85	3.33	3.10	–	1.19	1.64
Achatinidae	1.71	–	0.78	1.01	1.19	1.02
Dicroglossidae	–	–	0.78	1.01	–	0.41
Scincidae	–	3.33	0.78	1.01	1.19	1.02
Gekkonidae	–	–	–	1.01	1.19	0.41
Plant materials	–	–	–	4.04	1.19	1.02
Unidentified	1.71	8.33	2.33	6.06	4.76	4.09
Categories	16	13	21	20	21	24
Dietary breadth	6.77	9.67	11.6	9.64	9.93	9.91

Average prey length (58.24 ± 2.239 mm), prey width (15.11 ± 0.327 mm), and prey volume (746.71 ± 51.982 mm^3) in males were significantly larger than in females (length: 41.33 ± 2.511 mm; $F_{1,147} = 25.27$, $P < 0.001$; width 11.99 ± 0.367 mm: $F_{1,147} = 40.09$, $P < 0.001$; volume 453.72 ± 58.302 mm^3: $F_{1,147} = 14.07$, $P < 0.001$). The total volume of prey in males was 61,974.0 mm^3 and 29,942.7 mm^3 in females. In males, volume of prey consumed was not significantly different between seasons ($F_{1,82} = 3.39$, $P = 0.069$), whereas prey sizes were significantly different (length: $F_{1,82} = 17.56$, $P < 0.001$; width: $F_{1,82} = 8.26$, $P = 0.005$). Prey volume and sizes consumed by males among localities were not significantly different (length: $F_{4,82} = 1.72$, $P = 0.155$; width: $F_{4,82} = 0.77$, $P = 0.552$; volume: $F_{4,82} = 1.27$, $P = 0.291$). Both prey volume and sizes consumed by females were not significantly different between seasons (length: $F_{1,65} = 3.78$, $P = 0.056$; width: $F_{1,65} = 3.11$, $P = 0.083$; volume: $F_{1,65} = 1.07$, $P = 0.304$) or among localities (length: $F_{4,65} = 0.62$, $P = 0.651$; width: $F_{4,65} = 0.43$, $P = 0.783$; volume: $F_{4,65} = 0.38$, $P = 0.821$).

In both seasons, we observed the foraging behavior of this species in the field. In the dry season, we collected 60.5% (49 observations) of lizards when lizards were hunting prey compared with 71.1% (54 observations) in the wet season. In the dry season, 22.2% (nine observations) of individuals were basking compared with 9.21% (eight observations) in the wet season. The percentage of individuals using sit-and-wait foraging was low for both the dry (11.1%) and wet seasons (11.8%). Therefore, the foraging behavior of *E. multifasciata* best fits a widely foraging or active forager model with 65.6% falling into that category compared with only 27.4% of sit-and-wait or basking in the sun (with 7.01% of other behaviors).

Adult *E. multifasciata* showed significant positive correlations between mouth width (MW) and prey sizes consumed (between MW and prey length: $r = 0.268$, $F_{1,147} = 11.36$, $P = 0.001$; between MW and prey width: $r = 0.309$, $F_{1,147} = 15.53$, $P < 0.001$; and between MW and prey volume: $r = 0.202$, $F_{1,147} = 4.082$, $P = 0.014$); whereas between SVL and prey sizes were not significant (SVL and prey length: $r = 0.143$, $F_{1,147} = 3.083$, $P = 0.081$; SVL and prey width: $r = 0.014$, $F_{1,147} = 0.035$, $P = 0.866$; SVL and prey volume: $r = 0.074$, $F_{1,147} = 0.812$, $P = 0.371$).

In the feeding ecology of the species, SVL and MW were considered the predictor variables in diet, because there were strong positive correlations between the morphological measurements (between SVL and MW: $r = 0.719$, $F_{1,147} = 161.182$, $P < 0.001$, Fig. 5A; between MW and BM: $r = 0.602$, $F_{1,147} = 86.473$, $P < 0.001$, Fig. 5B; and between SVL and BM: $r = 0.897$, $F_{1,147} = 549.195$, $P < 0.001$, Fig. 5C). Results of multiple linear regressions between prey size (length, width, and volume) and body size (SVL, BM, and MW) were positively significant (prey length: $r^2 = 0.078$, $F_{3,145} = 4.081$, $P = 0.008$; prey width: $r^2 = 0.191$, $F_{3,145} = 11.32$, $P < 0.001$; and prey volume: $r^2 = 0.056$, $F_{3,145} = 2.891$, $P = 0.038$).

