

DIET OF *SCELOPORUS MELANORHINUS* (REPTILIA: PHRYNOSOMATIDAE) IN A PATCH OF DECIDUOUS FOREST IN WESTERN MEXICO

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Abstract.—Feeding habits within *Sceloporus* species have been studied for nearly a century; however, few information gap still exists for some species, particularly those that occur in the lowlands of the Mexican Pacific coast. In this study, we analyzed the diet composition of the Pastel Tree Lizard (*Sceloporus melanorhinus*), a conspicuous and widespread lizard in the deciduous forests of western Mexico. Using stomach flushing on 41 captured adults from August 2016 to May 2017, we observed eight distinct prey of six orders of arthropods (Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera and Orthoptera), as well as vegetation remains and unidentifiable matter. There were no differences in diet between sexes, and body size had no effect on prey item weight. Our results revealed that female and male *S. melanorhinus* tend to specialize on hymenopterans and coleopterans during the study period, which is consistent with other Sceloporine studies from arid and mountain ecosystems.

Key Words.—Mexico; sceloporine lizard; specialist behavior; trophic divergence

INTRODUCTION

The lizards of the genus *Sceloporus* (> 100 species) show a wide geographic distribution and can be found in a broad array of environmental conditions and habitat types (Smith 1939; Leaché et al. 2013). This has provided an interesting model to conduct ecological studies, particularly on trophic niches and niche partitioning. Sceloporine lizards commonly use the sit-and-wait mode of foraging strategy (Vitt et al. 1981), with some species opportunistic and most are insectivorous (Feria-Ortiz and Pérez-Malvárez 2001; Serrano-Cardozo et al. 2008; Hierlihy et al. 2013; Castro-Franco et al. 2017; Puga y Colmenares et al. 2019). Knowledge regarding food habits of *Sceloporus* species from the Mexican Pacific lowlands remain scarce (e.g., Hierlihy et al. 2013).

The Pastel Tree Lizard (*Sceloporus melanorhinus*; Fig. 1) is one of the wide-ranging sceloporine species distributed in the Tropical Dry Forests, Semi-deciduous Forests, and Pine Forests of the Pacific coast of Mexico (Ponce-Campos and García-Aguayo 2013). Some aspects of its life history have been previously evaluated, such as reproductive biology (Ramírez-Bautista et al. 2006), habitat use, and activity patterns (García 2008; García and Cabrera-Reyes 2008); however, to our knowledge the specific feeding habits are unknown. Here, we analyze feeding habits of *S. melanorhinus* from a patch of deciduous forest within an estuary in Puerto Vallarta, Mexico.

MATERIALS AND METHODS

Study area.—El Salado Estuary (20°40'19.85"N, 105°14'11.35"W) is located in Puerto Vallarta, Jalisco, Mexico. Vegetation is dominated by Red Mangrove (*Rhizophora mangle*), White Mangrove (*Laguncularia racemosa*), and Black Mangrove (*Avicennia germinans*), as well as some species of deciduous forests such as West Indian Elm (*Guazuma ulmifolia*), fig trees (*Ficus* sp.), and acacias (*Vachellia* sp.). The climate is characterized by two seasons: the dry season from December to May, and the rainy season from June to November. The annual temperature fluctuates around 26° C, while precipitation fluctuates from 931 mm to



FIGURE 1. Pastel Tree Lizard (*Sceloporus melanorhinus*) during basking activity. (Photographed by Petr Myska).

1,668 mm (Acevedo Rosas and Cházaro Bazañez 1996; Cupul-Magaña 2000).

