

DIET AND HABITAT USE OF *Ptychoglossus bicolor* (SQUAMATA:
GYMNOPHTHALMIDAE) IN AN ORGANIC COFFEE SHADE PLANTATION IN
COLOMBIA

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Universidad Industrial de Santander

Facultad de Ciencias

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Bucaramanga

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A mi madre por darme la vida
y enseñarme el valor de amar lo que hago,
a mi hermano por ser mi bastón en la vida,
a mis compañeros por su amistad
a Lilian por ser luz en mi camino

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TITULO: DIETA Y USO DEL HABITAT DE *Ptychoglossus bicolor* (SQUAMATA: GYMNOPHTHALMIDAE) EN UNA PLANTACION DE CAFÉ ORGANICO BAJO SOMBRA EN COLOMBIA *

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Palabras claves: Palabras claves: dieta; uso del hábitat; lagartijas tropicales; Gymnophthalmidae; ecología

Ptychoglossus bicolor es un pequeño lagarto de la familia Gymnophthalmidae, que se distribuye en el valle alto del Rio Magdalena de Colombia. Estudiamos características ecológicas de la dieta, Microhábitat y temperatura de una población encontrada en una plantación de café orgánico en la Cordillera Oriental colombiana. Esta población tiene una dieta altamente especializada, alimentándose casi exclusivamente de isópodos. El Índice de Importancia Relativa de los isópodos fue 98.8%, no hubo diferencias significativas en el contenido estomacal y el volumen de isópodos consumidos durante el año de muestreo. Un gran número de lagartos fueron encontrados activos en la hojarasca, enterrados alrededor de las raíces de los arboles de café y debajo ó entre troncos en descomposición. La temperatura corporal estuvo correlacionada positivamente con la temperatura del suelo y la temperatura del aire y las diferencias entre los sexos no fueron significativas. En esta localidad no se encontraron lagartos fuera de los cultivos de café. Estos resultados sugieren que estos lagartos habitan exitosamente áreas de café orgánico como resultado de las condiciones ofrecidas por el cultivo. Por lo tanto, esta población puede ser vulnerable a cualquier modificación del hábitat que cambie la disponibilidad de microhábitats y la abundancia de isópodos.

* Proyecto de Grado

** Facultad de Ciencias. Escuela de Biología. Director: Víctor Hugo Serrano Cardozo. Codirectora: Martha Patricia Ramírez Pinilla

Abstract

TITULO: DIET AN HABITAT USE OF *Ptychoglossus bicolor* (SQUAMATA: GYMNOPHTHALMIDAE) IN AN ORGANIC COFFEE SHADE PLANTATION IN COLOMBIA *

AUTORES: Jaime Mauricio Anaya Roja, Víctor Hugo Serrano Cardozo, Martha Patricia Ramírez Pinilla**

Keywords: Diet; habitat use; tropical lizards; Gymnophthalmidae; ecology

Ptychoglossus bicolor is a small gymnophthalmid lizard distributed in the Upper Magdalena Valley of Colombia. We studied ecological features of diet, microhabitat and temperature of a population found in an organic coffee shade plantation at the Cordillera Oriental of the Colombian Andes. This population has a highly specialized diet, feeding almost exclusively on isopods. The Relative Importance Index of isopods was 98.8 %; there were no significant difference in the full stomach content and volume of isopods eaten during the sampling year. A large number of lizards were found active in the leaf-litter, buried around coffee tree roots, and under or in rotting logs. Body temperature was positively correlated with soil temperature and air temperature, and sex differences were not significant. At this locality we did not find lizards out of the coffee fields. Our results suggest that these lizards successfully inhabit organic coffee areas as a result of the conditions offered by the farming. Thus, this population may be vulnerable to any modification of the habitat that changes microhabitat availability and abundance of isopods.

* Proyecto de Grado

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1. INTRODUCCION

New World tropical forests are well known for their biotic diversity, as well as the effect of some agroforest systems on biodiversity (Wilson, 1988; Perfecto et al. 1996; Perfecto et al. 2003; Vitt et al. 2005; Ritcher et al. 2007). More and more tropical forest regions have experienced some type of deforestation or habitat modification, making necessary additional ecological studies of individual species, species assemblages, communities, and ecosystems (Vitt and Zani 2005). Diet, microhabitat and thermal ecology studies of single species may provide a basis for understanding the role of each species in complex ecosystems, the evolutionary history of such traits, and the effects of habitat alterations (Pianka and Vitt 2003; Vitt et al. 2003b; Vitt and Zani 2005). Therefore, this kind of evidence might also provide a good arsenal for defending the value of natural ecosystems when drastic habitat alteration is under consideration, as well as practices that combine biodiversity conservation with sustainable agricultural systems (Glor et al. 2001; Pianka and Vitt 2003; Vitt et al. 2003b; Vitt and Zani 2005; Borkhararia et al. 2006). Organic farming or traditional shade coffee farming unites biodiversity conservation with sustainable agricultural practices, because these plantations overlap with biodiversity hot-spots and because of their biological control of coffee pests (in contrast to sun coffee plantations, where biodiversity is significantly lower than that of coffee shade plantations) (Hardner and Rice 2002). For all these reasons, understanding how species live in these modified systems is important (Perfecto et al. 1996, 2003, 2007; Borkhararia 2006).

