Herpetology Notes, volume 8: 401-405 (2015) (published online on 12 August 2015)

Notes on the diet of seven terrestrial frogs in three agroecosystems and forest remnants in Northwestern São Paulo State, Brazil

Marcelo Menin[1,*], Rodrigo Souza Santos[2], Rinneu Elias Borges[3], Liliana Piatti[4]

Abstract. Anurans are predators of a great diversity of invertebrates, but studies on agroecosystems are very scarce. Herein we described the diet composition of seven species of terrestrial anurans captured in three different agroecosystems (corn, soybean and rubber tree) and in forest remnants of the Northwestern region of São Paulo state, Brazil. Ten prey categories were identified in the stomachs of 80 specimens belonging to the families Bufonidae, Leptodactylidae and Microhylidae. Hymenoptera (Formicidae) was consumed by all species. Coleoptera was the most frequent item, consumed by six of the seven species followed by Araneae and Isoptera. Isoptera was the most abundant item followed by Formicidae, Coleoptera and Araneae. Adults and juveniles of *Physalaemus nattereri*, the most abundant species in our study, consumed Formicidae and Isoptera more than other food items and there is not a significant difference in the abundance of consumed prey items between the age categories. In summary, the majority of the studied species can be considered generalists predators and, probably, consumed the prey items available in the environment. The most abundant species found in our study can be considered here as having a specialized diet, by consuming social insects in great frequency.

Keywords. Amphibians, feeding ecology, natural history, pitfall traps

Introduction

Anurans are predators of a great diversity of invertebrates, and many species are considered generalists and opportunists (Duellman and Trueb, 1994). Moreover, the diet can be related to the availability of preys in the environment (Menin et al., 2005). On the other hand, some species may be considered specialist predators (Duellman and Trueb, 1994; Santana and Juncá, 2007). The majority of the studies on the diet of the anurans were developed in pristine areas (e.g. Sugai et al., 2012), fragmented landscape (e.g. Silva and Rossa-Feres, 2010) or also in disturbed areas such as ponds in pasture areas (e.g. Rossa-Feres, 1997). However, studies on agroecosystems such as soybean, rice and coffee plantations are very scarce (Attademo et al., 2005; Piatti and Souza, 2011; Hoyos-Hoyos et al., 2012).

Agroecosystems can produce deleterious effects due the fragmentation of the habitat resulting in a change of the fauna composition and the relationships among the species in the communities (Altieri et al., 2003). Moreover, in these agricultural systems the use of pesticides is a common practice that negatively affects amphibian communities (Bridges and Semlitsch, 2000; Semlitsch et al., 2000). Another important factor is the effect of the agriculture on the feeding habits of the species (Hoyos-Hoyos et al., 2012). However, there are a few set of studies regarding productive systems in the Neotropical region evaluating the effects of these

[1] Departamento de Biologia, Instituto de Ciências Biológicas, Universidade Federal do Amazonas, Av. General Rodrigo Otávio Jordão Ramos 3000, 69077-000, Manaus, AM, Brazil.

[2] Embrapa Acre, Caixa Postal 321, 69900-970, Rio Branco, AC, Brazil.

[3] Universidade do Rio Verde, Caixa Postal 104, 75901-970, Rio Verde, GO, Brazil.

[4] Programa de Pós-Graduação em Ecologia, Instituto de Biociências, Universidade de São Paulo, Rua do Matão 321, Trav. 4, 05508-090, São Paulo, SP, Brazil.

* Corresponding author: menin@ufam.edu.br

Table 1. Number of individuals and snout-vent length (SVL ± standard deviation and range) of seven anuran species captured in three agroecosystems and forest remnants in the municipalities of Jaboticabal and Guaíra, state of São Paulo, Brazil.

