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DIET OF THE BRONZE SKINK *Eutropis macularius* (REPTILIA: SQUAMATA: SCINCIDAE) FROM THUA THIEN HUE PROVINCE, CENTRAL VIETNAM

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In this study, we examined the diet of 149 males and 147 females of *Eutropis macularius* from Thua Thien Hue Province, central Vietnam using a nonlethal stomach-flushing technique. The prey items of *E. macularius* composed of Araneae, Insecta (Blattodea, Coleoptera, Hymenoptera, Isoptera, Odonata, and Orthoptera), Mollusca (Philomycidae), and plant materials. The most important prey items were insect larvae, hymenopterans (including ants), grasshoppers, and termites, for both sexes in three populations. Plant materials were also found in the stomach of *E. macularius* with an index of relative importance of 7.19%, suggesting that *E. macularius* is an omnivorous species. However, the dominant prey categories of *E. macularius* were insects, including insect larvae, hymenopterans, grasshoppers, and termites, with many small, sedentary, clumped prey items. Simpson's heterogeneity index of skinks from three populations from Bach Ma National Park as well as from Aluoi and Huong Tra districts were 10.07, 7.85, 3.94, respectively. *Eutropis macularius* showed significant positive correlations between mouth width (MW) and prey width ($P = 0.001$) and between MW and prey volume ($P < 0.0001$). There are significant positive correlations between snout-vent length (SVL) and prey sizes consumed: between SVL and prey length, $P < 0.0001$; SVL and prey width, $P < 0.0001$; and between SVL and prey volume, $P < 0.0001$. These results indicated that SVL and MW are the limiting factors on the size of prey consumed in this skink.

Keywords: diet; *Eutropis macularius*; feeding; prey; skinks.

INTRODUCTION

The Bronze Skink, *Eutropis macularius*, is a common terrestrial skink species in central Vietnam (Nguyen et al., 2009; Uetz and Hošek, 2019). The pantropical scincid lizard genus Mabuya was recently split into four different genera (Mausfeld et al., 2002; Mausfeld and Schmitz, 2003; Nguyen et al., 2009) and the South American species have retained in the genus *Mabuya* Fitzinger, 1826. The genus *Eutropis* Fitzinger, 1843 was assigned for the species from Asia, *Euprepis* Wagler, 1830 contained the species from Africa, and the genus *Chioninia* Gray, 1845 was endemic to the Cape Verdian Islands (Mausfeld et al., 2000, 2002; Mausfeld and Schmitz, 2003). Currently, five species belonging to the genus *Eutropis* have been recognized in Vietnam (Nguyen et al., 2009; Uetz and Hošek, 2019) with different reproductive modes: *E. longicaudatus* and *E. macularius* are oviparous, *E. multifasciatus* is viviparous, however, data about the reproduction of *E. chapaensis* and *E. darevskii* are unknown (Nguyen et al., 2009; Hoang et al., 2012).

In terms of feeding ecology, several studies on the diet of *E. multifasciatus* and *E. longicaudatus* were documented by Ngo et al. (2014, 2015) and Huang (2006), however, little is known about the dietary ecology of *E. macularius* (Nguyen et al., 2009). In this study, we investigate the dietary composition of *E. macularius* across its range in Thua Thien Hue Province, central Vietnam. We also compare the prey composition of skinks between males and females to examine sex-dependent dietary variation and test the hypothesis that the size of con-