The Gymnophthalmidae contains approximately 180 small-bodied lizard species in 36 genera, occurring throughout most of the habitats of South and Central America

(Pellegrino et al. 2001; Castoe et al. 2004). The genus *Ptychoglossus* contains 15 species of small lizards that live in the leaf litter of moist tropical forest in Panama, Costa Rica and the Northwestern quarter of South America (Harris 1994). *Ptychoglossus bicolor* is distributed on the Upper Magdalena Valley of Colombia between 1500 and 2100 m elevation, within zones of premontane and low montane very humid forests (Harris 1994). These lizards are cryptic in dorsal color, resembling the soil and fallen leaves. No ecological data exist for this genus, but most gymnophthalmids prefer leaf-litter microhabitats and microhabitats rich in decaying wood; most gymnophthalmids also maintain body temperatures slightly higher than soil temperature (Hillis 1985; Avila-Pires 1995; Vitt et al. 2003a; Vitt and Pianka 2004; Doan 2008). The aim of this study is to identify feeding preferences, document how lizards are distributed, and quantify thermal preferences of a population of *Ptychoglossus bicolor* found in an organic coffee shade plantation at La Mesa de Los Santos in Colombia.

2. MATERIALS AND METHODS

2.1 FIELD AND LABORATORY PROTOCOLS

We looked for individuals of *Ptychoglossus bicolor* over all possible areas in the coffee shade plantations, as well as areas out of the coffee fields, including paddocks and banana plantations, of La Hacienda el Roble. This plantation is an organic coffee farm located on the western slope of Cordillera Oriental of Colombian Andes found between the municipalities of Los Santos and Piedecuesta, Santander – Colombia (06° 52' N – 73° 03' W, 1500 – 1700m elevation). Historically, this zone has had two peaks of rain (March to June and August to November), with a mean annual precipitation of 1143 mm (Hijmans et al.

2004; Figure 1), historical data were not significantly different to that of the sampling period (Paired $t_{(11)} = -0.276$, $P = 0.787$).

Lizards were collected by hand during haphazard excursions through the coffee shade plantations from April 2005 to April 2006. We recorded type of microhabitat for 166 lizards collected. We used three microhabitat categories: leaf-litter, rotting logs, and coffee tree roots. Subsequently, all lizards were euthanized by a lethal injection of Lidocain 2% within two hours of capture. Lizards were preserved in 10% formalin for 48 hours and stored in 70% ethanol to be deposited in the herpetological collection of the Museo de Historia Natural, Escuela de Biología, Universidad Industrial de Santander (UIS-R). *Ptychoglossus* bicolor has a marked sexual dichromatism (adult males with orange-red and females with pale beige ventral coloration), so sexes were easily separated; we also obtain the data of the reproductive stage of each individual from the study over the same set of animals of E.P. Ramos (personal communication, 2008).

We dissected stomachs of all lizards: 75 from males, 77 from females, and 14 from juveniles. We did not use the intestine content because the material found there was highly digested. Prey items were separated on a Petri dish, and identified to family level when possible (all were identified at least to order). We excluded the material that was too fragmented (digested material) from the prey category determination. For each lizard we measured prey volume and stomach volume directly using the volumetric displacement method (Magnuson et al. 2003) with an accuracy of 0.2 mm^3 . To calculate the relative contribution of each prey category to the total of dissected stomachs, we used the relative importance index, IIR, from Pinkas et al. (1971) using the following equation: $IIR = (\%N + \%V) * \%F$, where %N is the numeric percentage of items of each prey category, %V is the volumetric percentage of each prey category, and %F is the percentage of occurrence of each prey category in the total number of stomachs. We also calculated the percentage of lizards that had empty stomachs and the percentage of digested material (Huey et al. 2001)

We collected another 52 lizards during a second excursion from February to August 2007 to measure cloacal temperature (= Body T_b), air temperature (T_a), and substrate temperature (T_s) using a quick-reading thermometer with an accuracy of 0.2 °C (Avinet Inc. Dryden, NY), and relative humidity (% RH) using a digital thermometer and hygrometer (*RadioShack*TM).