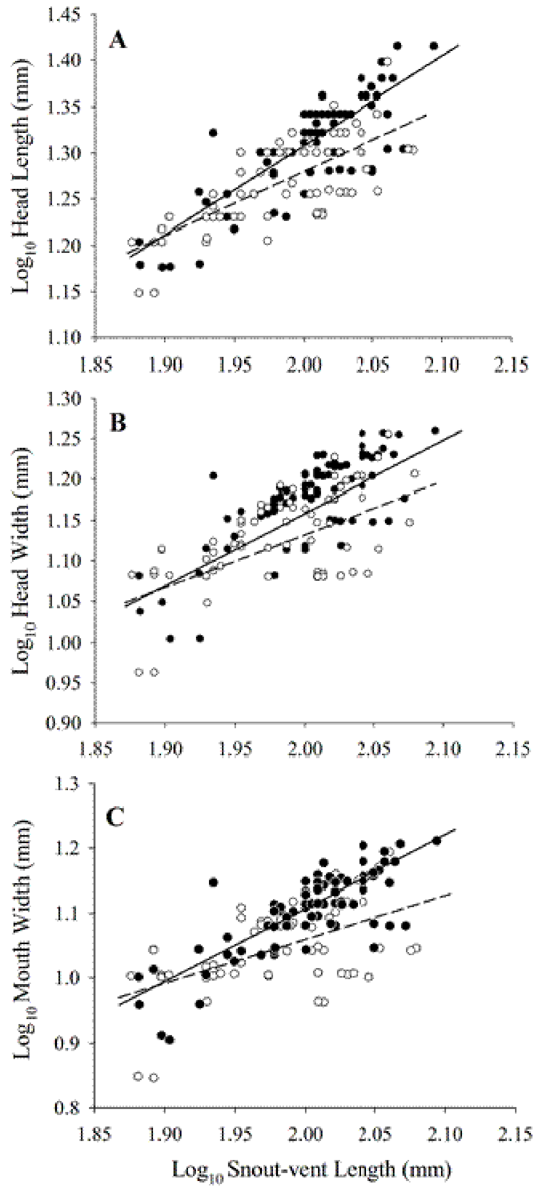

FIGURE 3. The relationships between (A) snout-vent length (SVL) and head length (HL), (B) head width (HW), and (C) mouth width (MW) in adult males and females of Common Sun Skink, *Eutropis multifasciata*. All variables have been log-transformed using base 10. Filled circles and solid lines indicate adult males ($\log_{10}[HL] = 0.967\log_{10}[SVL] - 0.625$; $\log_{10}[HW] = 0.922\log_{10}[SVL] - 0.669$; $\log_{10}[MW] = 1.082\log_{10}[SVL] - 1.051$). Open circles and broken lines indicate adult females ($\log_{10}[HL] = 0.692\log_{10}[SVL] - 0.105$; $\log_{10}[HW] = 0.656\log_{10}[SVL] - 0.169$; $\log_{10}[MW] = 0.719\log_{10}[SVL] - 0.374$).

Multiple regression results for possible effects of temperature, relative humidity, and rainfall on prey volume were significant among seasons ($r^2 = 0.126$; $F_{3,145} = 6.951$, $P < 0.001$); whereas temperature and

