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Interpopulation dietary comparisons in the common sun skink, *Eutropis multifasciata* (Squamata: Scincidae)

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Abstract. *Eutropis multifasciata*, the common sun skink, is a live-bearing member of the family Scincidae and exhibits a tropical distribution in Southeast Asia. While commonly encountered, its abundance at the edge of forests and near human settlements raises questions concerning its natural history, particularly diet. This study aims to understand the trophic ecology of the species in two geographically different regions, the first in the north (Kledang Saiong Eco Park, Ipoh, Peninsular Malaysia) and the second in the south (campus of Universiti Malaysia Sarawak in Kota Samarahan and the Sebungan Oil Palm Estate near Bintulu, Sarawak, both in East Malaysia). Stomach contents were collected over seven months in the north (n = 19) and south (n = 25) using a non-lethal (stomach-flushing) technique. Prey from the following eight taxa were identified: Blattodea, Araneae, Diptera, Dermaptera, Coleoptera, Hymenoptera, Odonata, and Orthoptera. Termites and cockroaches were the most preferred prey. In situ feeding observations identified previously undocumented prey—a representative of the insect order Neuroptera. This study demonstrates that *E. multifasciata* displays both active and ambush foraging strategies, presumably influenced by specific prey encountered within the habitat. Prey between regions and seasons appear to show significant differences. Environmental changes such as temperature, precipitation, and seasonal variances between regions may influence prey type distribution and impact dietary patterns.

Key words. trophic ecology, diet, prey taxa, foraging strategies

INTRODUCTION

Understanding dietary patterns falls under the category of trophic ecology, which is analogous to the field of foraging ecology and includes the assessment of dietary preferences. Understanding feeding methods such as selective or opportunistic behaviour and niche dynamics requires knowledge of trophic ecology (Jaksic, 2001). The feeding ecology of lizards, akin to that of any predatory animal, is influenced by factors such as the presence of prey in the surrounding habitat and the selectivity of their dietary choices (Vrcibradic & Rocha, 1995; Rocha & Anjos, 2007). The dietary pattern of lizards plays a crucial and ever-changing role in their ecological interactions within their respective environments and in their interactions with coexisting species (Duffield & Bull, 1998).

Intensity of biotic interactions tends to vary with latitude. Latitudinal gradients of biodiversity are biogeographic patterns that define how components of taxonomic, phylogenetic, functional, genetic, or phenetic dimensions change with a latitudinal position on the surface of the earth (Wiling & Presley, 2013). When systematically observed across temporal and geographic dimensions, these metrics can provide valuable elucidations associated with dietary preferences alongside its possible geographical range expansion or compression (Reese et al., 2023). Seasonality and latitude are known to influence a species' dietary quality and intake quantity and have been well-documented in the scientific literature (Karachle & Stergiou, 2008; Storms et al., 2008; Ely & Ravelling, 2011). Temporal variation in diet is a consequence of the temporal fluctuations in prey abundance and composition (Schafer et al., 2002), and energetic requirements of consumers influenced by life history factors such as seasonally dependent reproduction (Thometz et al., 2014).

Eutropis multifasciata is a terrestrial skink, commonly found in forest edges and around human settlements across Southeast Asia. This species is diurnal and its diet is largely composed of arthropods (Das, 2010). Reilly et al. (2007) reported that when different types of prey are abundant in the stomachs of insectivorous lizards, they are positively correlated with relative prey abundance or general availability of prey of the appropriate size and type in the microhabitat. Several researchers have claimed that lizards, in general, exhibit opportunistic feeding behaviour, consuming whatever sustenance is readily accessible within their ecological surroundings (Arnold, 1987; Robinson, 1987; Diaz & Carrascal, 1990; Durtsche, 1995; Wapstra & Swain, 1996).

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Fig. 1. Map of Southeast Asia, showing sampling locations in the northern and southern regions. Map data ©2022 Google.

The present study examines the dietary ecology of a skink along a line transect, as described by Mancini et al. (2015) and Araújo et al. (2016), along with examination of stomach contents via stomach-flushing (Jensen & Das, 2008a, 2008b), within a larger study of the ecology of the species. Opportunistic observations of feeding events (see utility in Veerappan & Vasudevan 2012), contribute to the analysis of the dietary habits of the species. This study aims to enhance our understanding of the diet of *E. multifasciata* from two latitudinally discrete regions - one in Perak, Peninsular Malaysia (4°N) and two in Sarawak, East Malaysia (1°N and 3°N) - and sheds light on its ecological role and discovers potential implications for conservation.

MATERIAL AND METHODS

Field studies were conducted at Kledang Saiong Eco Park, Ipoh, Perak (4.6838°N, 101.06848°E), which represented the northern (seasonally dry) site, and at two sites in Sarawak representing the southern (wet year-round), Kota Samarahan, Samarahan Division (1.4657°N, 110.4484°E) and Sebungan, Bintulu Division (3.1687°N, 113.3673°E). Fig. 1 shows a map of the three distinct sampling locations representing the northern and southern regions.

The Kledang Saiong Forest Eco Park, located in the state of Perak, is characterised by its hill dipterocarp forests. The landscape is on mineral soil, and the site itself is an urban park showing signs of disturbance. The second site is Real Living Lab, in the Samarahan campus of Universiti Malaysia Sarawak; the habitat comprises a combination of peat swamp forest, edged with lowland forests and mangrove swamps. The region experiences extensive flooding during periods of heavy precipitation and is under weak tidal influence. The third site at Sebungan, on the other hand, is characterised by an oil palm plantation that was situated on peaty soil, and the original vegetation was comprised of lowland dipterocarp forests. At the Perak site, sampling took place between December 2021 and February 2022, as well as in January 2023. This coincided with the wet spell of the Northeast monsoon, as indicated by MET Malaysia (Malaysian Meteorological Department, 2024). Field data collection at the second site (RLL) took place from June to July 2022, corresponding with a period of dry weather. Similarly, sampling occurred from August to September at the third site (Sebungan Oil Palm Plantation) during a dry spell.