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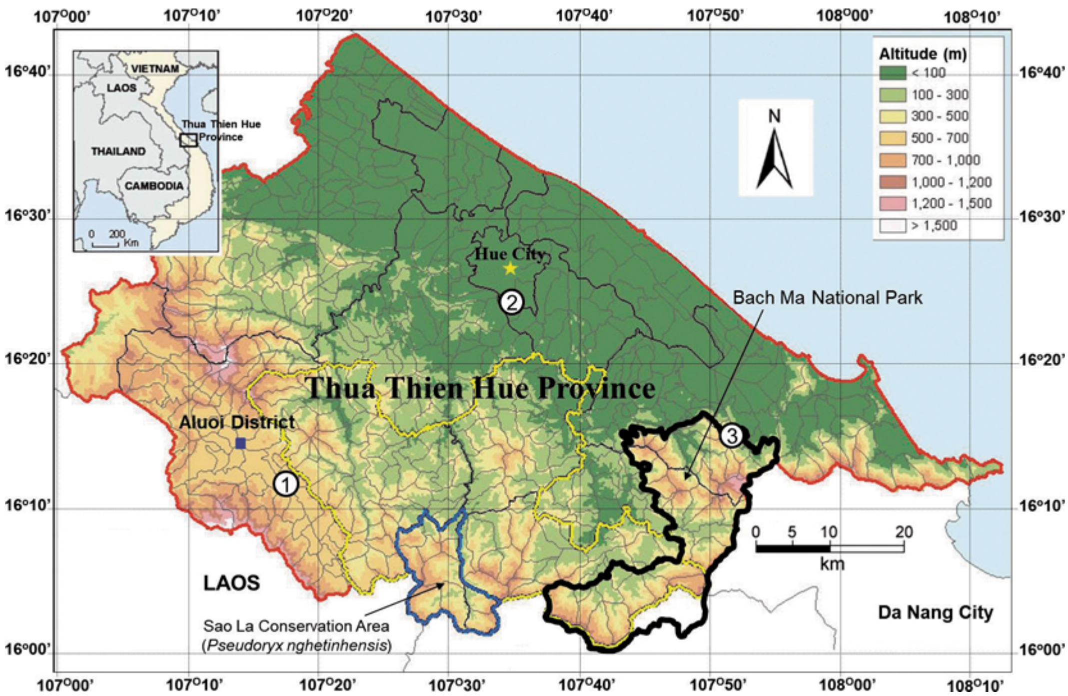

Fig. 1. Map of Thua Thien Hue showing the sampling sites of *Eutropis macularius*: (1) A Luoi District; (2) Huong Tra District; and (3) Bach Ma National Park.

sumed prey is correlated with body size (SVL). Because the mouth size of lizards is positively correlated with prey size found in their stomachs (Reilly et al., 2007), we tested the differences in mouth width of *E. macularius* skinks correlated with different sizes of prey types consumed. In addition, this study provides baseline information for understanding resource use patterns of *E. macularius* and examined the quality and quantity of prey consumption by this omnivorous lizard in different habitat types.

MATERIAL AND METHODS

Field surveys were conducted in the dry season (from February to July) in 2017 at Thua Thien Hue Province, central Vietnam. Stomach contents of *E. macularius* were collected at the three localities in Thua Thien Hue Province: (1) The mountain area in A Luoi District (16°12′04″ N 107°17′21″ E); (2) the plains area in Huong Tra District (16°24′02″ N 107°35′22″ E); and (3) the midland belonging to Bach Ma National Park (16°15′05″ N 107°52′24″ E) (Fig. 1). This region is characterized by the tropical climate, with an annual average precipitation of 4980 ± 377 mm and an annual temperature averaging 24.4 ± 0.41°C. The dry season extends from January to July, with a monthly rainfall of approximately 120 mm. Most rainfall is concentrated in the main rainy season, from September to December, the monthly mean of 738 ± 96 mm (Nguyen et al., 2013).

Surveys were conducted between 09:00 and 16:00, at least four times per month from February to July at three sites. We visually searched for skinks and collected specimens by hand, some specimens were collected by using a noosing pole or pitfall traps. The specimen was kept individually in a cloth bag. Relevant information was recorded at the site, for example, habitat type, time, ambient temperature, and relative humidity. Coordinates with datum WGS 84 was recorded by using a GPS unit (Garmin 400t, Garmin Corporation, Taipei, Taiwan) for each voucher specimen at the site.

To measure body mass (BM), we used an electronic balance (Prokits, Taipei, Taiwan) and recorded measurements to the nearest 0.01 g. We used a digital caliper (Mitutoyo Corporation, Kawasaki, Japan) to measure the snout-vent length (SVL), tail length (TaL: only measured for specimens with intact tails), head length (HL), head width (HW), and mouth width (MW) to the nearest 0.1 mm.

We used the stomach-flushing method (Legler and Sullivan, 1979; Leclerc and Courtois, 1993; Sole et al., 2005) to obtain stomach contents without sacrificing skinks. Each skink was stomach-flushed only once following the guidelines approved by the American Society of Ichthyologists and Herpetologists for animal care (Beaupre et al., 2004). After stomach-flushing, we used visible implant elastomer tags (Nauwelaerts et al., 2000; Hoffmann et al., 2008) to mark each skink, then animal was released at the place of capture. Prey items were preserved in 95% ethanol for further analyses.