2.2 STATISTICAL ANALYSIS

To determine if the volume of the most important prey eaten and the full stomach content volume differed between males and females, we used an ANCOVA (Separated-Slope model) with SVL as the covariate and sex as the class variable. We also tested if stomach content (full stomach volume) and the most important item varied over time by using an ANCOVA (Separated-Slope model) with SVL as the covariate and month of capture as the class variable. A plot of total stomach volume against SVL visualized the relationship between stomach volume and lizard size, and allowed us to estimate relative fullness of sampled lizards (Huey et al. 2001).

Differences in microhabitat use of all individuals captured during the whole year were tested by a Chi-square test. The relationship between the T_b , T_a and T_s was analyzed by means of a Pearson's Correlation, and a simple linear regression. To test the null hypothesis that lizards do not choose microhabitats based on T_b , we used an ANCOVA with T_b as the dependent variable, microhabitat as the class variable, and T_s as the covariate because it was more correlated with T_b than was T_a . Finally, we also tested the null hypothesis that males and females are active using different body temperatures by performing an ANCOVA with T_b as the dependent variable, T_s as the covariate, and sex as the class variable.

3. RESULTS

From 166 lizards analyzed, 14 had empty stomachs or stomachs full of digested material. Thus, the remaining 152 lizards examined had stomachs with a total of 468 prey items in 11 prey categories (Isopoda, Coleoptera larvae, Coleoptera, Dermaptera, Strepsiptera, Hemiptera, Orthoptera, Psocoptera, Hymenoptera, Collembolla, and Aranae, Table 1). Volumetrically and numerically, isopods, coleopteran larvae, coleopterans, and dermapterans dominated the diet. Most lizards ate numerous isopods, sometimes in combination with other items, although some lizards ate only coleopteran larvae. Predominance of a highly restricted diet on isopods is apparent in values of RII% (98.8%, Table 1). On the other hand, isopod volume distribution was highly skewed, and most of these preys were small, with a mean prey volume of 0.01 mL. No sex differences were found in the volume of isopods eaten (ANCOVA, $F_{(1,148)} = 0.916$, $P = 0.339$) and full stomach volume (ANCOVA, $F_{(1,148)} = 0.616$, $P = 0.434$). We did not find microhabitat differences in the volume of isopods (ANCOVA, $F_{(2,146)} = 0.655$, $P = 0.521$) or in the isopods and full stomach content during the sampling period (Isopods: ANCOVA, $F_{(11, 114)} = 0.611$, $P = 0.815$, and full stomach content; ANCOVA, $F_{(11,114)} = 0.496$, $P = 0.901$; Figure 2). Total prey volume and SVL were positively related ($R^2 = 0.065$, $F_{1, 150} = 10.424$, $P = 0.002$). Few lizards reached full stomach volume: about 26% of the full stomach volume was digested material and nearly 12% of stomachs were empty (Figure 3).

All lizards were found in coffee shade plantations; no lizards were found outside of this habitat. Thus, we restricted our further study to the coffee fields. Among 166 lizards collected, 93 (56%) were found diving into the leaf-litter, 57 (34%) were interred in the compost around coffee tree roots, and 16 (10%) were under or in rotting logs (Figure 4). This variation in microhabitat use was statistically significant ($X^2 = 31.278$, $df = 2$; $P < 0.05$). No significant differences were found in relative

humidity between leaf litter, rotting logs, and coffee tree roots ($F_{(2,49)} = 2.476$; $P = 0.095$, Table 2).

A summary of T_b , T_a and T_s of 52 living lizards is shown in Table 3. T_b was positively correlated with both T_a ($R^2 = 0.109$; $F_{(1, 50)} = 6.125$; $P < 0.05$), and T_s ($R^2 = 0.306$; $F_{(1,50)} = 22.139$; $P < 0.05$; Fig. 5). T_b averaged 4.35 ± 2.22 °C higher than T_s (Paired $t_{(51)} = 14.13$; $P < 0.05$), and 1.36 ± 2.73 °C higher than T_a (Paired $t_{(51)} = 3.607$; $P < 0.05$). No sex differences were apparent in T_b (Sex: $F_{(1,50)} = 0.763$, $P = 0.387$) and T_b did not vary significantly among the different microhabitats ($F_{2,49} = 2.357$, $P = 0.105$, Table 2).

4. DISCUSSION

This population of *Ptychoglossus bicolor* has a highly specialized diet; its preference for isopods is strongly marked and this may explain in some way its microhabitat preference. Leaf litter, rotting logs, and roots are always full of decomposers like isopods (Paoletti and Hassall 1999), so lizards might choose to forage at these microhabitats. Because no differences were found in the volume of isopods eaten in the three categories of microhabitats, and because no lizards were found out of the microhabitats offered by the coffee field, a study of the relative abundance of isopods and diet of *P. bicolor* both in and out of the coffee fields in areas without an anthropogenic influence would be worthwhile. Such a study would provide a good basis to compare if natural populations of *P. bicolor* have similar dietary preferences or if these preferences are historically constrained.