The transect at the Sebungan Oil Palm Estate was 1.2 km long, and glue traps (Max-catch™ glue traps) were used for trapping (Ribeiro-Júnior et al., 2006). Since peatland floods on continuous wet days, glue traps were utilised as an alternate passive method replacing pitfall traps because during high precipitation, pitfall traps would be flooded. A total of four glue traps were positioned on both right and left sides of the trail at intervals of 300 m, and a total of 30 glue traps were used during the study at this site. At the Real Living Lab within the campus of Universiti Malaysia Sarawak, the length of the trail was 300 m, with the placement of two glue traps occurring at regular intervals of 20 m on the sides of the trail and necessitating regular monitoring hourly to mitigate potential risks associated with lizard mortality or stress caused by exposure to sunlight. A total of 30 glue traps were used here. At the Kledang Saiong Forest Eco Park, pitfalls were used for passive data collection (due to soil conditions allowing it) together with glue traps. In order to establish a standardised approach, a total of 30 glue traps were deployed. These traps were strategically positioned on both the right and left sides of the trail, with a consistent interval of 20 meters, along a trail length of 300 meters. Individuals found in pitfall traps were mostly utilised for transmitter attachment, with only those 100 mm in SVL or greater being subjected to flushing procedures. Lizards were caught in glue traps, by hand and in pitfall traps. Skinks ensnared in glue traps were extracted using Johnson's® baby oil. Application of two to three drops onto the traps permitted weakening of the adhesive. Subsequently, skinks were detached from the traps by gently scraping away surplus glue manually. Through this method, the scales of the skinks remained intact. Field methods were approved by the Animal Ethics Committee of UNIMAS. Snout-vent length (SVL) and tail length (TL) were measured with a vernier calliper or ruler, and weight (WT) measured with a Pesola™ or Digital balance balance (compact, 3000 × 0.1g) for captured individuals. Sex was determined primarily by secondary sexual characteristics of the species or by manual eversion of hemipenes (Harlow, 1996).

In this study, a total of 17 individuals were subjected to telemetric attachment using Holohil BD-2T transmitters, weighing 0.9 g and 1.4 g, chosen according to individual body mass. The temperature-sensitive radio transmitters used were below 7% of the animal's body weight. The process of tracking the individuals provided valuable insights into their behaviour, particularly foraging behaviour, which was recorded during the active periods (0900–1200h). The findings from these observations are of significant importance, shedding light on the foraging behaviour of these individuals and contributing to our understanding of their ecological roles. Regurgitated and scat samples from lizards caught in pitfall traps or glue traps were obtained. Modified methods of Griffiths (1986) and Rivas et al. (1996) and the standard stomach-flushing technique (Legler & Sullivan, 1979; Gittins, 1987; Leclerc & Courtois, 1993; Barreto-Lima, 2009) were used to obtain stomach contents. Regurgitated and scat samples were immediately preserved in numbered plastic vials containing 70% ethanol. Prey items were examined using an Olympus™ SZX9 stereomicroscope in the laboratory using magnification range 6.3×–57×. Prey items were sorted and identified to the lowest taxonomic level possible (typically to order, with family-level identifications made when possible). Operational taxonomic units (OTUs) were used to classify dietary items (Sneath & Sokal, 1962). Prey item sizes were estimated based on fragment size (using Hill & Abang, 2010). Mandibles, heads, thorax, wings, and legs of invertebrates were measured to the nearest 0.01 mm with a pair of digital callipers. Total prey volume in stomach/faecal samples was calculated using the formula for ellipsoidal objects (volume = 4/3π (½ × length) × (½ × width)²), incorporating the value of π as 3.14159. Parasitic nematodes were obtained from the stomachs and faeces of some individuals as part of the collection of regurgitated and scat samples but were excluded from these analyses, being non-dietary items.

Fig. 2. Male *Eutropis multifasciata* from pitfall trap at Kledang Saiong Eco Park, Perak, Malaysia, being stomach-flushed. Photo by Thanisha Kumar.

Stomach contents were obtained immediately after capture by stomach-flushing (Fig. 2). The stomach content extraction technique was initially introduced by Legler & Sullivan (1979). This method involves retrieving ingested food components before the culmination of the digestive process. The procedure was done by gently inserting an intravenous catheter directly into the stomach through the pharynx. Two sizes of soft catheter tubes (4 or 5 mm inner diameter) with appropriate syringes (5 or 10 ml) were used, and clean water was pumped at least thrice (depending on the size of the skink) into the stomach slowly to flush out food content without injuring the lizard. As skinks rarely open their mouth naturally, dissecting forceps were used to gently open the lizard's jaws. If there was no stomach content during the initial flush, the catheter was left in place and only the syringe removed to refill the water for a subsequent flush.

Stomach contents of each individual were evaluated based on percentages of abundance (% N), volume (% V), and occurrence (% FO):

$$\%N = \frac{\text{number of categories of prey}}{\text{total number of prey}} \times 100$$

$$\%V = \frac{\text{volume of categories of prey}}{\text{total volume of prey}} \times 100$$

$$\%FO = \frac{\text{number of skinks where food item found}}{\text{total number of prey samples}} \times 100$$