We sorted and identified prey items in each stomach to the order level, but in some case, identification could be made to the family. We referred to and followed keys and descriptions in Brusca et al. (2016) and Johnson and Triplehorn (2005). We measured the length and width of each prey item using a digital caliper to the nearest 0.1 mm. Sand and stones were excluded from the prey items in our analyses.

We determined the percentage of frequency of occurrence (*F*%) and the percent count (*N*%) for each food item. For the volume of each food item (*V*), we used the formula for a prolate spheroid, where

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

(see Magnusson et al., 2003; Biavati et al., 2004; Ngo et al., 2014), and calculated volumetric percentage (V%) for each food category (Works and Olson, 2018). We used the index of relative importance (IRI) to determine the overall importance of each prey taxon in the diet of *E. macularius* (Biavati et al., 2004; Caldart et al., 2012), where IRI = (*F*% + *N*% + *V*%)/3. We adopted the reciprocal Simpson's heterogeneity index (dietary breadth), $1/D$, to calculate dietary heterogeneity, where

$$D = \sum_i \frac{n_i(n_i - 1)}{N(N-1)}$$

n_i is the number of food items in the *i*th food category and N is the total number of food categories (Krebs, 1999; Magurran, 2004).

To determine if the sexes were size dimorphic, we used one-way analysis of variance (ANOVA) to compare SVL, TaL, HL, HW, MW, and BM between males and females. If the sexes of skinks were dimorphic in body size, we used analysis of covariance (ANCOVA) to test morphological measurements of HL, HW, BM, and TaL with SVL as a covariate. We used χ^2 tests to examine the number of stomachs collected between sexes and among localities. We used one-way ANOVA to determine if prey length, prey width, prey volume, or the number of prey items significantly differed between males and females. We tested correlations between prey size (length, width, and volume) and body size of skinks to determine if prey size was correlated with skink size. All statistical analyses were performed in STATISTICA ver. 10 software (StatSoft Inc., Tulsa, Oklahoma, USA) for Windows 10 with an α of 0.05 to indicate significance. All means are followed by ±SD (standard deviation).

RESULTS

We collected 296 stomach contents (149 males and 147 females) of *E. macularius* from three localities in Thua Thien Hue Province, central Vietnam. Juvenile and gravid skinks were not collected for stomach content analysis. Some diagnostic characters for *E. macularius* such as small body and head sizes, lower eyelid not scaly or transparent, dorsum bronze, generally with dark spots in longitudinal rows, flank dark brown with white dots, dorsal scales have 5 keels, 7 – 8 infralabial scales, 6 – 7 supralabial scales, 5 – 9 lamellae under 1st toe, and 14 – 19 lamellae under 4th toe.

The numbers of collected stomachs did not differ significantly between sexes ($\chi^2 = 1.24$, $df = 5$, $P = 0.941$) or among localities ($\chi^2 = 3.256$, $df = 10$, $P = 0.975$). The largest male was 66.83 mm SVL (mean = 49.81 ± 9.04 mm; $n = 149$) and the largest female was 65.61 mm SVL (mean = 49.04 ± 9.16 mm; $n = 147$). The average SVL was not significantly different between sexes ($F_{1,295} = 0.53$, $P = 0.467$). The average HW also did not differ significantly between males and females ($F_{1,295} =$ $= 3.38$; $P = 0.067$). However, the average measurements of TaL, HL, MW, and BM were significantly different by sex (Table 1). When SVL was taken into account as a

TABLE 1. Summary of Morphological Characters of the Bronze Skink, *Eutropis macularius*, from Thua Thien Hue Province, Central Vietnam

Trait	Males			Females			*F*	*P*
	n	Mean ± SD	Range	*n*	Mean ± SD	Range		
SVL, mm	149	49.81 ± 9.04	28.71 – 66.83	147	49.04 ± 9.16	28.32 – 65.61	0.53	0.467
TaL, mm	137	68.85 ± 17.58	30.42 – 108.53	119	61.57 ± 14.18	30.12 – 100.61	13.03	<0.0001
HL, mm	149	11.39 ± 2.11	6.64 – 19.41	147	10.61 ± 2.04	5.13 – 18.94	10.78	0.001
HW, mm	149	8.25 ± 1.47	5.13 – 11.52	147	7.95 ± 1.32	4.23 – 11.23	3.38	0.067
MW, mm	149	5.37 ± 1.23	3.14 – 8.34	147	5.05 ± 1.36	2.83 – 8.12	4.42	0.036
BM, g	137	4.48±1.32	2.81 – 7.69	119	3.79 ± 1.43	2.14 – 6.79	15.98	<0.0001

Note. SVL, snout-vent length; TaL, tail length; HL, head length; HW, head width; MW, mouth width.