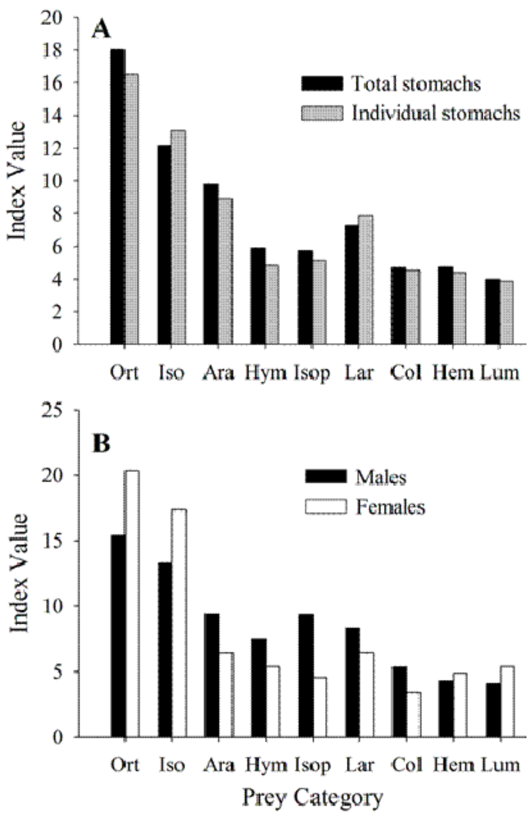

FIGURE 4. Relative importance indices of prey in the Common Sun Skink, *Eutropis multifasciata* based on total and individual stomach contents (A) and the index of relative importance for prey categories consumed by males vs. females (B) in the Central Highlands of Vietnam. Ort = Orthoptera; Iso = Isoptera; Ara = Araneae; Hym = Hymenoptera; Isop = Isopoda; Lar = Insect Larvae; Col = Coleoptera; Hem = Hemiptera; Lum = Lumbriculida.

relative humidity, but not precipitation, were associated positively with prey volume (temperature: $r^2 = 0.089$; $F_{1,147} = 14.34$, $P < 0.001$; relative humidity: $r^2 = 0.071$; $F_{1,147} = 11.26$, $P = 0.001$; precipitation: $r^2 = 0.015$; $F_{1,147} = 2.201$, $P = 0.141$). Results of multiple linear regressions for the effects of temperature, relative humidity, and rainfall on the number of prey types indicated no significant effect (overall: $r^2 = 0.014$; $F_{3,145} = 0.711$, $P = 0.549$; temperature: $r^2 = 0.013$; $F_{1,147} = 1.981$, $P = 0.161$; relative humidity: $r^2 = 0.041$; $F_{1,147} = 0.552$, $P = 0.461$; precipitation: $r^2 = 0.001$, $F_{1,147} = 0.015$, $P = 0.944$).

DISCUSSION

The sexes differed in snout-vent length, body mass, head size, tail length, and some ratios in the skink, *E. multifasciata*. Adult males had larger heads, BM, and TL than females of the same body length. These results are consistent with some data that have been reported in skinks and in many other lizard species worldwide (Clemann et al. 2004; Schwarzkopf 2005; Huang 2006; Ji et al. 2006; Gifford and Powell 2007). The mean SVL of adult males was significantly larger than adult females. The concept of sexual size dimorphism (SSD) crosses multiple bounds in biology including behavior, ecological requirements, life-history theory, and the evolution of essential morphological characteristics (Andersson 1994; Fairbairn et al. 2007; Bakkegard and Rhea 2012). The pattern of SSD in the viviparous *E. multifasciata* of this study is similar to that reported for this species in China (Ji et al. 2006), but opposite to that reported for the two viviparous lizards, *Sphenomorphus indicus* (Ji and Du 2000) and *Phrynocephalus vlangalii* (Zhang et al. 2005), in which females are the larger sex.