Family/Species	Jaboticabal				Guaíra			Total of individuals	SVL
	Corn	Soybean	Rubber Tree	Forest Remnant	Corn	Soybean	Forest Remnant		
Bufonidae									
Rhinella schneideri (Rs)	-	-	-	-	-	3	-	3	56.79±1.79 (55.52-58.84)
Leptodactylidae									
Leptodactylus fuscus (Lf)	2	1	1	-	-	-	-	4	31.13±5.91 (25.83-39.59)
Leptodactylus mystacinus (Lm)	3	6	3		1	-	1	14	34.00±12.74 (23.69-66.87)
Physalaemus cuvieri (Pc)	4	3	1	2	1	-	-	11	27.09±6.10 (17.51-33.23)
Physalaemus marmoratus (Pm)	-	-	-	-	6	-	-	6	26.77±4.67 (22.68-35.24)
Physalaemus nattereri (Pn)	37	7	6	-	2	1	-	53	28.76±6.17 (20.35-47.98)
Microhylidae									
Dermatonotus muelleri (Dm)	-	-	-	-	3	-	-	3	31.04±4.33 (28.24-36.03)
Total	46	17	11	2	13	4	1	94	

systems on the herpetofauna community (e.g., Attademo et al., 2005; Silva et al., 2009; Piatti et al., 2010; Hoyos-Hoyos et al., 2012). In spite of the limited interpretation of the results in these studies, some authors emphasize the importance of the amphibians as important agents on arthropods control in agricultural areas (Attademo et al., 2005).

In this study we describe the diet composition of seven species of terrestrial anurans captured in three different agroecosystems (corn, soybean and rubber tree) and also in forest remnants in two areas of the Northwestern region of São Paulo state in Brazil. We also provide information on the diet composition according to the age of the most abundant species found in our study.

Material and Methods

The study took place in two areas in the State of São Paulo, Brazil: (1) Fazenda de Estudo, Pesquisa e Produção of the Faculdade de Ciências Agrárias e Veterinárias, Universidade Estadual Paulista, municipality of Jaboticabal (-21.2561ºS, -48.3161ºW) and (2) plantations located in municipality of Guaíra (-20.5680°S, -48.6180°W). The regional climate is tropical seasonal (Cwa of the Köppen-Geiger system), with hot summer and dry winter (Peel et al., 2007). Temperature and rainfall annual averages are approximately 22 ºC and 1,552 mm, respectively (Sacramento and Pereira, 2003).

Anurans were captured in pitfall traps between December 2004 and April 2005 in three different agroecosystems (corn, soybean and rubber tree in Jaboticabal and corn and soybean in Guaíra) and in forest remnants near the agroecosystems. The mesophytic semideciduous forest remnants were adjacent to soybean plantations in both areas (Jaboticabal: one fragment of 22 ha; Guaíra: two fragments of 6 and 48 ha). Two transects of 90 m long and 10 m apart each other were installed in each crop environment. Each transect had ten white plastic cups (500 mL) installed every 10 m (Santos and Cividanes, 2007; Silva et al., 2009). Two transects with 24 cups (500 mL) each one were installed in the forest remnants. A total of 20-24 pitfall traps were installed in each agroecosystem and forest remnant. Specimens were collected from the pitfall traps once a week, totaling 13 samples in each agroecosystem type and forest remnant and 97 days of total effort (Silva et al., 2009).

In order to determine the diet of the anuran species, a total of 94 individuals, which were fixed in formalin 10%, were dissected and the stomach contents were counted and identified to order or family following

Table 2. Number and frequency of occurrence (% of the stomachs containing the item) of prey taxa in the diet of seven anuran species captured in three agroecosystems and forest remnants in the municipalities of Jaboticabal and Guaíra, state of São Paulo, Brazil. Species codes as in Table 1. The parenthesis below the species codes indicated the number of filled and empty stomachs.