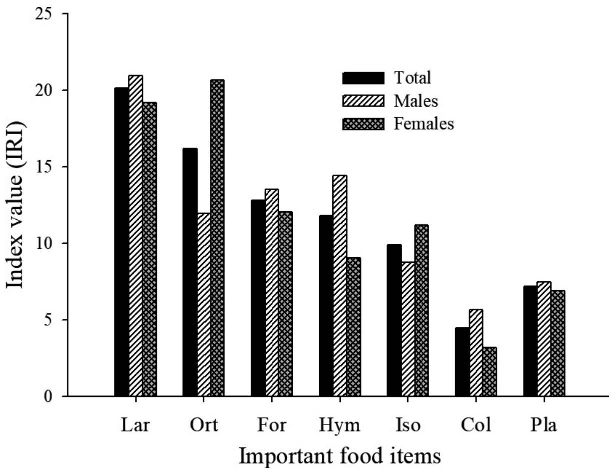

Fig. 2. The index of relative importance of food items in the Bronze Skink, *Eutropis macularius*, based on total stomach contents in males and females: Lar, insect larvae; Ort, Orthoptera; For, Formicidae; Hym, Hymenoptera; Iso, Isoptera; Col, Coleoptera; Pla, plant materials.

covariate, the proportions at which head length and mouth width increased with SVL were greater in males than in females (HL: $F_{2,293} = 305.26$, $P < 0.0001$; HW: $F_{2,293} = 129.01$, $P < 0.0001$). Male tail length and body mass were also significantly greater than that of females with SVL as a covariate (TaL: $F_{2,253} = 90.39$, $P < 0.0001$; BM: $F_{2,253} = 714.32$, $P < 0.0001$).

A total of 20 stomachs (11 males and 9 females) of 296 stomachs (approximately 6.8% of the total number of collected specimens) of *E. macularius* were empty. We identified 615 prey items in the stomachs of *E. macularius*. The number of prey items consumed by males (322 items) and females (293 items) was not significantly different ($F_{1,275} = 1.04$, $P = 0.309$). Prey items of *E. macularius* represented 12 animal categories, 58 plant items, and 11 unidentified items (mainly insects). A total of 12 prey categories were found and the stomachs of *E. macularius*, included mainly invertebrates (Table 2). The mean number of prey items per stomach was 2.23 ± 1.71 (ranging from 1 to 8; $n = 276$). Mean prey length was 7.81 ± 4.91 mm (ranging from 2.32 to 54.13 mm, $n =$ = 615), mean prey width was 3.24 ± 1.44 mm (ranging from 1.13 to 8.52 mm, $n = 615$), and average prey volume was 65.85 ± 90.61 mm^3 (ranging from 1.73 to 665.53 mm^3, $n = 615$).

The total dietary breadth of *E. macularius* from Thua Thien Hue Province, central Vietnam was 8.72. The broadest dietary breadth was from Bach Ma National Park (10.07), whereas the narrowest dietary breadth was found at the Huong Tra District (3.94). The intermediate dietary breadth was found at the A Luoi District (7.85) (Table 3). The dietary breadth of skinks was similar to each other between females (8.83) and males (8.51). All three populations of *E. macularius* consumed insect larvae, grasshoppers, ants and other hymenopterans, termites, beetles, and plant materials, with a total IRI value of approximately 83.4% (Table 3).