Terrestrial isopods are soil-dwelling arthropods often showing sensitiveness to soil physical-chemical properties and limited dispersal capabilities, and thus may constitute good indicators of soil properties (Paoletti and Hassall 1999), especially on a local scale perspective (Almerão et al. 2006). The diet of terrestrial isopods is

mostly decaying organic materials such as leaf-litter, decayed wood (rotting logs), and fungi and bacteria mats, plus coprophagy improves nutrient uptake, especially for juveniles (Paoletti and Hassal 1999). At the same time, isopods and coleopteran larvae are soft-body arthropods. Still, soft-bodied ants are abundant at the coffee field, yet no ants were found in the diet of *P. bicolor*, suggesting that the lizards select higher quality prey or avoid prey that might contain noxious chemicals. Vitt et al. (2003b) noted the same pattern in other gymnophthalmids. Thus, organic farming, high relative humidity, a rich leaf-litter layer from coffee trees and shade trees, and the shade provided at the plantations might enhance isopod richness, resulting in a high continuous source of food for these lizards, probably also influencing the continuous reproductive pattern observed in this population (E.P. Ramos personal communication, 2008).

Lizards of *P. bicolor* live in coffee shade plantations, diving into the leaf-litter of this terrestrial habitat and burying into the roots of coffee trees and under rotting logs. Thus, in terms of microhabitat use, *P. bicolor* is very similar to other gymnophthalmids (Harris 1994; Teixeira and Fonseca 2003; Santos et al. 2008). *Ptychoglossus bicolor* is common at these coffee fields but not in open areas out of these plantations, reflecting a marked microhabitat preference for areas rich in coffee leaf litter, similar to gymnophthalmids in the Amazon rainforest and in the Cerrado of Brazil (e.g. *Prionodactylus eigenmanni*, Vitt et al. 1998b; *Leposoma scincoides*, Teixeira and Fonseca 2003; *Prionodactylus oshughnessyi*, Vitt et al. 2003b; *Alopoglossus angulatus* and *A. atriventris*, Vitt et al. 2007). These microhabitat preferences may derive from the substantial availability of food and space resources found at these coffee fields. Organic coffee agrosystems and coffee shade plantations have been recognized as a potential refuge for biodiversity, mainly because these environments have special properties (like an abundant layer of organic material undergoing continuous nutrient cycling by a rich macroinvertebrate fauna) and greatly overlap with global biodiversity hotspots (Hardner and Rice 2002; Perfecto et al. 2007; Ritcher et al. 2007).

Ptychoglossus bicolor occurs in relative cool microhabitats, differing in its T_b from other gymnophthalmids that occupy terrestrial microhabitats (Vitt and Avila-Pires 1998; Vitt et al. 1998a; Vitt et al. 2003b; Vitt et al. 2007; Table 4). This variation may result from altitudinal differences in their habitats, as *P. bicolor* occurs at higher elevations than other gymnophthalmids studied. The T_b of *P. bicolor* is similar to that of *Neusticurus epleopus* (23.88 °C and 23.8 °C, respectively); however, *N. epleopus* is associated with stream banks and frequently enters water, explaining its relative cold body temperature (Vitt et al. 1998a). Maintenance of T_b significantly higher than T_a may reflect a behavioral mechanism for gaining heat (Verwajen and Van Damme 2007); *P. bicolor* probably use small sunlit patches in the leaf litter of the coffee shade plantation, as do gymnophthalmids in Amazonian rainforests (Vitt et al. 2003b). This ability to perform with such a low body temperature may reflect the highly abundant source of food, promoting a more passive foraging mode that allows them to be active during cloudy days and in cold microhabitats (Karasov and Anderson 1984; Verwajen and Van Damme 2007). The significant relationships observed between T_b , T_a and T_s suggest that microhabitats might be chosen at least partially on the basis of temperature; however, other factors may influence *P. bicolor* microhabitat preferences as stated above. The absence of these lizards in habitats out of the coffee field does not allow us to explore this issue.

Ecological traits of this population open a new window to understand the impact of organic agrosystems on species interactions and diversity, especially in such poorly-known groups as the gymnophthalmids. Most studies focus on gymnophthalmids of the Amazonian and Cerrado forest regions (Vitt and Zani 1998; Vitt et al. 2003b; Mesquita et al. 2006), with few studies of gymnophthalmids in agroforest systems (*Leposoma scincoides*, Teixeira and Fonseca 2003) or in high elevation habitats (*Proctoporus*, Doan 2008). *Leposoma scincoides* was found related to a coffee field, as was *P. bicolor*, and similarly isopods were the most important food item, but its niche breadth was wider than *P. bicolor*. *Leposoma*

scincoides eats more of other prey than does *P. bicolor* (e.g. numerically Isopoda, 55%; Araneae, 41%; Collembola, 17%; Blattodea, 14%; and Coleoptera, 14% dominated its diet; Teixeira and Fonseca 2003).