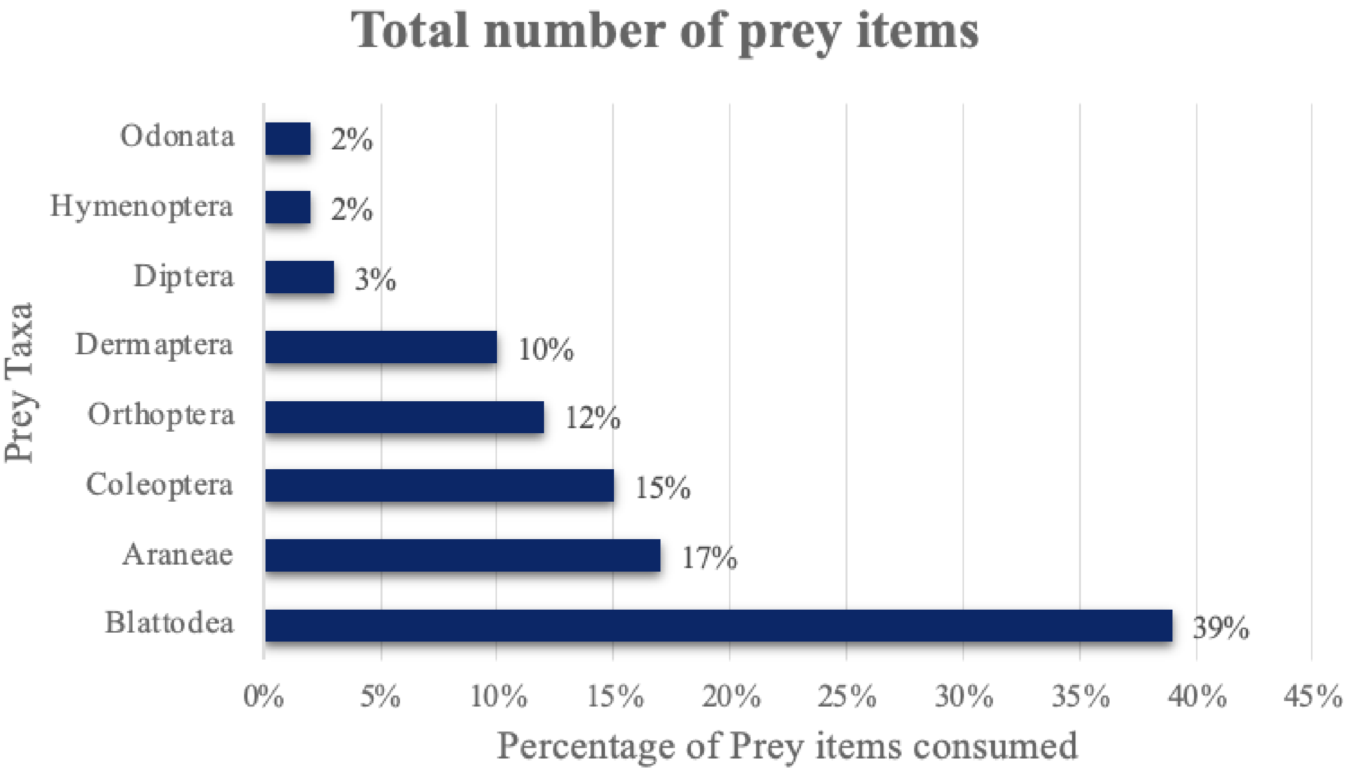

Fig. 3. Total number of prey items consumed by *Eutropis multifasciata* at both the regions.

Following the classification by Bigot & Bodot (1973), prey was further classified as "constant prey" (50%), "common prey" (25% ≥ %FO > 50%), "accidental prey" (10% ≥ %FO > 25%), or "very accidental prey" (10%). Dietary types were classified using an index of relative importance (IRI). Using the following formula, the quotient (IRI) provides an accurate estimation of food item consumption compared to the three components considered separately (frequency, number, or volume), following Biavati et al. (2004):

$$IRI = (\%N + \%V + \%FO)/3$$

The Berger-Parker diversity index was employed to assess variations in the level of dominance among different food types in adult stomach samples over the course of the sampling period. The Index is calculated as the ratio of the number of individuals in the most abundant resource type (Nmax) to the total number of individuals (N).

$$d = Nmax / N$$

The measure utilised in this study was the reciprocal form, as described by Magurran (2004), whereby the Index exhibits an upward trend in response to higher levels of prey variety and a downward trend in dominance. The utilisation of rank correlation coefficients enables the establishment of evidence regarding the variation in prey ranking among the sites, hence showing the importance of particular prey types (Martin et al., 1996). Spearman's rank correlation coefficient was used to compare the sites relative to IRI rankings for prey categories. Regression were used to examine the potential for a relationship between the estimated prey volume and lizard SVL. The variables were first log-transformed to check for linearity and to calculate the coefficient of determination and r^2. A chi-square test was used to compare the estimated prey volume between sexes and different sites. Finally, a Pearson's correlation test was used to determine significant differences between types of prey selected at the two zones.

RESULTS

Dietary composition. Individuals of *E. multifasciata* were sampled over a period of seven months (December 2021 to January 2023) to examine diet preferences. A total of 44 samples, consisting of regurgitated and scat examples, were collected from the northern (N = 19) and southern areas (N = 25). Prey samples were grouped into operational taxonomic units (OTU). From the 44 stomach content samples, 34 (77.3%) were classified into OTUs, the remaining 10 (22.7%) were categorised as 'indeterminate arthropods'. The assessment involves the analysis of stomach contents, which consisted of fragmented samples and unidentifiable objects, including non-food substances such as parasites (including nematodes and ticks) and miscellaneous items (such as substratum), with the intention of gaining a deeper understanding of the feeding habits of *Eutropis multifasciata*.

The dietary composition of the study species across sites in Malaysia is presented in Table 1. The diet from the northern site included five taxonomic orders of arthropods: Aranea, Blattodea, Coleoptera, Odonata, and Hymenoptera. In contrast, the southern site lacked members of the Hymenoptera and Odonata, while demonstrating the presence of three additional orders: Diptera, Dermaptera and Orthoptera; see Table 2. Fig. 3 depicts the cumulative percentage of prey taxa consumed by *E. multifasciata* in the present study. The taxonomic category Blattodea exhibits the

Table 1. Dietary composition in *Eutropis multifasciata* across sites. OTUs = operational taxonomic units; n = abundance; v = volume (mL); FO = frequency of occurrence; IRI = index of relative importance; PC = prey classification; CP1 = constant prey; CP2 = common prey; AP = accidental prey; VAP = very accidental prey.

Prey type (OTU)	N	N%	V	V%	FO	FO%	IRI	PC
Arachnida								
Araneae	7	17.073	0.054	4.281	7	21.212	10.831	AP
Insecta								
Blattodea	16	39.024	0.349	27.760	10	30.303	24.688	CP2
Coleoptera	6	14.634	0.181	14.375	6	18.182	12.852	AP
Dermaptera	4	9.756	0.016	1.285	4	12.121	5.802	AP
Diptera	1	2.439	0.003	0.0248	1	3.030	1.352	VAP
Hymenoptera	1	2.439	0.001	0.0832	1	3.030	1.371	VAP
Odonata	1	2.439	0.321	25.502	1	3.030	9.844	VAP
Orthoptera	5	12.195	0.336	26.690	3	9.091	13.594	VAP
Total:	**41**	**100%**	**1.258**	**100%**	**33**	**100%**	**80.333**	

Table 2. Dietary composition in *Eutropis multifasciata* in northern and southern regions. OTUs = operational taxonomic units; n% = percentage of abundance; v% = percentage of volume; FO % = percentage of frequency of occurrence; PC = prey classification; CP1 = constant prey; CP2 = common prey; AP = accidental prey; VAP = very accidental prey.

