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ARTICLE

Seasonal variation of understory insectivorous birds and arthropods in an area of secondary Atlantic Forest, southeast Brazil

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ABSTRACT: Seasonal variation of understory insectivorous birds and arthropods was investigated in an area of secondary Atlantic Forest, in southeast Brazil. Birds were captured with mist-nets and arthropods collected on the ground and foliage. A total of 348 captures of 243 individuals belonging to 15 bird species were obtained. Among 3416 arthropods, 1782 were collected on the ground and 1634 on the foliage. There was no significant variation in numbers of captures, individuals and bird species between dry and rainy seasons. However, arthropods were more abundant on the foliage during the dry season and on the ground in the rainy season. In this way, although the number of arthropods varied between seasons, it seems to be a sufficient resource to insectivorous birds feeding along the year. Besides, these birds can present some plasticity, changing the frequency of their foraging tactics repertoire in search of this feeding resource.

KEY-WORDS: arthropod abundance, foraging birds, seasonality, semideciduous forest, trophic ecology.

INTRODUCTION

Insectivorous birds comprise most of the understory bird species in tropical forests (Cueto & Casenave 2000, Dário *et al.* 2002), and together with the food resources that they explore (insects and other arthropods), involve important issues on ecological interactions (Karr *et al.* 1982, Develey & Peres 2000, Codesido & Bilenca 2004). Some studies have evaluated the relationship between food resources and dynamics of populations and bird communities in many temperate and tropical regions (*e.g.* Loiselle & Blake 1990, Poulin & Lefebvre 1996, Burger *et al.* 1999, Malizia 2001). However, few studies have investigated the responses of insectivorous birds to the availability of their feeding resources in forest environments (Raley & Anderson 1990, Poulin *et al.* 1994, Manhães & Dias 2011).

The prey consumed by understory insectivorous birds, found both on the ground and foliage of trees and shrubs, can vary in different microhabitats due to the influence of abiotic conditions and vegetation structure (Smith *et al.* 1978). Furthermore, although arthropods can be a highly abundant and regular resource when compared to flowers and fruits (Buskirk & Buskirk 1976, Poulin *et al.* 1994), they may also present seasonal variations, reducing their abundance in dry periods (Develey & Peres 2000). Consequently, the uneven spatial and temporal distribution of this prey resource can influence the number of individuals or the composition of insectivorous bird species in a community (Martin & Karr 1986, Horne & Bader 1990, Chesser 1995, Naranjo & Ulloa 1997).

Most studies relating the composition of the bird communities to the available food resources have been carried out with frugivorous birds (Moermond & Denslow 1985, Loiselle & Blake 1990), whereas studies with insectivores still remain restricted, mainly to the descriptive analysis of their diet (Ralph *et al.* 1985, Blake & Rougès 1997, Gomes *et al.* 2001, Rougès & Blake 2001).Thus, this study aimed to investigate the seasonal relationship between the richness and abundance of understory insectivorous birds and arthropods from different microhabitats (soil and foliage) in an area of the secondary Atlantic Forest in southeastern Brazil.

METHODS

Study area

The study area is a secondary Atlantic Forest fragment with 56 ha (Manhães *et al.* 2010), classified as a lower montane semideciduous forest (Oliveira-Filho *et al.* 2005) belonging to a private property named "Fazenda Continente". The farm is located at 21°37'S; 43°21'W, between the municipalities of Juiz de Fora and Coronel Pacheco, Minas Gerais state, southeastern Brazil (Fig. 1). The altitude of the region varies between 670–800 m, and the climate is classified as Köppen Cwa (humid subtropical), with annual temperatures of around 20.2°C. The region has well-defined dry and rainy seasons (Granzinolli & Motta-Jr. 2006) and the annual rainfall varies around 1536 mm (Fig. 2).

Bird samplings

Birds were captured during December 2005, January and February 2006 (rainy season), and June and July 2006 (dry season). Birds were captured by using 12 × 3 m mist-nets, with 38 mm mesh, installed at ground level in four pre-established transects (Fig. 1), standardizing 10 nets in line on each transect. Each transect was sampled twice for two consecutive days, with at least 20 days between the two samplings of the same transect, totaling 16 sampling days with mist-nets at each season. Captures began around 06:00 h and 06:30 h and continued for 10 h on the first day and 9 h on the second, settling intervals of 30–45 min to monitoring nets. The sampling effort totaled 3040 mist-net h, 1520 at each season. Birds captured were marked with numbered aluminum rings, provided by *Centro Nacional de Pesquisa e Conservação de Aves Silvestres (CEMAVE)* of *Instituto Chico Mendes de Conservação da Biodiversidade (ICMBio)*, and they were subsequently released near the capture sites. The classification of birds followed Remsen-Jr. *et al.* (2015).

