The golden lancehead Bothrops insularis (Serpentes: Viperidae) relies on two seasonally plentiful bird species visiting its island habitat

Otavio A. V. Marques [a] , Marcio Martins [b] , Pedro F. Develey [c] ,
Arthur Macarrão [d] & Ivan Sazima [e]

[a] Laboratório de Ecologia e Evolução, Instituto Butantan, Av. Vital
Brazil 1500, 05503-900, São Paulo, SP, Brazil

[b] Departamento de Ecologia, Universidade de São Paulo,
05508-090, São Paulo, SP, Brazil

[c] BirdLife/SAVE Brasil. R. Fernão Dias 219 cj.2, 05427-010, São
Paulo, SP, Brazil

[d] Programa de Pós Graduação em Biologia Animal, Instituto de
Biociências, Letras e Ciências Exatas, Universidade Estadual
Paulista, Rua Cristóvão Colombo, 2265, São José do Rio Preto-SP,
15054-000, Brazil

[e] Museu de Zoologia, Universidade Estadual de Campinas,
(associate researcher, retired), Campinas, 13083-970, SP, Brazil

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The golden lancehead *Bothrops insularis* (Serpentes: Viperidae) relies on two seasonally plentiful bird species visiting its island habitat

Otavio A. V. Marques[a]*, Marcio Martins[b], Pedro F. Develey[c], Arthur Macarrão[d] and Ivan Sazima[e]

[a]*Laboratório de Ecologia e Evolução, Instituto Butantan, Av. Vital Brazil 1500, 05503-900, São Paulo, SP, Brazil;* [b]*Departamento de Ecologia, Universidade de São Paulo, 05508-090, São Paulo, SP, Brazil;* [c]*BirdLife/SAVE Brasil. R. Fernão Dias 219 cj.2. 05427-010, São Paulo, SP, Brazil;* [d]*Programa de Pós Graduação em Biologia Animal, Instituto de Biociências, Letras e Ciências Exatas, Universidade Estadual Paulista, Rua Cristóvão Colombo, 2265, São José do Rio Preto-SP, 15054-000, Brazil;* [e]*Museu de Zoologia, Universidade Estadual de Campinas, 13083-970, Campinas, SP, Brazil (associate researcher, retired)*

Adult individuals of the island pitviper *Bothrops insularis* have a diet based on birds. We analysed bird species recorded in the gut of this snake and found that it relies on two out of 41 bird species recorded on the island. When present, these two prey species were among the most abundant passerine birds on the island. A few other migrant birds were very occasionally recorded as prey. A resident bird species (*Troglodytes musculus*) is the most abundant passerine on the island, but seems able to avoid predation by the viper. *Bothrops insularis* is most commonly found on the ground. However, during the abundance peak of the tyrannid passerine *Elaenia chilensis* on the island, more snakes were found on vegetation than on the ground. We suggest that one cause may be that these birds forage mostly on vegetation, and thus cause the snakes to search for prey on this arboreal substratum.

Keywords: endemic snake; *Bothrops insularis*; Queimada Grande Island; diet; migrant birds; abundant birds

Introduction

The diet of many snake species seems to be related mostly to prey availability (Arnold 1977; Kephart 1982; Kephart and Arnold 1982). This relationship is poorly known for tropical snakes because of the difficulty of obtaining data on gut contents and food availability in the field. However, for snakes whose prey is locally abundant, there is the opportunity to obtain a better view of their feeding ecology (e.g. Godley 1980; Carfagno et al. 2006; Luiselli 2006a, 2006b).

The golden lancehead (*Bothrops insularis*) is a viper endemic to Queimada Grande Island in south-eastern Brazil. It has an ontogenetic shift in diet: juveniles eat mostly ectothermic prey (centipedes, frogs and lizards) whereas adults, particularly the females which attain a larger body size, tend to feed mostly on perching birds (Marques et al. 2002; Martins et al. 2002). This viperid is considered a critically endangered species both globally and locally (Machado et al. 2008; IUCN 2010), but snakes

*Corresponding author. Email: otaviomarques@butantan.gov.br

are still abundant on the island (Martins et al. 2008) and birds in the snake's habitat are easily recorded from their vocalizations.

The availability of food resources for snakes is often temporally and spatially variable and snakes should often therefore be opportunists (Luiselli 2006a). The bird assemblage of Queimada Grande Island is seasonally variable and comprises mainly migrant passerines that visit the island and provide the main food for the snakes (Marques et al. 2002). Here we present the seasonal variation of perching bird richness and abundance on the island and in the snake's diet, to test the hypothesis that the golden lancehead relies on migrant birds, the seasonally most abundant prey.