Prey type	Northern Region				Southern Region			
	N%	V%	FO%	PC	N%	V%	FO%	PC
Araneae	11.11	0.86	16.67	AP	21.74	6.00	23.81	AP
Blattodea	72.22	11.68	58.33	CP1	13.04	35.84	14.29	AP
Coleoptera	5.56	10.94	8.33	VAP	21.74	16.10	23.81	AP
Dermaptera	0	0	0	–	17.39	1.93	19.05	AP
Diptera	0	0	0	–	4.35	0.04	4.76	VAP
Hymenoptera	5.56	0.25	8.33	VAP	0	0	0	–
Odonata	5.56	76.27	8.33	VAP	0	0	0	–
Orthoptera	0	0	0	–	21.74	40.1	14.29	AP

Table 3. The results of Spearman rank correlation coefficient (r_s) to assess the relationship between percentage abundance (%n), percentage volume (%v) and percentage frequency of occurrence (%FO) of dietary items in *Eutropis multifasciata.*

Sites	%N %V	%N % FO	% FO %V
Northern region	$r_{s(10)} = -0.224$ P = 0.718	$r_{s(10)} = 1.000$ P = 0.000	$r_{s(10)} = -0.224$ P = 0.718
Southern region	$r_{s(12)} = -0.516$ P = 0.295	$r_{s(12)} = 0.750$ P = 0.086	$r_{s(12)} = 0.088$ P = 0.868
Both region	$r_{s(16)} = 0.610$ P = 0.108	$r_{s(16)} = 0.975$ P = 0.001	$r_{s(16)} = 0.512$ P = 0.194

Table 4. The results of the Spearman rank correlation coefficient (r_s) to assess the relationship between ranking of prey types based on index of relative importance (IRI) across study sites in Malaysia by *Eutropis multifasciata.*

Sites	Northern region	Southern region
Northern region	1	$r_{s(11)} = 0.300$ P = 0.624
Southern region	$r_{s(11)} = 0.300$ P = 0.624	1

Table 5. The results of the Berger-Parker diversity index (d), which measures the inverse of food dominance, indicates the diversity of prey types in the northern and southern regions for *Eutropis multifasciata*.

Regions	Berger-Parker diversity index	Inverse of the Berger-Parker index (1/ d)
Northern (n = 18)	d = 0.722	D = 1.385
Southern (n = 23)	d = 0.217	D = 4.608
Total (n = 41)	d = 0.390	D = 2.564

Table 6. Results from Pearson correlation of regression equations for correlation between body size and prey volume of stomach-flushed individuals of *Eutropis multifasciata*.

Sites	Equations	N	r	P
Northern region	$y = 9.81 - 5.85\chi$	12	– 0.392	0.208
Southern region	$y = -18.93 + 8.5\chi$	23	0.319	0.158

Table 7. Comparison in adult males and females of *Eutropis multifasciata* prey volume at the northern and southern sites. Chi-square test (χ^2), sample size (n) and significance (P).

Sites	Sex	Estimated volume of diet (ml)			n	chi-square test (χ^2)	P
		0.000 – 0.010	0.011– 0.099	0.100			
Northern region	Male	1	3	3	7	2.890	0.236
	Female	1	4	0	5		
Southern region	Male	4	10	0	14	2.471	0.116
	Female	0	7	0	7		
Total		6	24	3	**33**		

Table 8**.** Comparison of seasons versus prey types in *Eutropis multifasciata*. Ara = Araneae, Blat = Blattoidea, Col = Coleoptera, Dip = Diptera, Der = Dermaptera, Od = Odonata, Ort = Orthoptera, Hym = Hymenoptera, chi-square (χ^2), sample size (n), and significance (P).

Seasons	Prey Categories								n	χ^2	df	P
	Ara	Blat	Col	Dip	Der	Od	Ort	Hym				
Northeast (Northern region)	2	7	1	0	0	1	0	1	12			
										14.150	7	0.049
Southwest (Southern region)	5	3	5	1	4	0	3	0	21			
Total	7	10	6	1	4	1	3	1	33			

highest consumption rate at 39%, followed by Araneae at 17%, Coleoptera at 15%, Orthoptera at 12%, Dermaptera at 10%, and Diptera at 3%. Conversely, the taxa Hymenoptera and Odonata have the lowest consumption rates, at 2%. The dietary data collected were assessed based on the percentage of abundance (%N, percentage of volume (%V) and percentage of frequency of occurrence (%FO). There were no statistically significant differences in %N, %V, and %FO ($p > 0.05$) obtained in prey samples collected from the study sites except for in V%N%FO between the two southern sites (Table 3), and the order Blattodea shows the highest percentage of FO in the focal species compared to other prey types in both regions, as shown in Table 1. However, upon examination of each region, it is found that in the northern region, Blattodea was consistently a common prey or primary prey item, resulting in seven occurrences (58.3%) of the total prey recorded. In the case of southern locations, it was observed that Diptera were generally accidental prey items, with a proportion under 10%. Table 1 illustrates that members of the Araneae, Blattodea, and Coleoptera showed a frequency of occurrence exceeding 10%. These data demonstrate that members of the Blattodea were the most abundant prey in the northern region, while in the southern region, representatives of Aranea and Coleoptera were the most numerically common prey taxa, with equal frequencies of occurrence. IRI rankings of prey taxa at the two sites did not show a significant relationship, suggesting differences in their respective utilisation of prey taxa (Table 4). Table 5 illustrates the level of prey taxa dominance observed in the northern, southern, and both regions combined. In the northern region, the inverse of the Berger-Parker index (D) of 1.385 indicates a relatively higher level of dominance (index value closer to 0) compared to the southern regions. This is reflected by the notable number of prey items originating from the Blattodea in the former. In contrast, in the latter, the corresponding value (4.608) is suggestive of a reduced level of dominance (Fig.4).