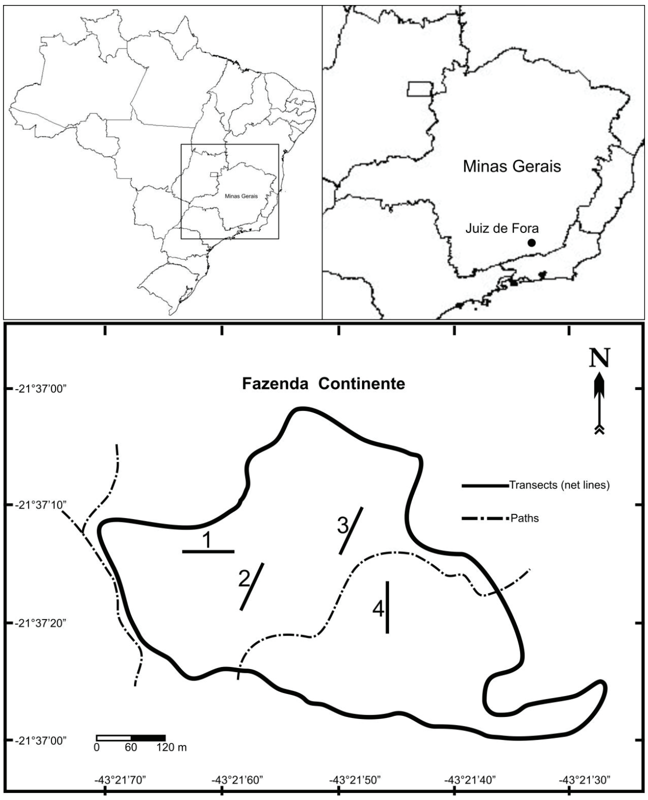

Figure 1. Map showing the localization of the study area and of the sampling transects (net lines). The "Continente Farm", state of Minas Gerais, southeastern Brazil.

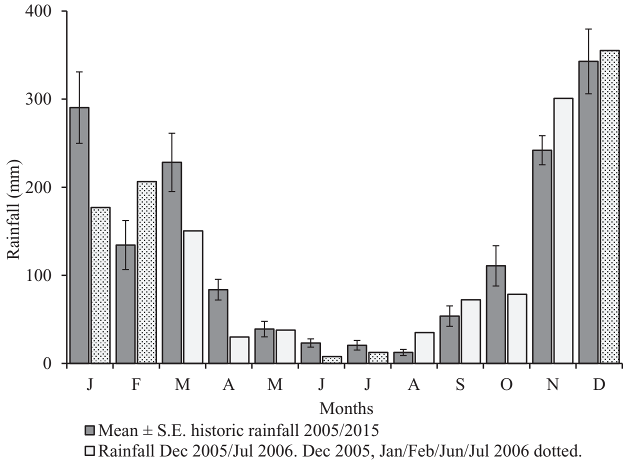

Figure 2. Rainfall Dec 2005/Nov 2006. Dec 2005, Jan/Feb/Jun/Jul 2006 dotted. Data from weather station of Juiz de Fora Federal University.

Arthropod sampling

Foliage arthropods were sampled using a branch-clipping technique, a method that involves pruning branches of trees or shrubs in the collection bags (Cooper & Whitmore 1990). Samplings between the left and right sides of the mist-nets were alternated every visit to the transect. For each sample, we used eight plastic bags (40 × 60 cm), and the samples were taken at about 1.5 m height and at a distance of 2–5 m perpendicular to the nets, excluding the first and the tenth. Disturbance level in vegetation was maintained as low as possible. Branches were wrapped in bags and pruned. Bags with vegetation samples were weighed using 500 g Pesola© scales. Vegetation was then shaken vigorously inside the bags to dislodge trapped arthropods, before being discarded. The remaining vegetation in the bags was carefully inspected on a cloth when the arthropods, collected with forceps, were transferred to envelopes and allowed to dry in a freezer. The inner walls of the bags were also inspected to check for possible arthropods adhered to them. Subsequently, the collected arthropods were counted and identified according to Borror *et al.* (1976) and McGavin (2000). Due to the variation in the volume of vegetation in each sample, always higher than 100 g, the number of arthropods was adjusted to 100 g of vegetation (excluding the weight of the bag) in the seasonality analysis.