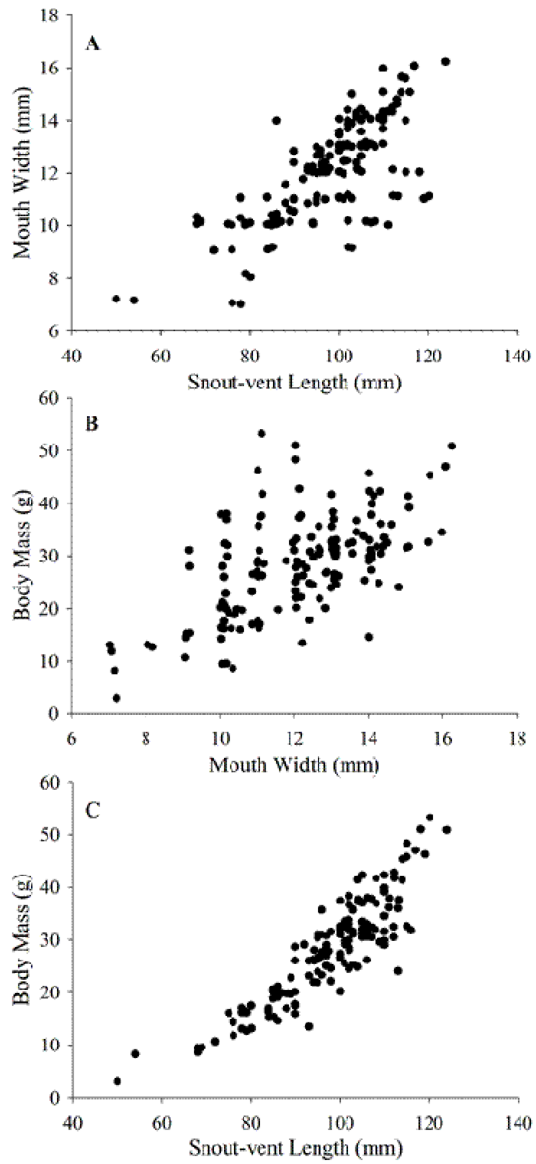

FIGURE 5. Dispersion diagrams from Pearson's correlations between (A) snout-vent length and mouth width ($r = 0.719$; $P < 0.001$), (B) mouth width and body mass ($r = 0.602$; $P < 0.001$), and (C) snout-vent length (SVL, mm) and body mass ($r = 0.897$; $P < 0.001$), of the Common Sun Skink, *Eutropis multifasciata* in the Central Highlands of Vietnam.

Sexual size dimorphism in head size has been found in many terrestrial lizard species around the world (e.g., Brana 1996; Schwarzkopf 2005; Ji et al. 2006; Gifford and Powell 2007; Reilly et al. 2007), perhaps because of an advantage of large head size in fights and intra-sexual competition for breeding and mating opportunities (Anderson and Vitt 1990; Clutton-Brock 2007) and access to resources necessary for successful reproduction, including parental care, breeding sites, and social rank (Clutton-Brock et al. 2006; LeBas 2006; Clutton-Brock 2007). There are fundamental differences in the operation of sexual selection in both sexes, which has played an important role in the evolution of secondary sexual characteristics of males and females (Clutton-Brock et al. 2006; Clutton-Brock 2007). As a result, the relative strength of intra-sexual competition and the development of characteristics that increase competitive success in males can be more strongly influenced by differences in distribution of resources than by variation in mating systems. In fact, *E. multifasciata* is a territorial and aggressive species, and fights may result in serious injury or death (Truong 2005, 2013; Phung 2013). Thus, male head size may be important in male-male competition and could be subject to sexual selection. Interestingly, similar levels of aggression have been found in other species of the genus *Eutropis* (Truong 2005; Le 2008; Phung 2013).

Previous studies indicate that for most reptile species living in tropical regions, fewer animals are captured during the wet season compared to the dry season (Reilly et al. 2007; McConnachie et al. 2009; Vitt and Caldwell 2009). In this study, we collected relatively equal numbers of lizards in both dry and wet seasons with a relatively equal proportion between the sexes. On average, prey size and volume of prey items consumed by males were larger than females. This species reproduces in the dry season (Lin et al. 2008; Phung 2013; Truong 2013). Previous studies indicate that pregnancy impaired feeding performances and locomotion in adult females, but such impairments were not persistent after parturition (Lin et al. 2008). In many lizard species, there is a positive correlation between body size (mouth width and snout-vent length) and prey size (Reilly et al. 2007; Truong 2013). Experimental studies on *E. multifasciata* and other lizards suggest that the size of the meal in *ad libitum* conditions is related to mouth width and the stomach capacity of lizards, and that the urge to eat is largely conditioned by daily and annual rhythms (Le 2008; Truong 2013).

Previous studies show that lizard species living in tropical and moderate regions mainly eat insects and some other invertebrates (Truong 2005; Reilly et al. 2007; Le 2008). We found that grasshoppers, termites, spiders, ants, and insect larvae were the most important prey categories for the populations that we studied. Beside invertebrate prey, *E. multifasciata* consumed vertebrates such as dicroglossid frogs, skinks, and geckos. We considered plant materials as food items of *E. multifasciata* because this skink has consumed a large number of plant types such as rice, papaya, banana, and raspberry seeds under artificial feeding conditions (Phung 2013). Another study on the diet of *E. multifasciata* in Bogor West Java, Indonesia, indicated that this species consumed a large amount of plant material (approximately 29.4% in the diet of this species; Puspitaningrum, R. 2009. Food analysis at interior cavity of lizard (*Eutropis multifasciata*) in Bogor West Java. Available at http://repository.ipb.ac.id/handle/123456789/17011. [Accessed 25 February 2014]). This evidence reveals that *E. multifasciata* are an omnivorous species. In addition, plant material was also found in stomachs of other skinks belonging to the genus *Eutropis*, such as the Bronze Grass Skink, *Eutropis macularia*, and the Long-tailed Sun Skink, *Eutropis longicaudata* (Truong 2005, 2013; Le 2008; Phung 2013).