Relationship between body size and prey volume. Table 6 presents data on the comparison of snout-vent length (SVL) of the skink and the associated volume of prey from the stomach contents. A regression analysis shows no statistically significant difference ($p > 0.05$; Fig. 6A). Corresponding analyses for the southern region exhibit a minimal upward trend in the linear relationship between prey size and volume, but again, relationships were not significant ($p > 0.05$; Table 6; Fig. 6B).

Relationship between sexes and prey volume. A comparison of prey volume, measured in millilitres (mL), between adult males and females is presented in Table 7. A chi-square test assessed the differences in prey volume between male and female skinks. Results show no significant differences in prey volume between males and females between sites ($p = 0.109$ northern; 0.116 for southern site), and suggest no relationship between prey volume and sex of skinks. Prey volume ranged from 0.000 mL to 0.010 mL, 0.011 mL to 0.099 mL, and ≥ 0.100 mL. The majority of prey in the northern and southern regions ranged from 0.011 to 0.099 mL. This suggests that most of the skink stomach contents had been partially digested before stomach flushing could be carried out, and/or that prey items were macerated/crushed prior to ingestion.

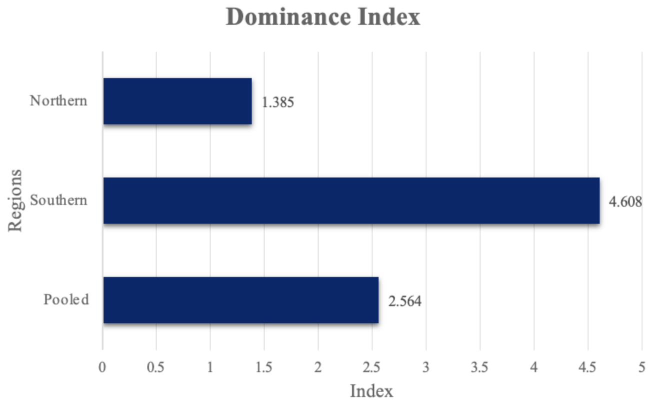

Fig. 4. Dietary variation in *Eutropis multifasciata* as determined by inverse of the Berger-Parker Index of Dominance.

Relationship between sexes and prey taxa. The dietary preferences of male and female skinks in the northern site, specifically a preference for Blattodea, clearly indicates that 57.14% of males (four individuals) and 60% of females (three individuals) fed on cockroaches. In the southern region, there was a notable difference in the dietary preference between males and females. Male individuals exhibited a preference for Coleoptera, which constituted 33.3% of the diet. Conversely, female individuals displayed a preference for Orthoptera, which accounted for two instances, or 40% of diet. Fig. 7 shows results of a comparative analysis between adults, both males and females and the types of prey found in stomach samples across various regions.

Table 8 presents a comparative analysis of prey types and their association with seasons in East and West Malaysia. The former area, being located on the island of Borneo, is characterised by a lack of distinct seasons, due to its proximity to the Equator. In contrast, West Malaysia, a part of the Asian mainland, experiences significantly long dry spells annually (Malaysian Meteorological Department, 2024). Seasonal classification utilised a priori in this analysis comprises the Northeast and Southwest Monsoons. A chi-square test shows statistically significant differences between prey types and seasons assumed to be linked to the passage of the monsoons, and Table 8 shows a significant difference between prey type and seasons in Malaysia.

In-situ and ex-situ feeding observations. During field data collection, two individuals of the target species were observed engaging in feeding, on separate occasions. Fig. 8A shows a free-ranging adult female attempting to feed on a swarm of flies (Diptera), in Kota Samarahan, Sarawak. A similar observation was observed from a radio-tracked skink from a separate study, and both appeared to employ a sit-and-wait strategy to capture airborne prey. Another observation (Fig. 8B) was made during fieldwork at the Kledang Saiong Eco Park, Perak, where an adult male skink was observed engaged in the act of swallowing of a member of the Blattodea. Fig. 8C records an observation made on a skink ex-situ in