Based on our dietary and spatial data, this population of *Ptychoglossus bicolor* is comprised of dietary specialists with specific microhabitat preferences, thus rendering this population highly vulnerable. Any modification affecting the availability of light, leaf-litter, humidity and off-course food resources such as isopods could be disastrous. Such quantifiable natural history data not only provide interesting insights into potential species interactions that maintain or generate biodiversity on local, landscape, and regional levels, but also provide crucial information necessary to defend protected and unprotected areas with convincing arguments regarding effects of habitat modification on resident species (Greene 1994; Vitt et al. 2003c).

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Figure 1. Climate of the study area. Data correspond to the monthly average precipitation and temperature of La Hacienda El Roble (Mesa de los Santos, Santander). Current data were recorded from the coffee farm station, and historical data were taken from the DIVA-GIS database.

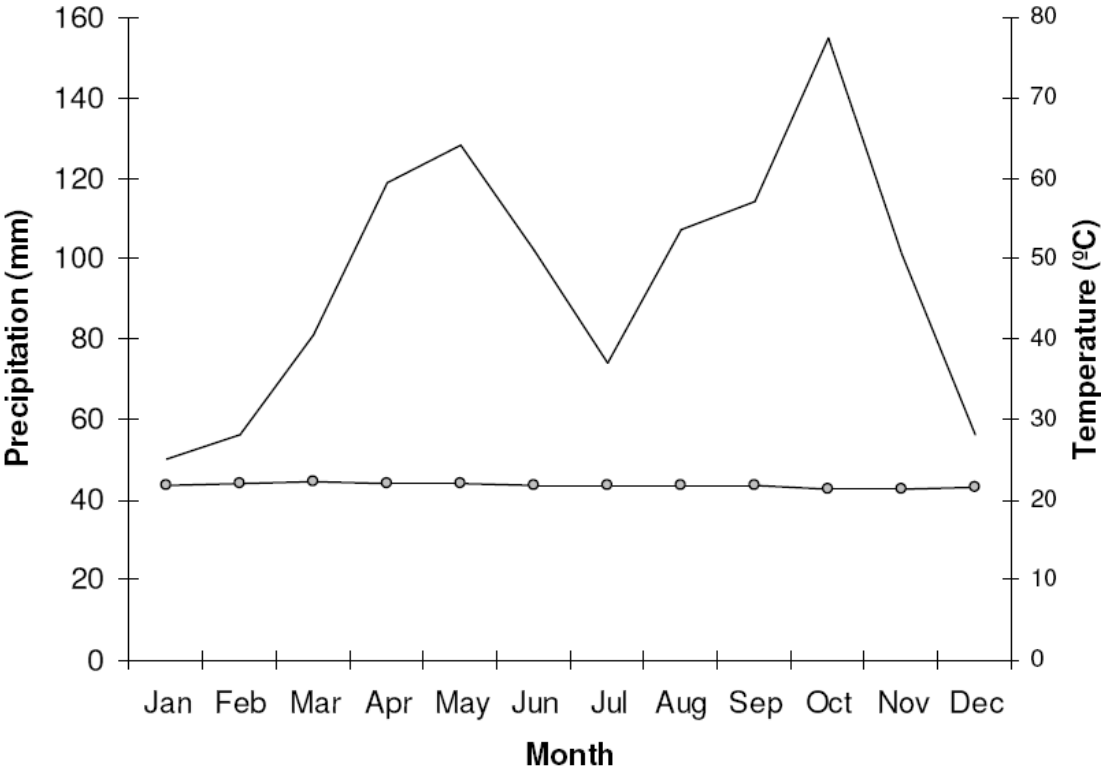


Figure 2. Diet variation over time of *Ptychoglossus bicolor*. Graph shows volume of isopods, and volume of the full stomach content variation. The bars represent \pm 95% confidence bounds for the means. Covariate mean for SVL: 1.74639.