Data collection.—We captured 62 *S. melanorhinus* by hand or by noose within the El Salado Estuary from August to November 2016 (rainy season) and February to May 2017 (dry season). We transported each lizard individually in a plastic box to the Laboratory of Biodiversity and Ecosystem Services at the Centro Universitario de la Costa of Universidad de Guadalajara, Mexico. In the laboratory, we measured the snout-vent length (SVL) with a 150 mm digital caliper (± 0.1 mm). Additionally, we obtained body mass (BM) with an analytical balance (± 0.01 g). We grouped lizards according to sex (based on coloration, femoral pores, and enlarged post-cloacal scales; Galindo-Gil et al. 2015), season, and size class (juveniles ≤ 62.1 mm SVL and adults > 62.1 mm SVL; Ramírez-Bautista et al. 2006). We did not include any hatchling lizards (hatchlings < 35 mm SVL) in our diet study, which left 41 juveniles and adult lizards. Diet did not differ significantly among seasons or size class; therefore, we combined these two categories for analysis. Of the 41 captured *S. melanorhinus*, 22 were males (SVL = 66.1 mm \pm standard deviation 13.9 mm; range, 45.0–92.0 mm), and 19 females (SVL = 61.5 \pm 19.0 mm; range, 38.0–86.0 mm). We used stomach flushing to obtain stomach contents, and we flushed stomachs three times consecutively in each individual to obtain the largest possible volume of stomach contents from each individual. We preserved stomach contents individually in 70% ethanol for laboratory analysis. After data collection, we observed all lizards for 24–36 h before releasing them at their capture locations. In the laboratory, we separated stomach contents using a Stemi DV4 stereoscopic microscope (Zeiss Stemi DR 1040, Jena, Germany) and examined contents under an Olympus CH30 optical microscope (Olympus Optical Co. LTD, Tokyo, Japan). We identified prey items to the lowest taxonomic level possible using specialized literature on insects (White 1983; Castner 2000; Eaton and Kaufman 2007; Evans 2007). We classified seeds, leaves, and flowers together as plant matter. We weighed each taxonomic group wet with an analytical balance (± 0.01 g).

Statistical analysis.—We used the Shannon-Weiner and Simpson diversity indices to quantify the diversity of prey consumed by *S. melanorhinus*. These two indices are commonly used to estimate the amount of specialization in feeding habits within lizard populations (Güizado-Rodríguez and Casas-Andreu 2011; Alcantara et al. 2019; Abu Baker et al. 2021; Caldas et al. 2021). The Shannon-Weiner Diversity Index allows the quantification of diet diversity and is:

$$H' = \sum_{i=1}^s pi \ln(pi)$$

where pi is the proportion of prey type i in the sample, and s is the total number of prey categories. The Simpson Diversity Index emphasizes the abundance of the prey categories and is:

$$D = \frac{1}{\sum_{i=1}^n pi^2}$$

and uses the same notation as the Shannon-Weiner index. We also evaluated the food niche breadth using Levin's Standardized Index:

$$B = \frac{\left(\frac{1}{\sum pi^2}\right) - 1}{n - 1}$$

where pi is the proportion of each prey category with respect to the total number of prey found in each group, and n is the number of prey categories in the diet of individuals (Levin 1970). This formula ranges from 0 to 1: a value of 1 for food niche breadth means that all of the preys were found in equal proportions (generalist feeding habits), whereas a value near 0, means that a few preys were found with high frequency (specialist feeding habits).

We conducted the above approaches of food niche individually to estimate intra and inter-sex specialization (Araújo et al. 2011). After testing for normality with the Shapiro-Wilk test, we estimated differences in the number of prey items per stomach between sexes using the Mann-Whitney U Test. We also performed t -tests to examine differences in the three approaches (Shannon-Weiner, Simpson, and Levin's) to explore the food niche between sexes. Finally, we performed Linear Regressions between SVL with prey items weight, diversity indices, and food niche breadths to assess whether each variable was related to body size. We used PAST 3.15 (Hammer et al. 2001) for all tests, and we considered $P \leq 0.05$ to be significant.

RESULTS

We found eight distinct prey items from stomachs of *S. melanorhinus*, including six orders of arthropods: Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera and Orthoptera, as well as vegetation matter and unidentifiable matter. The highest frequency of occurrence in stomach contents were of Hymenoptera (82.9% of 41 individuals), while the lowest frequency of occurrence were for Lepidoptera, Diptera, and Orthoptera (2.4% each; Table 1). We could identify some prey to the family and/or species levels for Hemiptera, Hymenoptera, Coleoptera, and Diptera. For Hemiptera, we identified individuals in the family Pentatomidae. For Hymenoptera, we identified individuals of Odorous

TABLE 1. Weight, occurrence (number found), and snout-vent length (SVL in mm \pm standard deviation) of prey found in stomachs of male and female Pastel Tree Lizards (*Sceloporus melanorhinus*) from El Salado Estuary, Puerto Vallarta, Mexico.