The most abundant prey items (with IRI values >5%) of *E. macularius* skinks were insect larvae, grasshoppers, ants, other hymenopterans, and termites, accounting for 69.27% of the number of prey items, 67.31% of occurrence frequency, and 76.04% of the total volume, with an index of relative importance of 70.88% (Table 2; Fig. 2). These data suggest that insect larvae, grasshoppers, ants and other hymenopterans, and termites could present the

TABLE 2. Diet Composition of *Eutropis macularius* ($n = 296$ stomachs) in Percentage Frequency of Occurrence (F), Number of Items (N), Volume (V), and the Index of Relative Importance (IRI) of Each Prey Category from Thua Thien Hue Province, Central Vietnam

Prey category	N	N%	F	F%	V, mm^3	V%	IRI
Araneae	11	1.79	11	1.94	2, 052.18	5.07	2.93
Blattodea	19	3.09	18	3.18	1, 309.38	3.23	3.17
Coleoptera	29	4.72	29	5.12	1, 450.24	3.58	4.47
Hemiptera	6	0.98	6	1.06	342.48	0.85	0.96
Hymenoptera (Formicidae)	100	16.26	78	13.78	3, 392.41	8.38	12.81
Hymenoptera (others)	64	10.41	61	10.78	5, 772.44	14.25	11.81
Insect larvae	112	18.21	97	17.14	10, 142.61	25.05	20.13
Isoptera	72	11.71	68	12.01	2, 443.64	6.03	9.92
Odonata	18	2.93	18	3.18	2, 204.19	5.44	3.85
Orthoptera	78	12.68	77	13.60	9, 042.76	22.33	16.21
Lumbriculida	10	1.63	10	1.77	800.51	1.98	1.79
Gastropoda (Philomycidae)	27	4.39	27	4.77	325.74	0.80	3.32
Plant materials	58	9.43	55	9.72	977.95	2.41	7.19
Unidentified items	11	1.79	11	1.94	238.44	0.59	1.44
Total	615	100	566	100	40, 494.98	100	100

highest nutritional values for males and females in three populations (Table 3). Formicidae, other hymenopterans, Isoptera, Orthoptera, insect larvae, and plant materials were the most important food items of *E. macularius*. Other prey types (Araneae, Hemiptera, Lumbriculida, and unidentified items) were 6.18% of the total number of prey items with an index of relative importance of 7.12% (Table 2). Also, we found 58 plant items in 55 stomachs of skinks, giving an index of relative importance of 7.19% (Table 2). Some sand and stones were also found in the stomachs, but they have likely swallowed accidentally with prey items.

Average prey length (7.83 ± 5.11 mm), prey width (3.27 ± 1.38 mm), and prey volume (68.75 ± 102.01 mm^3) in males were not significantly larger than in females (length: 7.81 ± 4.68 mm; $F_{1,275} = 0.44$, $P =$ = 0.507; width 3.22 ± 1.51 mm: $F_{1,275} = 0.19$, $P = 0.663$; volume: 63.21 ± 78.71 mm^3; $F_{1,275} = 0.16$, $P = 0.693$). The total volume of food items was 20, 350.23 mm^3 and 20, 144.75 mm^3 in males and females, respectively. In both sexes, the most abundant food categories by rank, defined as an importance value 5%, included insect larvae, Formicidae and other hymenopterans, Orthoptera, Isoptera, Coleoptera (only male), and plant materials (Table 4; Fig. 2). *E. macularius* skinks showed significant positive correlations between mouth width (MW) and prey width ($r = 0.136$, $P = 0.001$) and between MW and prey volume ($r = 0.192$, $P < 0.0001$); whereas prey length was not significantly correlated with MW ($r = 0.042$, $P = 0.301$). However, *E. macularius* skinks showed significant positive correlations between snout-vent length (SVL) and prey sizes consumed (between SVL and prey length: $r = 0.202$, $P < 0.0001$; between SVL and prey width: $r = 0.238$, $P < 0.0001$; between SVL and prey volume: 0.192, $P < 0.0001$). In the feeding ecology of *E. macularius*, both SVL and MW were considered as predictors of diet because there were strong positive correlations between morphological measurements (between SVL and MW: $r = 0.623$, $P < 0.0001$, Fig. 3A; between SVL and BM: $r = 0.852$, $P < 0.0001$, Fig. 3B).