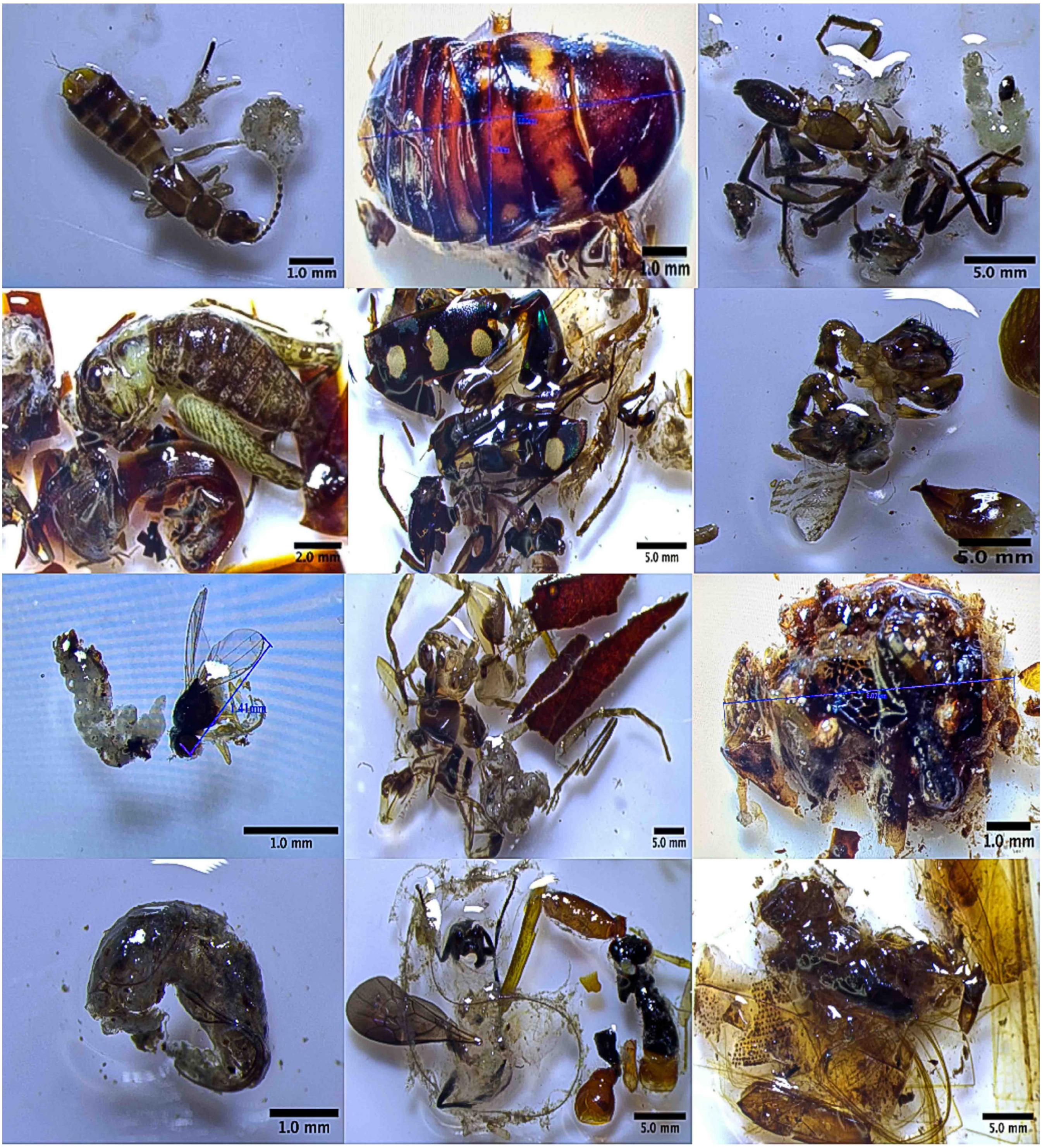

Fig. 5. Prey items and parasites collected via stomach flushing in *Eutropis multifasciata*. Top row, from left to right (southern site): earwig (Dermaptera), cockroach (Blattoidea), spider (Araneae). Second row, from left to right (southern site): cricket (Orthoptera), Cicindelinae (*Cosmodela aurulenta*), Salticidae (Araneae). Third row, from left to right (southern site): fly (Diptera), spider (Araneae), digested wings (Orthoptera). Fourth row. from left to right (northern site): termites (Blattoidea), fly (Diptera), and wings of dragonfly (Odonata).

a terrarium. This individual was also a radio-tracked skink from one of the southern sites. An owlfly (Ascalaphidae) of the order Neuroptera accidentally entered the open tank, whereupon the skink immediately attempted predation. Yet another observation was made while tracking the transmitter-fitted individual, which was discovered beneath a large leaf and was presumed to be feeding on termites emerging from peeling bark on which it was perched (Fig. 8D).

DISCUSSION

The study of the trophic ecology of organisms yields significant knowledge of ecosystem function, helping with assessment of ecosystem health, and serving as a predictor of species response to environmental change (Polis & Strong, 1996). Insectivorous lizards serve as appropriate study organisms for investigating food selection, due to

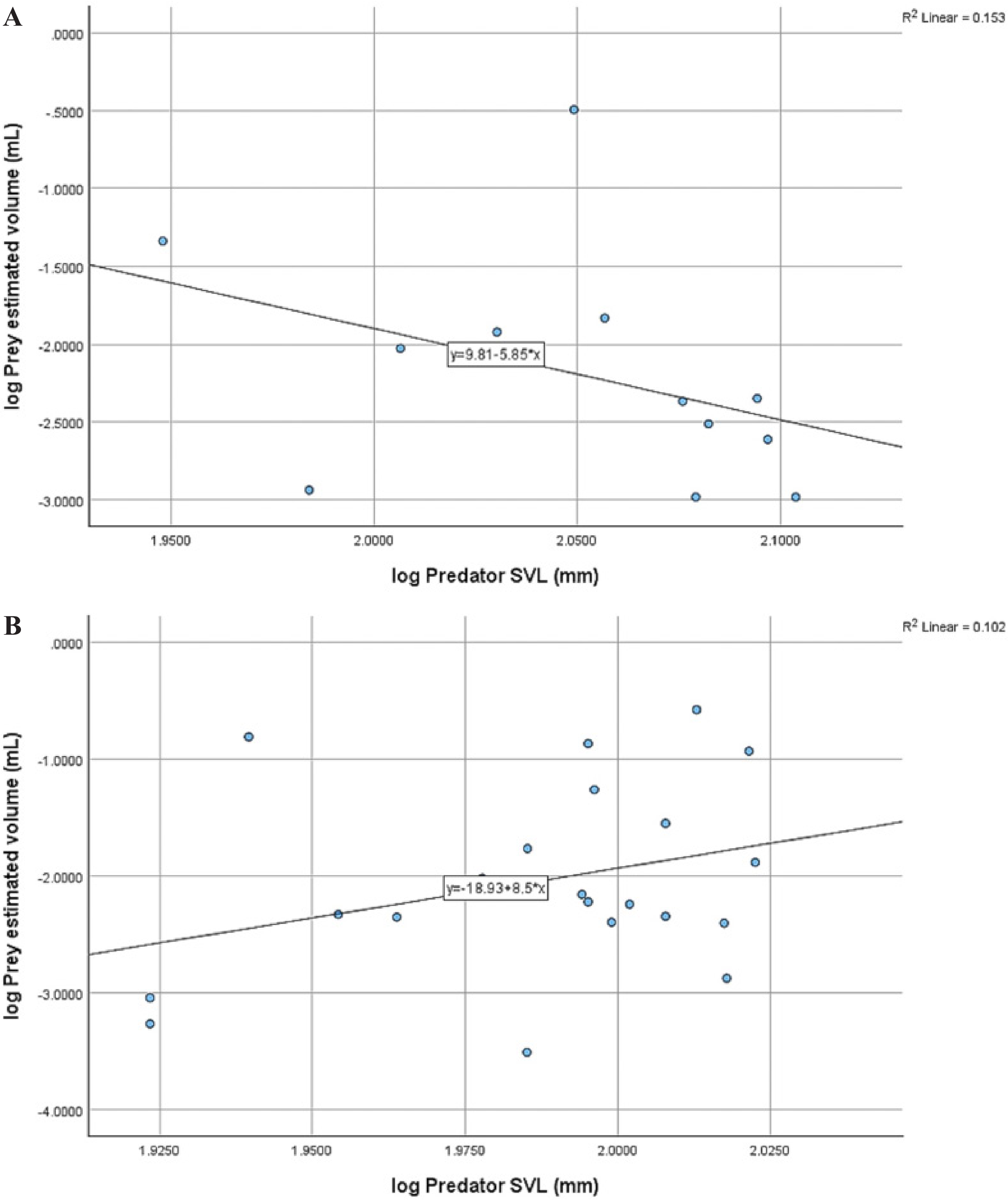

Fig. 6. A, correlation between log-prey volume (mL) and log-predator SVL length (mm) in stomach-flushed individuals of *Eutropis multifasciata* from the northern region; B, correlation between log-prey volume (mL) to log-predator SVL length (mm) in stomach flushed individuals from the southern region.