Soil arthropods on the ground were captured using pitfall traps, consisting of plastic pots with a diameter of 10 cm and depth of 15 cm, buried in the ground with borders at the surface level. Each pot was filled with 20 ml of a solution with water and inodorous soap (10%), modified from Haugaasen *et al.* (2003). Plastic screens were fitted for each trap at about 25 cm above the ground to prevent falling leaves and twigs from entering the pots. In each of the transects sampled with mist-nets, eight pitfalls were installed, from the second to the ninth net, located at a distance of 3–5 m perpendicular to the center of each one. The traps remained open simultaneously with the bird samplings, and capped after the end of these activities to avoid catching nocturnal arthropods. The right and left sides of the net lines were sampled alternately every sampling day. At the end of sampling, the contents present in the pots were transferred to filter paper and, after drying, analyzed under a 10× – 40× stereo microscope.

Data analysis

The seasonal variability of the captures (including recaptures), the number of individuals and the number of species classified as foliage and ground foraging insectivores according to literature (*e.g.* Willis 1979, Rodrigues *et al.* 1994, D'Angelo-Neto *et al.* 1998) were measured with chi-square (χ^2) test. Seasonal variability in the abundance of arthropods was evaluated using a paired *t*-test after checking the data normality with the Kolmogorov-Smirnov test, considering soil ("pitfalls") and foliage ("branch-clipping") arthropods separately. For statistical analysis, we used the BioEstat 5.3 (Ayres *et al.* 2007).

RESULTS

There were 348 captures of insectivorous birds, totaling 243 individuals from 15 species of ground and foliage foraging insectivores. Foliage insectivores accounted for the vast majority of these species (12 species), with only three species of ground foragers: *Conopophaga lineata*, *Corythopis delalandi* and *Pyriglena leucoptera* (Table 1). The highest number of captures (including recaptures) and individuals was also among the foliage insectivores, corresponding to more than 60% of the total. The number of captures ranged from one (three species) to 105 (*Platyrhinchus mystaceus*), and the most common species were *P. mystaceus* (26.3% of individuals captured), *Basileuterus culicivorus* (14.4%), *C. lineata* (14.4%), *P. leucoptera* (14.4%), *Anabazenops fuscus* (7.4%) and *Corythopis delalandi* (6.2%). The species with highest proportion of recaptures was *P. mystaceus* (*n* = 41; 39%) and the least was *B. culicivorus* (*n* = 9, 20.5%) (Table 1).

A total of 3416 arthropods were collected by both method. In the pitfall traps occurred 1782 and the most abundant groups were Hymenoptera Formicidae (28.3%) and Diptera (25.6%). Other prey categories, such as Coleoptera (18.7%) and Orthoptera (14.4%), were also

Table 1. Understory insectivorous bird species captured in the dry and rainy seasons in an area of secondary Atlantic Forest, southeastern Brazil. FI – Foliage insectivores; GI – Ground insectivores.

Species	Habit	Total of captures (%)	No. captures rainy season	No. captures dry season	Total of individuals (%)	No. individuals rainy season	No. individuals dry season	Total of recaptures (%)
Thamnophilidae								
Thamnophilus caerulescens Vieillot, 1816	FI	3 (0.9)	2	1	3 (1.2)	2	1	-
Dysithamnus mentalis (Temminck, 1823)	FI	5 (1.4)	2	3	4 (1.6)	2	3	1 (20.0)
Pyriglena leucoptera (Vieillot, 1818)	GI	52 (15.0)	31	21	35 (14.4)	23	20	16 (30.8)
Conopophagidae								
Conopophaga lineata (Wied, 1831)	GI	52 (15.0)	20	32	35 (14.4)	16	27	17 (32.7)
Furnariidae								
Anabazenops fuscus (Vieillot, 1816)	FI	25 (7.2)	16	9	18 (7.4)	13	8	7(28.0)
Synallaxis ruficapilla Vieillot, 1819	FI	16 (4.6)	6	10	11 (4.5)	6	9	5(31.3)
Tyrannidae								
Corythopis delalandi (Lesson, 1830)	GI	22 (6.3)	10	12	15 (6.2)	9	10	7 (31.8)
Leptopogon amaurocephalus Tschudi, 1846	FI	7 (2.0)	5	2	7 (2.9)	5	2	-
Hemitriccus diops (Temminck,1822)	FI	1 (0.3)	1	-	1 (0.4)	1	-	-
Poecilotriccus plumbeiceps (Lafresnaye, 1846)	FI	1 (0.3)	1	-	1 (0.4)	1	-	-
Tolmomyias sulphurescens (Spix, 1825)	FI	11 (3.2)	6	5	10 (4.1)	6	5	-
Platyrinchus mystaceus Vieillot, 1818	FI	105 (30.2)	55	50	64 (26.3)	46	36	41 (39.0)
Myiophobus fasciatus (Statius Muller, 1776)	FI	1 (0.3)	-	1	1 (0.4)	-	1	-
Lathrotriccus euleri (Cabanis, 1868)	FI	3 (0.9)	2	1	3 (1.2)	2	1	-
Parulidae								
Basileuterus culicivorus (Deppe, 1830)	FI	44 (12.6)	24	20	35 (14.4)	21	20	9 (20.5)
TOTAL		348 (100)	181	167	243 (100)	153	143	103 (29.6)