DISCUSSION

The Bronze Skink *E. macularius* is an omnivorous species with categories of animals and of 58 plant items (IRI = 7.2%) were found in their stomachs. The plant items were also found in stomachs of other skinks belonging to the genus *Eutropis*, such as the Common Sun Skink, *E. multifasciatus* and the Long-tailed Sun Skink, *E. longicaudatus* (Ngo et al., 2014, 2015; Phung, 2013). Scincid lizards are generally active foraging predators and their dietary composition is largely constrained by resource availability, foraging model, body size, and diversity of appropriately sized prey (Honda et al., 1999; Miles et al., 2007; Ngo et al., 2014, 2015). Foraging strategies of *E. macularius* in this study fit an active foraging predator model in the field and these skinks eat mainly small, sedentary, and clumped prey. It is not surprising that tropical-subtropical lizards have often been reported

TABLE 3. Comparison of the Occurrence of Prey Items, Unidentified Items, and Plant Materials in the Bronze Skink, *Eutropis macularius* from Thua Thien Hue Province, Central Vietnam, and the Dietary Breadth from Three Locations in Thua Thien Hue Province

Prey category	Locality			Total n = 296
	Luoi (n = 107)	Huong Tra (n = 91)	Bach Ma National Park (n = 98)	
Araneae	—	—	4.72	1.79
Blattodea	7.28	—	—	3.09
Coleoptera	5.36	4.13	4.29	4.72
Hymenoptera (Formicidae)	8.05	45.46	10.3	16.26
Hymenoptera (others)	13.79	6.61	8.58	10.41
Hemiptera	2.3	—	—	0.98
Insect larvae	22.61	13.22	15.88	18.21
Isoptera	12.26	9.09	12.45	11.71
Odonata	2.68	—	4.72	2.93
Orthoptera	13.41	12.4	12.02	12.68
Lumbriculida	1.53	—	2.58	1.63
Gastropoda (Philomycidae)	—	—	11.59	4.39
Plant materials	10.73	7.44	9.01	9.43
Unidentified items	—	1.65	3.86	1.79
Total categories	11	8	12	14
Dietary breadth	7.85	3.94	10.07	8.72

feeding on insects and spiders (Huang, 2006; Reilly et al., 2007; Ngo et al., 2014, 2015).

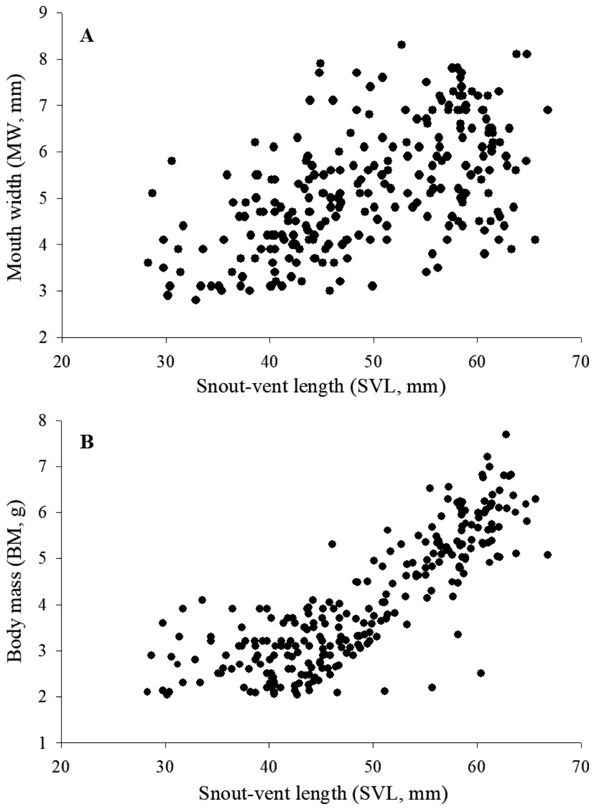

Fig. 3. Dispersion diagrams from Pearson's correlations between (A) snout-vent length and mouth width and between (B) snout-vent length and body mass of the Bronze Skink, *Eutropis macularius* in central Vietnam.

Most agamid, scincid, lacertid, tropidurid, and crotaphytid lizards eat a diversity of invertebrates along with some plant materials (Cooper and Vitt, 2002; Ngo et al., 2015). Some species eat primarily on leafy vegetation (Durtsche, 2000; Espinoza et al., 2004), some are specialists on specific invertebrates (Pianka and Pianka, 1970; Pianka and Parker, 1975; Simbotwe and Garber, 1979; Vitt et al., 1997; Ribeiro et al., 2015), while still others feed mainly on other vertebrates (Beck and Lowe, 1991; Pianka, 1994). Although the diet of *E. macularius* is relatively diverse (Table 2), this skink species trends to specialize on a few particular prey categories such as insect larvae, ants and other hymenopterans, grasshoppers, and termites, with many small prey items. The strong selection of prey by *E. macularius* skinks might suggest that this kind of prey presents the necessary requirements in proteins for male and female skinks from three populations. Energy obtained from these prey categories may significantly impact the rates of growth and reproduction from three populations, as is known for other lizards (Feria-Ortiz et al., 2001; Reilly et al., 2007; Leyte-Manrique and Ramírez-Bautista, 2010).