their relatively low metabolic rates and correspondingly diminished energy demands, compared to endotherms of similar mass (Pough, 1980). Simultaneously, it is worth noting that small arthropod prey exhibits a notable prevalence within many ecosystems (Schoener & Janzen, 1968; Stamps & Tanaka, 1981). While studies of diet composition are valuable in predicting foraging behaviour, determining food selection necessitates a comprehensive understanding of prey accessible to the predator (Diaz & Carrascal, 1990). Dietary evidence suggests that prey size and prey-availability variations among species may account for observed dietary heterogeneity in lizards (Truong, 2005; Reilly et al., 2007

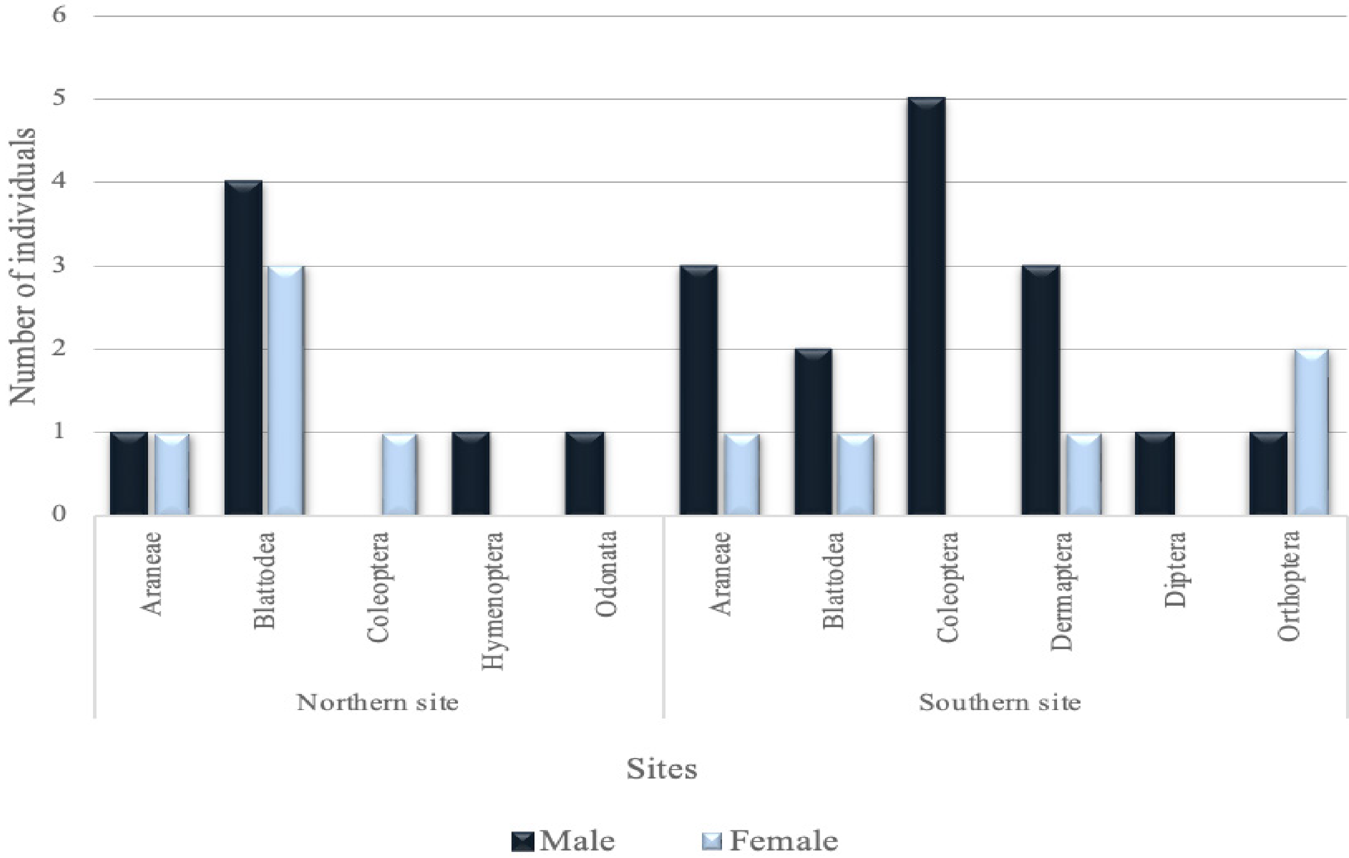

Fig. 7. Comparison between prey types in males and females of *Eutropis multifasciata* across northern and southern sites.

Le, 2008; Ngo et al., 2014). Skinks exhibit remarkable diversity and serve as a prominent and influential constituent within ecosystems. Skinks have been categorised as widely foraging, opportunistic predators that lack identifiable patterns of prey selection (Pianka, 1969; Taylor, 1986; Lunney et al., 1989; Brown, 1991; Wapstra & Swain, 1996). In this study, the diet preferences of *Eutropis multifasciata* was studied across a geographical range and in different habitat types in Malaysia.