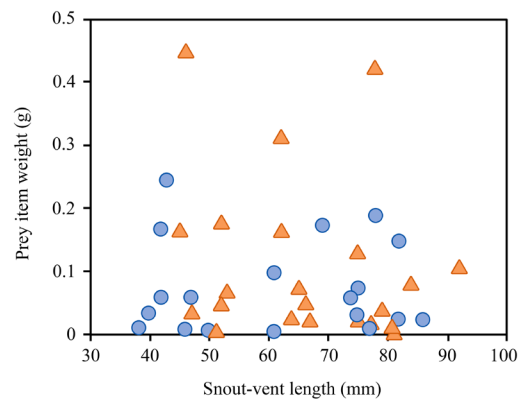
Prey item	Weight (g)		Occurrence		SVL (mm)	
	Females	Males	Females	Males	Females	Males
Coleoptera						
Buprestidae	0.16	0.38	7	11	54.6 \pm 15.3	69.4 \pm 14.9
Diptera						
Stratiomyidae	-	0.24	0	1	-	78.0
Hemiptera						
Pentatomidae	0.20	0.04	1	1	43.0	79.0
Hymenoptera						
Apidae						
<i>Apis</i>	0.54	0.30	8	4	66.5 \pm 16.9	70.5 \pm 16.4
Dolichoderinae	0.22	0.62	5	4	62.2 \pm 17.9	61.2 \pm 10.9
Formicinae						
<i>Paratrechina longicornis</i>	0.16	1.39	9	11	55.7 \pm 16.4	66.0 \pm 15.6
Myrmicinae						
<i>Atta mexicana</i>	0.04	0.01	1	1	43.0	52.0
Lepidoptera	-	0.02	-	1	-	67.0
Orthoptera	-	< 0.01	-	1	-	53.0
Vegetation matter	-	0.05	-	2	-	72.0 \pm 28.3
Non-identify matter	0.33	0.32	7	7	55.7 \pm 16.4	63.9 \pm 15.4

ants of the subfamily Dolichoderinae, Leaf-cutter Ants (*Atta mexicana*) of the Myrmicinae subfamily, Black Crazy Ants (*Paratrechina longicornis*) of the Formicinae subfamily, and *Apis* (bees) of the Apidae family. For Coleoptera, we identified buprestid beetles of the family Buprestidae, while some dipteran prey could be identified as pertaining to the family Stratiomyidae (Soldier flies).

We found four prey orders in stomach contents of females, and six orders in males. Ants of the family Formicidae were the prey category consumed in the greatest numbers by both females (37.8%) and males (65.7%). Females did not show plant matter in their stomach contents, although unidentifiable matter was the second highest percentage (45.4%) of prey items in females. In males, the prey items pertaining to Hemiptera, Lepidoptera, Orthoptera, and plant matter were found to be < 5%.

The number of prey items per stomach was similar between both sexes ($U = 182.0$, $P = 0.452$). Males and females had mean (\pm standard error) prey item weights of 0.15 ± 0.03 g and 0.09 ± 0.02 g, respectively. We found no significant differences in the mean weights of prey items between sexes ($t = -1.147$, $df = 39$, $P = 0.258$), nor did we observe relationships between SVL and prey item weights ($F_{1,39} = 0.340$, $P = 0.563$; Fig. 2). The mean values of prey-group diversity based on the Shannon and Simpson diversity indices for females was 0.40 and

0.25, respectively. Males showed a mean value of 0.52 for the Shannon index and 0.34 for the Simpson index. We did not observe differences in the diversity indices of prey groups between sexes (Shannon: $t = -0.799$, $df = 39$, $P = 0.428$; Simpson: $t = -0.905$, $df = 39$, $P = 0.370$). The diversity indices showed no significant relationship with SVL (Shannon: $F_{1,39} = 0.33$, $P = 0.571$; Simpson, $F_{1,39} = 0.32$, $P = 0.574$). The food niche breadth for females and males were 0.034 and 0.040, respectively. We did not observe significant differences in food niche breadth between females and males ($t = -0.307$, $df = 39$,


FIGURE 2. Relationship between body size and prey item weights in male (triangles) and female (circles) Pastel Tree Lizards (*Sceloporus melanorhinus*) from El Salado Estuary, Puerto Vallarta, Mexico.