The Bronze Skink (*E. macularius*) used 14 food categories (including plant items and unidentified items, whereas the Common Sun Skink (*E. multifasciatus*) from the plains of Thua Thien-Hue Province used 20 food categories and the Long-tailed Sun Skink (*E. longicaudatus*) from the mountain area in the A Luoi District used 16 different food categories (Ngo et al., 2015; Dang, 2017). The most abundant prey categories (i.e., IRI > 5.8) of *E. macularius* were Hymenoptera, Isoptera, Orthoptera, insect larvae, and plant materials. However, the important prey categories of *E. longicaudatus* and *E. multifas-*

TABLE 4. Dietary Composition (%) of *Eutropis macularius* from Thua Thien Hue Province, Central Vietnam, with Regard to Frequency of Occurrence (*F*), Number of Items (*N*), Volume (*V*), and the Index of Relative Importance (IRI) of Each Prey Category (*n* = 296 stomachs)

Prey category	Males (*n* = 149 stomachs)				Females (*n* = 147 stomachs)			
	N%	*F*%	*V*, mm^3	IRI	*N*%	*F*%	*V*, mm^3	IRI
Araneae	2.15	2.33	5.29	3.26	1.37	1.51	4.84	2.57
Blattodea	3.42	3.33	4.24	3.66	2.73	3.01	2.21	2.65
Coleoptera	5.91	6.33	4.77	5.67	3.41	3.76	2.38	3.18
Hymenoptera (Formicidae)	16.77	14.67	9.14	13.53	15.71	12.78	7.61	12.03
Hymenoptera (others)	12.42	13.01	17.88	14.44	8.19	8.27	10.57	9.01
Hemiptera	0.62	0.67	0.74	0.68	1.37	1.52	0.95	1.28
Insect larvae	19.88	19.33	23.66	20.96	16.38	14.66	26.45	19.16
Isoptera	10.25	10.33	5.67	8.75	13.31	13.91	6.42	11.21
Odonata	3.11	3.33	5.69	4.04	2.73	3.01	5.21	3.65
Orthoptera	9.94	10.67	15.29	11.97	15.70	16.92	29.41	20.68
Lumbriculida	1.24	1.33	3.01	1.86	2.05	2.23	0.95	1.74
Gastropoda (Philomycidae)	3.11	3.33	0.66	2.37	5.81	6.39	0.95	4.38
Plant materials	9.63	9.67	3.12	7.47	9.22	9.77	1.72	6.90
Unidentified items	1.55	1.67	0.84	1.35	2.02	2.26	0.33	1.54

ciatus were the same (Araneae, Orthoptera, Gastropoda, insect larvae, and plant materials).

Consumed prey sizes (length and width) were smaller in *E. macularius* skinks than those in both *E. longicaudatus* and *E. multifasciatus* (Phung, 2013; Ngo et al., 2014, 2015). On average, prey size and volume consumed by males and females were not significantly different. In many tropical lizards, there are positive correlations between prey size (length, width, and volume) and body size (MW: mouth width and SVL: snout-vent length) (Reilly et al., 2007; Truong, 2013). We found significant positive correlations between prey size and body size, which supports the hypothesis that SVL and MW are the limiting factors on the size of prey consumed in tropical scincid lizards. These results are consistent with general findings for other lizards in the natural world (e.g., neotropical lizards belonging to Autarchoglossa, Gekkota, and Iguania; Reilly et al., 2007). Vitt and Pianka (2007) indicated that under ad libitum conditions the sizes of prey ingested are correlated to stomach capacity of a lizard and its urge to feed, which is largely conditioned by daily and annual rhythms such as energy demands. Perhaps due to the limited gape size and the lower body capacity, *E. macularius* skinks have a limited ability to consume large prey that can be eaten. In general, larger tropical lizards tend to consume prey from larger size categories (Vitt and Pianka, 2007). However, the reasons underlying this relationship are very complex.

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