The predominance of grasshoppers, termites, spiders, ants, and insect larvae of *E. multifasciata* could be a response to natural fluctuations in prey populations. Previous studies on the diet of reptiles indicated that variation among diets of populations may be due to the difference in sizes of lizards and prey availability in the habitat (Dubas and Bull 1991; Truong 2005; Reilly et al. 2007; Le 2008). In our study area, the abundance of spiders and grasshoppers in habitats were higher in Krong Na and Ea Huar than the others; whereas abundance of termites were higher in Ea Nuol than remaining localities (unpubl. data). In fact, *E. multifasciata* in Ea Huar and Krong Na consumed a large number of spiders and grasshoppers compared to the others; while a large number of termites were consumed by skinks in Ea Nuol and Cuor Knia, and there was a significant difference among the localities.

Prey categories such as grasshoppers, termites, and spiders are the most conspicuous element of the leaf-litter arthropod fauna in open regions and secondary tropical forests in this study area, being more diverse and abundant in Ea Nuol, Ea Huar, and Krong Na localities (Truong 2013). Their great abundance and diversity in these three localities may favor their consumption by *E. multifasciata*. Grasshoppers, termites, spiders, and insect larvae may be energetically rewarding prey because they are less sclerotized than ants, pill bugs, and isopods. In general, orthopterans, termites, and insect larvae may contain higher contents of protein (64.38~70.75%) and fat (18.55~22.8%) than hymenopteras (protein: 13.9%, fat: 3.5%), coleopterans (protein: 13.4~19.8%, fat: 1.4~8.3%), and isopods (protein: 6.7%; e.g., Redford and Dorea 1984; Berenbaum 1996; Rumpold and Schlüter 2013). This evidence may partially explain the dietary discrepancy on these groups of prey between the sexes and why adult females consumed a large number of orthopterans and termites, but further studies are necessary.

Eutropis multifasciata showed sexual size dimorphism between adult males and females. Adult males were larger in SVL, TL, BM, and head size than in adult females. In both seasons, we observed the foraging behavior of this species in the field, the foraging mode of skinks appear to fit the widely foraging model. They tend to consume unpredictably distributed and clumped prey (e.g., termites and grasshoppers). This foraging mode is similar to some other lizard species, such as *Aspidocelis tigris*, *Dipsosaurus dorsalis*, *Eulamprus heatwolei*, *Eumeces fasciatus*, *Gallotia galloti*, *Podarcis lilfordi*, *Psammodromus algirus*, and *Varanus exanthematicus* (Reilly et al. 2007). All five populations of *E. multifasciata* demonstrate the consumption of prey items such as spiders, beetles, aphids, ants, isopods, termites, earthworms, grasshoppers, and insect larvae. *Eutropis multifasciata* are omnivorous and they have cannibalistic behavior. We documented the first occurrence of some unusual prey categories such as scincid lizards, geckos, and small frogs in the diet of this species.

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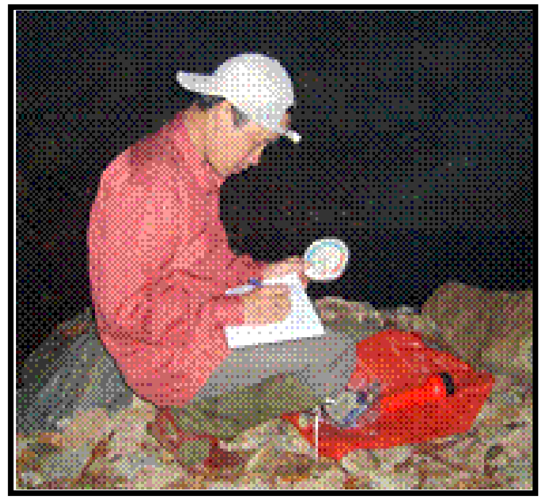

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