well represented, while the remaining 14 arthropod groups together accounted for less than 15% of the total (Table 2). Variations in the proportion of arthropod groups captured in different seasons were observed (Table 2). On the other hand, 1634 foliage arthropods, corresponding to 22 categories of at least 16 orders were collected using a branch-clipping method. Spiders were the most abundant arthropods (35.2%), followed by Isopoda (15.9%), Coleoptera (15.1%), Hemiptera Heteroptera (5.8%) and Hymenoptera Formicidae (5.4%). The proportions of each group underwent minor variations between seasons (Table 2).

There was no seasonal variation in bird richness, the total number of captures and the number of individuals captured in any of the categories of insectivores (all χ^2 tests with $P > 0.1$) (Fig. 3). The abundance of soil arthropods was higher during the rainy season (t = -2.89; df = 63; $P < 0.01$) (Fig. 4), while a greater abundance of foliage arthropods was found in the dry season (t = -6.84; df = 63; $P < 0.01$) (Fig. 4).

Table 2. Arthropods collected by "branch-clipping" (foliage) and "pitfall" (ground) methods in rainy and dry seasons. * Number of individuals per 100 g of vegetation.

Category	Foliage						Ground		
	Rainy		Dry		Total		Rainy	Dry	TOTAL
	Frequency	n*(%)	Frequency	n*(%)	Frequency(%)	n*(%)	n(%)	n(%)	n(%)
Mollusca (non-arthropod)	1	0.5(0.2)	-	-	1(0.1)	0.5(0.1)	1(0.1)	-	1(0.1)
Orthoptera	25	14.5(4.0)	22	14.3(2.1)	47(2.9)	28.8(2.7)	131(12.4)	126(17.5)	257(14.4)
Phasmatodea	1	0.6(0.2)	-	-	1(0.1)	0.6(0.1)	-	-	-
Dermaptera	6	3.3(0.9)	1	0.7(0.1)	7(0.4)	4.0(0.4)	-	-	-
Mantodea	1	0.6(0.2)	-	-	1(0.1)	0.6(0.1)	-	-	-
Blattodea	4	2.2(0.6)	11	7.3(1.1)	15(0.9)	9.5(0.9)	1(0.1)	3(0.4)	4(0.2)
Isoptera	-	-	-	-	-	-	-	2(0.3)	2(0.1)
Hemiptera Heteroptera	19	11.9(3.3)	83	49.9(61.8)	102(6.2)	61.8(5.9)	15(1.4)	3(0.4)	18(1.0)
Hemíptera non-Heteroptera	40	24.5(6.7)	27	16.3(2.4)	67(4.1)	40.8(3.9)	18(1.7)	6(0.8)	24(1.4)
Coleoptera	84	50.1(13.8)	164	108.8(15.9)	248(15.2)	158.9(15.1)	293(27.6)	40(5.6)	333(18.7)
Diptera	9	5.4(1.5)	25	17.1(2.5)	34(2.1)	22.6(2.2)	154(14.5)	303(42.0)	457(25.7)
Lepidoptera	1	0.6(0.2)	9	6.1(0.9)	10(0.6)	6.7(0.6)	2(0.2)	-	2(0.1)
Hymenoptera non-Formicidae	15	9.1(2.5)	41	29.9(4.4)	56(3.4)	39(3.7)	25(2.4)	8(1.1)	33(1.9)
Hymenoptera Formicidae	45	27.3(7.5)	43	30.2(4.4)	88(5.4)	57.5(5.5)	352(33.2)	153(21.2)	505(28.3)
Isopoda	74	42.7(11.8)	183	124.6(18.2)	257(15.7)	167.3(15.9)	30(2.8)	15(2.1)	45(2.5)
Pseudoscorpiones	15	9.3(2.6)	3	2.5(0.4)	18(1.1)	11.8(1.1)	1(0.1)	13(1.8)	14(0.8)
Opilliones	17	9.9(2.7)	-	-	17(1.0)	9.9(0.9)	1(0.1)	-	1(0.1)
Acari	4	2.5(0.7)	-	-	4(0.2)	2.5(0.2)	1(0.1)	-	1(0.1)
Araneae	219	129.6(35.7)	360	240.0(35.0)	579(35.4)	369.6(35.2)	24(2.3)	19(2.6)	43(2.4)
Diplopoda	-	-	-	-	-	-	1(0.1)	-	1(0.1)
Larvae	12	7.1(2.0)	31	20.3(3.0)	33(2.0)	27.4(2.6)	9(0.9)	9(1.3)	18(1.0)
Nymph	2	0.9(0.3)	10	6.8(1.0)	12(0.7)	7.7(0.7)	1(0.1)	19(2.6)	20(1.1)
Pupae	3	1.7(0.5)	8	4.8(0.7)	11(0.7)	6.5(0.6)	-	-	-
Not identified	16	9.0(2.5)	10	6.7(1.0)	26(1.6)	15.7(1.5)	1(0.1)	2(0.3)	3(0.2)
TOTAL	613	363.1(100)	1031	686.4(100)	1634(100)	1049.7(100)	1061(100)	721(100)	1782(100)