$P = 0.760$), nor did we observe a significant relationship between SVL and food niche breadth ($F_{1,39} = 0.31$, $P = 0.579$).

DISCUSSION

Understanding feeding habits is crucial to recognizing the ecological requirements of a particular species throughout its life stages. In this study, the food niche breadth suggested a tendency of *Sceloporus melanorhinus* to specialize on ants, bees, and beetles in our study area. Some studies have shown that coleopterans and hymenopterans are two of the most common orders of insects in the stomach contents of *Sceloporus* species (Medica and Arndt 1976; Ballinger and Ballinger 1979; Puga y Colmenares et al. 2019). Surprisingly, we did not find termites in the stomach contents of *S. melanorhinus* during both the dry and rainy seasons. The order Isoptera (now placed in the epifamily Termitoidea of the large Blattodea order) has been found to contribute to the diets of some *Sceloporus* species (Toliver and Jennings 1975; Gadsden and Palacios-Orona 1995; Serrano-Cardozo et al. 2008; Hierlihy et al. 2013). Consumption of other orders such as Lepidoptera, Diptera, Hemiptera, and Orthoptera by *S. melanorhinus* might reflect opportunistic feeding consistent with the sit-and-wait foraging model. The low percentage of plant matter found in the stomachs of two captured males of *S. melanorhinus* might reflect accidental intake during foraging activities (e.g., Feria-Ortiz et al. 2001; Ramírez-Bautista and González-Romero 2002; Leyte-Manrique and Ramírez-Bautista 2010).

The prey composition of *S. melanorhinus* consisting mainly of hymenopterans and coleopterans could suggest an energy-cost advantage. Optimal foraging strategies suggest predators tend to be specialists when prey densities are high and generalists when prey densities are low (Schoener 1971, 1974). Entomological studies conducted at the El Salado Estuary have reported 11 orders of arthropods (Guerrero et al. 2014; Mayra Guevara-Gatica, unpubl. report), of which six were found in the stomach contents of *S. melanorhinus* during our study. If we consider the lowest taxonomic level of ant species (Formicidae), *S. melanorhinus* ingested only three of 49 potential prey items in the study area (Vázquez-Bolaños et al. 2014). On the other hand, the profitability of the prey types could decrease foraging efficiency in *S. melanorhinus*. Vanhooydonck et al. (2007) classified 37 potential prey items of lizards based on hardness (hard, soft, and intermediate) and evasiveness (evasive, sedentary, and intermediate). Based on prey item classification, *S. melanorhinus* consumed mainly intermediate-evasive and hard prey (coleopterans and hymenopterans) in our study area.

The prey that were ingested at the lowest frequencies (larvae of lepidopterans, orthopterans, and dipterans) are classified as softer prey but evasive, which could affect the search time, capture attempts, and success rate of these prey types.

Prey availability may represent a powerful driver of foraging strategies. Some sceloporine lizards are specialists despite having a wide availability of prey in their environment, such as the Gadow's Spiny Lizard (*Sceloporus gadoviae*), Horrible Spiny Lizard (*S. horridus*), and Jalapa Spiny Lizard (*S. jalapae*) from semiarid habitat (Serrano-Cardozo et al. 2008), and the Mezquite Lizard (*S. grammicus*) in mid and high elevations (Leyte-Manrique and Ramírez-Bautista 2010). Some studies have shown *Sceloporus* species to consume the same prey items despite body size differences and fluctuations of prey abundance between weather season (e.g., Ballinger and Ballinger 1979; Serrano-Cardozo et al. 2008). Therefore, we suggest that the lack of trophic divergence could be due to food resources (coleopterans and hemipterans, mainly) being abundant year-round, regardless of the season in the El Salado Estuary, which might reduce intra- and inter-sexual competition. Valtierra-Azotla et al. (2010) similarly observed no differences in habitat use of *S. melanorhinus*. These studies suggest that male and female *S. melanorhinus* may show a similar capacity to use the same feeding niche across different life stages and seasons. Future work on the feeding habits among populations of *S. melanorhinus* could determine if diet diversity and food niche breadth vary among environmental and habitat gradients.

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