Category of preys	Species						
	Rs (2/1)	Lf (4/0)	Lm (9/5)	Pc (10/1)	Pm (6/0)	Pn (48/5)	Dm (2/1)
Araneae	-	3 (75)	6 (21)	5 (36)	8 (83)	1 (2)	-
Coleoptera	18 (67)	3 (75)	4 (14)	4 (36)	9 (67)	1 (2)	-
Dermaptera	-	-	1 (7)	2 (9)	-	-	-
Diptera	-	-	2 (14)	-	1 (17)	-	-
Hemiptera	-	-	-	1 (9)	-	-	-
Hymenoptera (Formicidae)	114 (67)	1 (25)	2 (14)	292 (91)	254 (83)	473 (55)	180 (33)
Hymenoptera (others)	1 (33)	-	-	-	-	-	-
Isoptera	-	-	2 (7)	33 (36)	70 (17)	1,573 (64)	8 (33)
Mollusca Gastropoda	-	-	1 (7)	-	-	-	-
Unidentified insect larvae	-	1 (25)	6 (36)	3 (18)	4 (50)	7 (13)	-

Triplehorn and Jonnson (2011) identification keys. Anurans voucher specimens are deposited in the Amphibian Collection of the Departamento de Zoologia e Botânica, Universidade Estadual Paulista, São José do Rio Preto, São Paulo, Brazil (DZSJRP 8280-8282, 8284-8305, 8308-8339, 8341-8372, 8375-8379). The nomenclature in this study is in accordance with Amphibian Species of the World (Frost, 2015). Adults and juveniles were classified according to the snout-vent length (SVL) following information available on the literature (*Rhinella schneideri* – adults SVL > 118.0 mm and *Leptodactylus fuscus* – SVL > 42.8 mm, Silva et al., 2008; *Leptodactylus mystacinus* – SVL > 50.5 mm, De-Carvalho et al., 2008; *Physalaemus cuvieri* – SVL > 29.0 mm, Silva and Rossa-Feres, 2010; *Physalaemus marmoratus* – SVL > 34.6 mm, Giaretta and Menin, 2004; *Physalaemus nattereri* – SVL > 29.0 mm, Silva and Rossa-Feres, 2010; *Dermatonotus muelleri* – SVL > 56.9 mm, Vaz-Silva et al., 2003).

The abundance of the consumed prey items was compared by the T test to adults and juveniles of *P. nattereri*, the most abundant species in our study. Statistics were performed with the software MYSTAT 12.0.

Results

Were captured a total of 94 specimens of seven species belonging to families Bufonidae (*Rhinella schneideri*), Leptodactylidae (*Leptodactylus fuscus*, *L. mystacinus*, *Physalaemus cuvieri*, *P. marmoratus*, and *P. nattereri*), and Microhylidae (*Dermatonotus muelleri*) (Table 1). The most abundant species was *P. nattereri* corresponding to 56% of the total of captured individuals (Table 1). For diet analysis we used the total number of individuals per species in all sampled areas due to the small number of individuals in each agroecosystem type and forest fragment. Of the 94 anurans examined, 80 had stomach contents (85.1%). Ten prey categories and 3,094 prey items were identified in the stomachs (Table 2). Hymenoptera (Formicidae) was consumed by all species. Coleoptera was consumed by six of the seven species followed by Araneae and Isoptera (found in the stomachs of five species). Isoptera was the most abundant item (1,686 individuals) followed by Hymenoptera (Formicidae) (1,316 individuals), Coleoptera (39), Araneae (23), Unidentified Insect larvae (21), Diptera (3), Dermaptera (2), Hemiptera (1), Other Hymenoptera (1) and Mollusca (1). The items with greater frequency in the individual stomachs were Hymenoptera (Formicidae) (14 to 100%), Araneae and Coleoptera (2 to 83%) and Isoptera (7 to 62%).

Adults and juveniles of *P. nattereri* consumed Hymenoptera (Formicidae) and Isoptera more than other food items (Table 2). Isoptera was the most frequently food item in the diet of both adults and juveniles (Table 3). There is not a significant difference in the abundance

Table 3. Absolute abundance (N), relative abundance (N%), frequency (F; number of stomachs containing the prey item), and frequency of occurrence (F%; percentage of the stomachs containing the prey item) of each prey item in the diet of adults and juveniles of *Physalaemus nattereri* captured in three agroecosystems in the municipalities of Jaboticabal and Guaíra, state of São Paulo, Brazil.