The focal species in this study showed a higher predation rate on members of the Blattodea (termites and cockroaches), followed by Araneae (spiders) and Coleoptera (beetles). These match the findings of Ngo et al. (2015) in central Vietnam and of Hazarika & Sharma (2018) in Assam, India. The order Blattodea accounted for 39% of the total prey abundance, with a frequency occurrence percentage of 30%. The FO% value suggests that these prey taxa form secondary prey preferences or are common prey within the overall prey taxonomic diversity. In terms of frequency of occurrence across sites, members of the order Blattodea comprised 58.3% in the northern region, representing a commonly consumed prey (fide Bigot & Bodot, 1973). Lizards that feed on termites are commonly referred to as active searching predators due to termites often being hidden with a patchy distribution (Huey & Pianka, 1981; Vitt & Cooper, 1986). The quantification of termite predation by the skinks was slightly challenging to determine in this study due to the near-complete digestion of stomach contents, leaving behind only head capsules and abdomens. Individuals obtained from glue traps or pitfall traps tend to be those species that exhibit foraging activity.

The order Araneae (spiders) represents a common prey type observed in both the northern and southern sites. Manicom & Schwarzkopf (2011), Ngo et al. (2014), and Ngo et al. (2015) indicate that Araneae is a frequently targeted prey order by skinks. In this study, spiders were identified to the family level. Skink stomach contents reveal the presence of two families, namely Gnaphosidae in the southern region and Salticidae in both regions. The family Gnaphosidae is commonly referred to as 'ground spiders' and can be observed on the soil and on bark surfaces by day. According to Pekár & Jarab (2011), they occasionally seek shelter in bark crevices and underneath leaf litter. It is noteworthy that this particular group of spiders are nocturnal. Spiders belonging to the family Gnaphosidae are subject to predation during periods of sedentary behaviour. Jumping spiders (Salticidae) have been observed to be diurnally active and exhibit high mobility, as indicated by their hunting behaviour (Forster, 1982) and eye structure (Land, 1969).

Representatives of the orders Coleoptera and Orthoptera exhibit comparable levels of prey abundance. One such example observed is *Cosmodela aurulenta*, a member of the Coleoptera (family Cicidelidae). This species is known to inhabit water bodies such as forest streams (Acciavatti & Pearson, 1989), while their larvae inhabit deep clefts in rocks in clay-sand or sandy soil (Putckov & Markina, 2020). However, in the southern sites, the habitat was comprised

Fig. 8. A, adult female *Eutropis multifasciata* feeding on flies (Diptera), snout-vent length (SVL) unrecorded; B, adult male feeding on cockroach (Blattoidea); C, adult male skink feeding on net-winged insect (Neuroptera), SVL 82.79 mm; D, a colony of termites associated with an adult skink.

of peat soil and ditches along plantations. A generalisation for *C. aurulenta* cannot be made, as the prey is a singleton in stomach samples, recovered from a skink taken from the banks of a ditch. Nonetheless, Coleoptera in general, along with members of the Araneae, were a dominant prey type in the southern region. It is predicted that the ambush foraging strategy is employed for the capture of this particular prey type. Additional prey types such as members of the orders Diptera and Hymenoptera, are generally characterised as active and mobile prey, and are also likely to be caught by ambush foraging.

Plant material, specifically leaves, have been found within the stomach contents of the species. Considering that the presence of plant material was solely detected in a single regurgitated sample, it is suggested that these items were inadvertently ingested, potentially during the capture of prey close to a plant. Most agamid, scincid, lacertid, tropidurid, and crotaphytid lizards eat diverse invertebrates and some plant material (Cooper & Vitt, 2002; Ngo et al., 2015). Phung (2013) observed that *E. multifasciata* actively consumes plants, and Ngo et al. (2015), reported on its omnivorous behaviour. However, it is important to note that the available data from this study are insufficient to support this claim, with plant material likely ingested incidentally. The evidence suggests that *E. multifasciata* is more likely a strict insectivore.

Minor differences in behavioural patterns, activity patterns, and microhabitat preferences can cause corresponding differences in dietary patterns observed across sites. Environmental variation across the sites may determine prey type distribution. The size of prey and volume consumed by skinks are impacted by ambient temperature, relative humidity and precipitation (Huey & Pianka, 2007). In a general context, the availability of arthropod prey is seldom a limiting resource in a tropical system (Gaston, 2000). Evidence of significant variations among prey types and seasons are presented for the current study. However, the variation in prey taxa cannot be just attributed to seasonality; the topography of the locations and land use of the area may have influenced the composition and abundance of prey species in the regions. Given that one of the study sites is an oil palm plantation, the agricultural areas may exhibit a distinct array of species as a result of the use of fertilisers, pesticides, and other chemicals. The sampling was not conducted during the dry season in the northern region and the rainy season in the southern region. The variation in prey taxa between the areas cannot be solely attributed to seasonality. Certain species of lizards exhibit a seasonal shift in their dietary composition (Pianka, 1970; Vitt & Lacher, 1981; Schoener et al., 1982), with observed variations primarily attributed to fluctuations in the abundance of food resources within respective habitats (Pianka, 1970; van Sluys, 1994). It is a prevalent phenomenon for species residing in tropical settings, where local production is influenced by rainfall cycles, to exhibit a seasonal alteration in their dietary patterns. Tropical insectivorous lizard species show a diverse prey type, thereby potentially cutting out competition for food resources. Skinks are opportunistic predators that engage in active foraging, searching for sedentary, active or patchily distributed prey. The present study reveals that the observed skink species exhibits both active and ambush-foraging behaviour, depending on the prey type encountered.

CONCLUSION

Trophic studies are an important component of ecology since they provide valuable insights into natural history. Although information on the diet of *E. multifasciata* has been published from extralimital populations, there is limited research on the topic for tropical Southeast Asia and for Borneo. Furthermore, there are few studies that compare the influence of geographical and habitat differences in diet choice. In this study, the focal species showed a consumption pattern that includes nine operational taxonomic units of prey. As most samples were recovered from flushed stomachs, and therefore in a fragmented state, species-level determination of prey as well as of mass and quantity could not be accurately assessed. Nonetheless, the target species displayed the characteristic of being an opportunistic feeder. It was found to exhibit both active and ambush foraging strategies, contingent on prey availability within the habitat. An analysis of latitudinal location of study sites did not yield any statistically significant differences in prey preference in populations within the species. The study revealed variation in dietary preferences of *E. multifasciata* across locations, although there was insufficient evidence to suggest the existence of dietary differences based on latitudinal variations. Studies of prey selection are of great interest, particularly given the wide variety of habitats occupied by the target species. Additionally, predation on the lizard appears to be common, helping place the skink in a wider context of its food chain and trophic web.

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