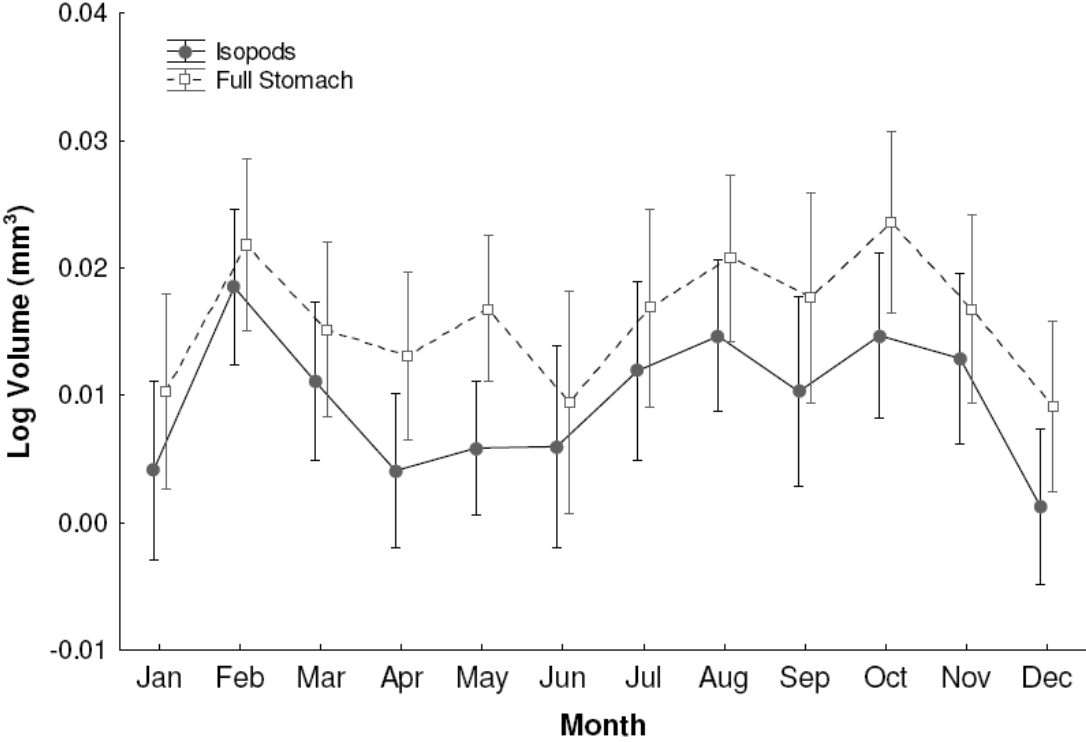


Figure 3. Relationships between lizard size and total volume of prey in stomach of *P. bicolor*. The degree of fullness of the stomach varies among individuals. The upper line is an estimate of where points for lizards with completely full stomach should lie; points for lizards with a nearly empty stomach would approach the x axis. Data are shown non-log-transformed to illustrate that most stomachs were not nearly full.

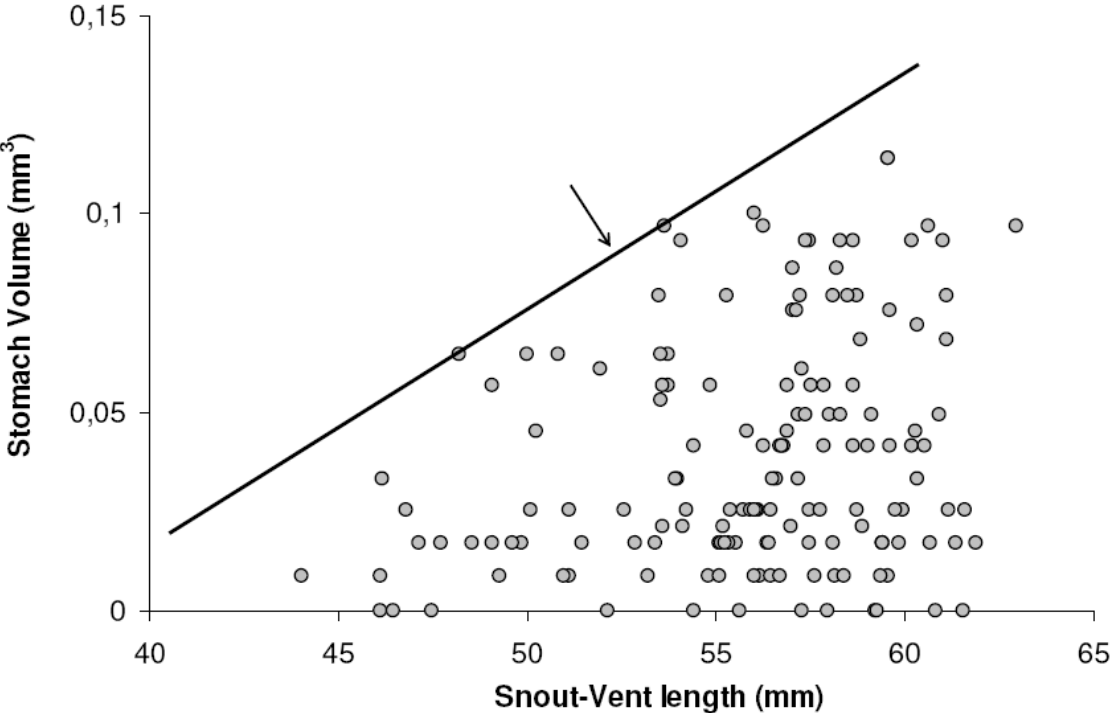


Figure 4. Frequency of lizards in different microhabitats in a coffee shade plantation at La Mesa de los Santos (Santander, Colombia)