Category of preys	Adults (n = 21)				Juveniles (n = 32)			
	N	N%	F	F%	N	N%	F	F%
Araneae	-	-	-	-	1	0.08	1	3.1
Coleoptera	1	0.11	1	4.8	-	-	-	-
Hymenoptera (Formicidae)	123	14.01	10	47.6	350	29.74	18	56.2
Isoptera	752	85.65	14	66.7	821	69.75	20	62.5
Unidentified insect larvae	2	0.23	2	9.5	5	0.43	5	15.6
TOTAL	**878**	**100.0**	-	-	**1,177**	**100.0**	-	-

of consumed prey items between the age categories (t = -0.275, df = 8, p = 0.79).

Discussion

In spite of limited interpretation of our results due to the small sample size to many species, it is the first study evaluating the diet of the Brazilian frogs in corn, soybean and rubber tree plantations as far as we know. The only other study on crop environment in Brazil is that by Piatti and Souza (2011) in rice fields in Pantanal, Brazil. The species found in the sampled area are considered habitat generalists (Silva et al., 2009), commons in open areas and forest remnants in the studied region (Rossa-Feres 1997; Silva and Rossa-Feres, 2007, 2010). Isoptera was the most abudant item and can be related to the abundance of winged individuals during the period of this study (R.S.Santos, personal observation). Two species (*R. schneideri* and *L. mystacinus*) are also reported in agricultural environments in Argentina (Attademo et al., 2005). *Rhinella schneideri*, *P. marmoratus*, and *D. muelleri* are cited for the first time in crop environments, while *L. fuscus*, *L. mystacinus*, *P. cuvieri*, and *P. nattereri* were found by Silva et al. (2009) in the same study area. The number of species and individuals captured in the forest remnants were very small. Despite this, some species from open areas are found in forest remnants in Northwestern São Paulo State (Silva and Rossa-Feres, 2007, 2010).

The prey items found in the diet of the majority of species in our study were similar to those reported in other studies of different localities and Biomes in Brazil (Moreira and Barreto, 1996; Rossa-Feres, 1997; Vaz-Silva et al., 2003; Giaretta and Menin, 2004; Santos et al., 2004; Araújo et al., 2007; De-Carvalho et al., 2008; Silva and Rossa-Feres, 2010; Batista et al., 2011; Sugai et al., 2012). However, the diversity of prey items consumed by *R. schneideri*, *L. fuscus*, *L. mystacinus*, *P. cuvieri* and *P. marmoratus* was lower than reported in these studies which were developed in pristine areas, forest fragments or water bodies in pasture. This fact probably occurs due to three possibilities: 1) small number of sampled frogs (exception to *P. nattereri*), 2) the small diversity of prey items in the agroecosytems (Altieri et al., 2003), or 3) the majority of individuals captured in our study was juveniles (see the size of individuals in Table 1) and this can contribute to the small diversity of prey items in the stomachs. The pitfall traps used in our study were installed with the initial purpose of capturing edaphic insects, so they are much smaller than those used in herpetofaunal studies. Thus, the small trap size permitted the capture of juveniles of large-size anurans or juveniles and adults of small-size anurans.

Physalaemus nattereri is considered a diet specialist, consuming Hymenoptera (Formicidae) and Isoptera in greater abundance and frequency. This result is similar to the ones found by other authors to areas in São Paulo state, Brazil, including populations studied in artifical ponds in pasture areas (Rossa-Feres, 1997) and forest remnants (Silva and Rossa-Feres, 2010), suggesting that the diet of this species is a conservative characteristic (Silva and Rossa-Feres, 2010).

In summary, some terrestrial anuran species can be found in agroecosystems in the studied regions. The majority of the studied species can be considered generalist predators and, probably, consumed the prey

items available in the environment. Based on the great similarity in the diet composition of *Physalaemus nattereri*, the most abundant species found in our study in comparison to other studies in different habitats, this species can be considered a diet specialist consuming social insects in great frequency.

Acknowledgments. We thank Luciana Maira de Sales Pereira (Universidade Federal do Acre – UFAC) for the English review; Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for a Research Productivity Grant to MM.

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Accepted by Martin Jansen