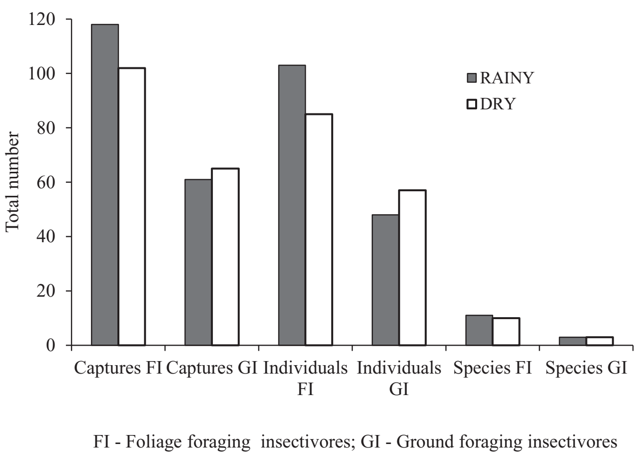

Figure 3. Seasonal variation in the number of captures, individuals and species of insectivorous birds in a secondary Atlantic Forest area, southeastern Brazil.

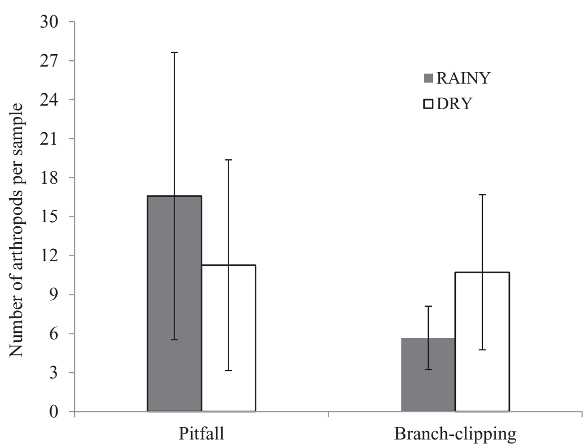

Figure 4. Mean ± standard deviation of arthropods individuals by sample captured by "pitfall" (ground) and "branch-clipping" (foliage) methods, in dry and rainy season in the Atlantic Forest area, state of Minas Gerais, Brazil.

DISCUSSION

Some studies have shown seasonal variations in the abundance of food resources, and although these variations are more pronounced in temperate regions where winters are marked by severe food scarcity, they also occur in tropical areas (Karr 1976, Newton 1980, Loiselle & Blake 1990). The abundance of arthropods in the tropics is related to the regime of dry and rainy seasons, with its higher density generally associated with rainy periods (Develey & Peres 2000).