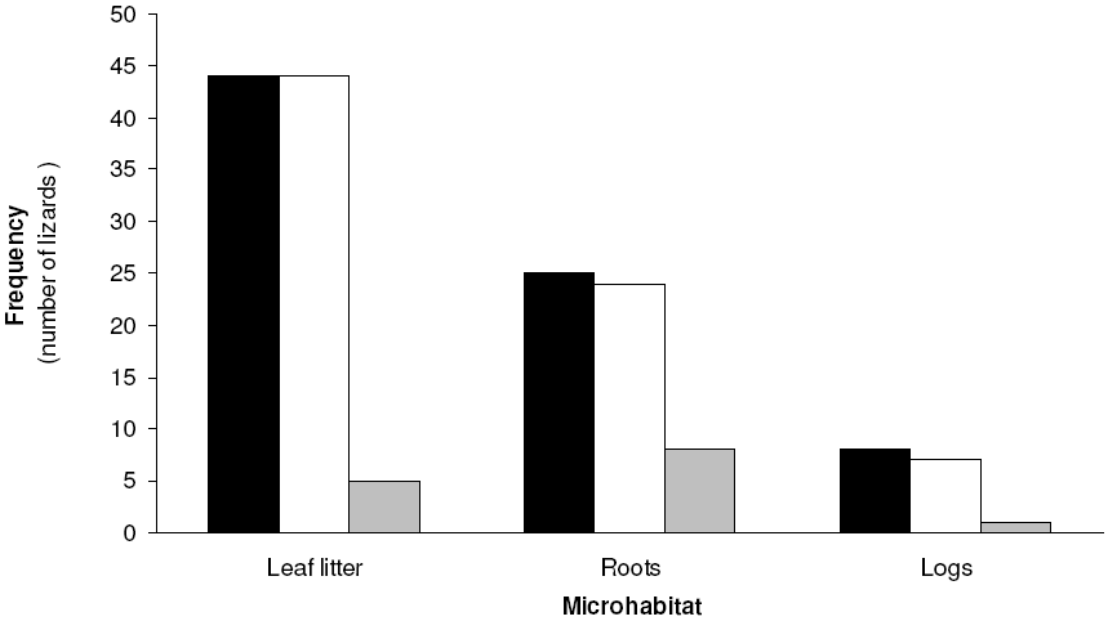


Figure 5. Relationship between lizard body temperature (T_b) and substrate temperature (T_s) for *Ptychoglossus bicolor*. $T_b = -21.28 + 2.312x$ ($R^2 = 0.307$).

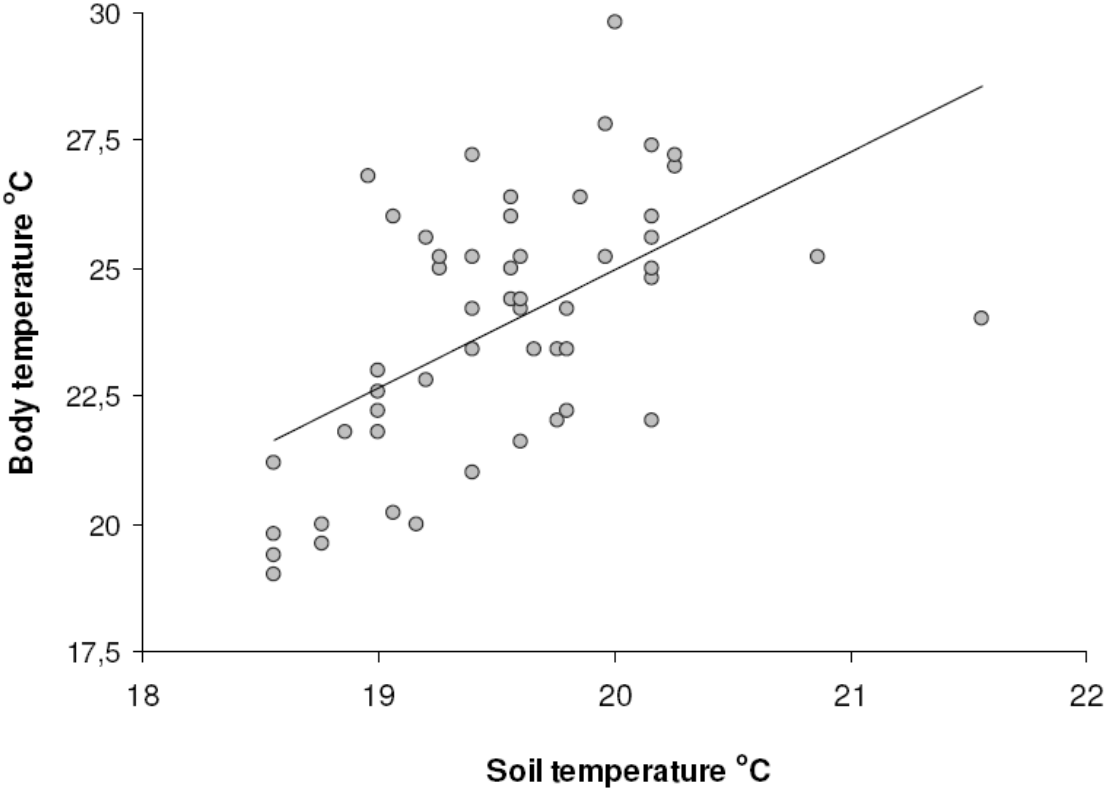


Table 1. Diet of *Ptychoglossus bicolor* at the coffee shade plantations. No, Number of items; %No, Numerical percentage of the prey type; Vol (ml), Total volume of prey type; %Vol, Volumetric percentage of the prey items; %Fq, percentage of lizards containing a particular prey type.

	No	% No	Vol ml	% Vol	% Fq	IRI
ISOPODS	417	89.13	8.73	80.8	87.93	98.82
COLEOPTERA LARVAE	16	3.41	0.82	7.56	10.34	0.30
COLEOPTERA	12	2.56	0.35	3.25	9.48	0.36
DERMAPTERA	11	2.35	0.43	4.02	10.34	0.43
OTHERS*	12	2.56	0.47	4.36	9.48	0.06
B (Simpson)	1.25	1.51				
Levin (Ba)	0.09	0.11				

*.Strepsiptera, Hemiptera, Orthoptera, Psocoptera, Hymenoptera, Collembola, and Araneae.

Table 2. Microclimatic characteristics of the microhabitats occupied by *Ptychologssus bicolor* in an organic coffee shade plantation. Relative humidity (RH%), soil temperature (T_s), and air temperature (T_a) are shown. N, number of microhabitat measured; SD, standard deviation; Min, lowest value, and MAX, maximum value.

	MICROHABITAT														
	Leaf litter					Log					Root				
	N	Mean	SD	min	MAX	N	Mean	SD	min	MAX	N	Mean	SD	min	MAX
RH%	33	79	7	66	92	7	79	10	62	90	12	83	7	70	93
T_s °C	33	19.62	0.52	18.56	20.86	7	19.65	0.93	18.76	21.56	12	19.21	0.51	18.56	20.26
T_a °C	33	21.96	2.03	19.00	25.56	7	22.98	3.18	20.56	27.96	12	21.03	1.15	19.60	23.56

Table 3. Body temperature (T_b), soil temperature (T_s), and air temperature (T_a, 5 cm above the ground) of *Ptychoglossus bicolor* are shown for all individuals. N, number of lizards; min, lowest value; MAX, maximum value; SD, standard deviation. Temperatures in °C.

	N	Mean	min	MAX	SD
T _b	52	23.89	19.00	29.80	2.49
T _s	52	19.53	18.56	21.56	0.60
T _a	52	21.88	19.00	27.96	2.10

Table 4. Comparative temperature (°C) between some gymnophthalmids. *Ptychoglossus bicolor* performs with the lowest T_b, T_s and T_a of these lizards.

Species	Body Temperature	Soil Temperature	Air Temperature	Microhabitat	Source
<i>Alopoglossus angulatus</i>	26.1 ± 1.15 (N= 2)	25.1 ± 0.3 (N= 10)	25.9 ± 0.4 (N= 10)	Leaf litter	Vitt et al.. 2007
<i>A. atriventris</i>	27.0 ± 0.02 (N= 63)	25.7 ± 0.4 (N= 10)	26.6 ± 0.4 (N= 10)	Leaf litter	Vitt et al.. 2007
<i>Neusticurus ecpleopus</i>	27.0 ± 0.02 (N= 63)	25.5 ± 0.02 (N= 63)	26.1 ± 0.1 (N= 63)	Streams	Vitt et al.. 1998
<i>Prionadactylus argulus</i>	29.9 ± 0.44 (N= 10)	27.2 ± 0.3 (N= 5)	27.3 ± 0.3 (N= 5)	Vines	Vitt et al.. 2003
<i>P. eigenmanni</i>	29.0 ± 0.3 (N= 13)	27.2 ± 0.19 (N= 10)	27.1 ± 0.20 (N= 10)	Leaf litter	Vitt et al.. 1998b
<i>P. oshaughnessyi</i>	23.89 ± 2.49 (N= 52)	27.2 ± 0.5 (N= 14)	27.1 ± 0.4 (N= 14)	Leaf litter and Trunk	Vitt et al.. 2003
<i>Ptychoglossus bicolor</i>	23.89 ± 2.49 (N= 52)	19.53 ± 0.6 (N= 52)	21.88 ± 2.10 (N= 52)	Leaf litter	This study