In the studied area, the higher abundance of soil arthropods was found in the rainy season, with a substantial decline during the dry season. The study area has its own characteristics of a semideciduous forest, marked by a relatively severe dry season, usually from April to September (Morellato & Haddad 2000, Oliveira-Filho & Fontes 2000), when the reduced availability of water can lead to a reduced number of arthropods, which could have difficulties in obtaining their water requirements (Janzen & Schoener 1968). In addition, the reproductive activities of arthropods associated with rainy periods increase their populations during this season (Orians 1980).

However, these patterns were not observed for the foliage arthropods, whose abundance was high in the dry season. Although the density of arthropods can be associated with a peak in vegetation productivity (Orians 1980) that is characteristic of the rainy season in the tropics, seasonal variations in the abundance of arthropods seem to be less pronounced in those regions than in temperate regions (Newton 1980). Another relevant factor is the frequent and intense rains, typical of tropical summers, which may hinder the permanence of arthropods on the foliage, making them less accessible to insectivorous birds foraging on the substrate, as previously suggested (Manhães 2007). While it still seems difficult to explain an increase in the number of arthropods during the dry season, Murakami (2002) suggests that the understory of semideciduous forests may harbor, during the dry season, arthropods that live in the canopy, as some plant species lose leaves in this period and arthropods need to search for food resources elsewhere.

Although the highest consumption of arthropods by insectivorous birds is associated with the breeding season of these birds (Develey & Peres 2000), which in the tropics occurs during the rainy season, along with the increased availability of arthropods (Orians 1980), the results indicated no relationship between the seasonal variations of the arthropods and the abundance of insectivorous birds. Although the rainy season has showed the greatest abundance of soil arthropods, ground foraging bird species remained the same in both seasons. Likewise, the foliage insectivores showed no seasonal variation, although the number of foliage arthropods was higher in the dry season. Only a small difference in the bird species composition by season was observed, probably due to the capture of species with low representability, such as *Poecilotriccus plumbeiceps*, *Hemithriccus diops* and *Myiophobus fasciatus*, captured only once throughout the sampling periods. Codesido & Bilenca (2004) found similar results in a study on the seasonality of birds in the Chaco subtropical semiarid forest of Argentina, and did not find seasonal variations in the abundance of ground and foliage insectivores. In addition, this study revealed that seasonal variations experienced by some groups of insectivores occurred in migratory species, arriving in the tropical forests during summer, possibly attracted by a greater availability of arthropods. Lefebvre & Poulin (1996) observed relationship for some migrant species in mangrove forests of Panama. In the case of the current study area, we detected no migratory birds, with the insectivorous assemblage composed essentially by resident species, which may also have contributed to the absence of seasonal variations in the abundance of such birds, in addition to the composition of species. Cueto & Casenave (2002), in Argentina, attributed the lack of seasonality of coastal woodland insectivorous bird densities to a discrete temporal climate change, probably insufficient to generate an overall food scarcity. Thus, changes in the availability of food resources possibly cannot be the only factor responsible for variations that are occasionally found in the abundance of insectivorous species. Newton (1980) stated that food alone should not be considered a limiting factor for birds, because it is usually associated with several other factors, such as reproduction, territoriality and competition.

Another important factor to consider is the great plasticity of birds, which can be observed even in short periods of time (Tebbich *et al.* 2004), allowing them to exploit other microhabitats to obtain food within a fragment. According to Newton (1980), the insectivorous birds consume only a small part of resources available in the environment and can therefore find food in the periods in which there is some reduction of these resources. According to Murakami (2002), birds may differ in response to seasonal variations in prey distribution, using different tactics and/or foraging substrates, and often change to new prey types to compensate for the reduced availability of feeding resources.

Despite having been carried out in a single forest patch, our results support those found in previous studies (Codesido & Bilenca 2004, Manhães 2007), whose variations in arthropod abundance in response to seasonality are not accompanied by a variation in the abundance of insectivorous birds in tropical forests. The presence of the most common bird species throughout the year suggests the absence of extensive migration of insectivorous birds to the studied area, common in other locations (Lefebvre & Poulin 1996, Poulin & Lefebvre 1996), possibly explaining, to a large extent, the different patterns of responses from insectivorous birds in relation to the availability of their prey, according to the location studied.

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