Materials and methods

Study area

Queimada Grande (24°30′ S, 43°42′ W; QGI hereafter) is a small island, 0.43 km^2, located about 34 km off the coast of São Paulo, south-eastern Brazil (Amaral 1921; Martins et al. 2008), with an altitude of up to 200 m asl. Monthly mean air temperatures range from 18.3°C in August to 27.2°C in March and rainfall ranges from 0.2 mm in July to 135.2 mm in December (Figure 1). About 0.25 km^2 of the island is covered by rainforest (Lower Montane Rain Forest, cf. Oliveira-Filho and Fontes 2000). The remaining areas are bare rock and open areas covered mostly with grasses; many of these open areas result from the removal of the forest by humans (Marques et al.
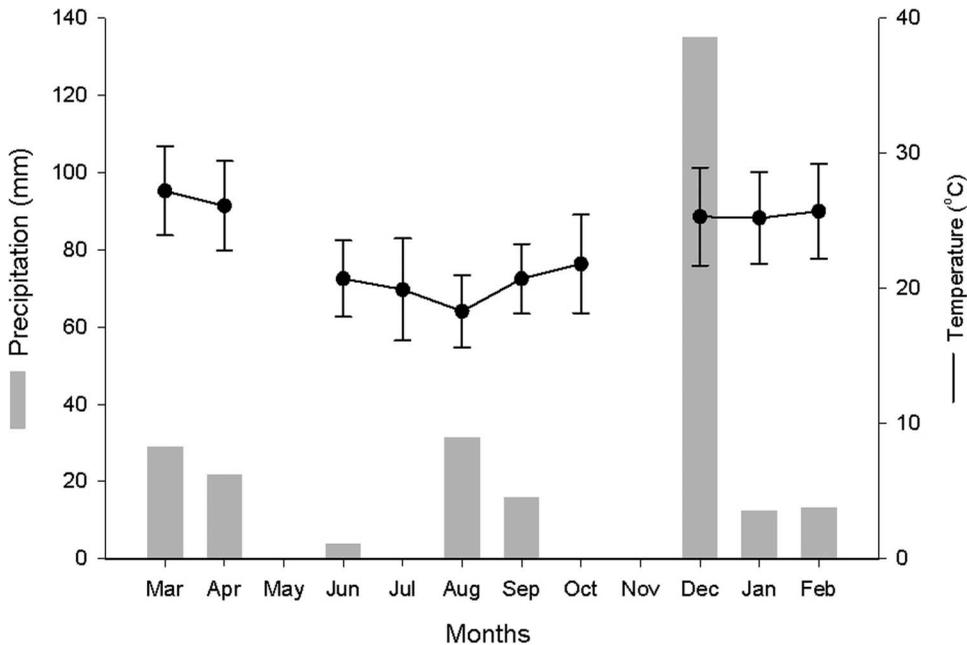

Figure 1. Annual distribution of mean monthly temperature (°C) and rainfall at Queimada Grande Island in 2007 and 2008. Lines are mean temperature (with max and min indicated by error bars) and bars are rainfall.

2002). The forest is the main habitat of *B. insularis*, which is rarely found in grassy areas (Martins et al. 2008). There are no small terrestrial mammals on the island (Marques et al. 2002).

Data collection

Data obtained during 10 field trips from 1996 to 2008 were analysed for this study (Table 1). In 1996–1997 and 2007–2008 birds were sampled with the use of 24 point counts every 50 m along a 1.3 km trail that crosses the island in a north–south orientation (see Martins et al. 2008). Two of us (PFD or AM) counted all birds sighted or heard from the fixed point. The sampling time at each fixed point was 10 min (Bibby et al. 1992, 2000). Due to very adverse meteorological conditions we were unable to obtain samples in all four seasons in 2008. We considered as the viper's potential prey only perching birds (Passeriformes), since these are the only bird prey recorded for the golden lancehead to date (Amaral 1921; Duarte et al. 1995; Marques et al. 2002). Additionally, all passerine species recorded on QGI have a size compatible with the swallowing capacity of this relatively small pitviper (Marques and Sazima 2009; our pers. obs.). In contrast, all non-perching bird species recorded on QGI (e.g. pigeon, owl, hawk) have a large body size. We classified the passerines as migrants or residents. We regarded as residents only those bird species that were recorded throughout year and displayed signs of breeding activity (e.g. territorial vocalizing, courting, nesting). Snakes were sampled along the bird census trail. At least four people searched for snakes visually, two searching the ground and two searching the vegetation including the canopy (inspected from the ground and/or from tree branches located as close to the top of the canopy as possible). We recorded the distance to the ground and to the trail for each snake sighted. To compare the number of snakes found on vegetation or on the ground on each trip we used a chi-square test. Results were considered significant when $p < 0.05$.

All snakes we caught ($n = 493$) were palpated for detection of prey in the gut and we made them regurgitate their prey by carefully pushing it forwards in the gut. Almost all prey was identified to the level of species or genus. The percentage of snakes with birds in the gut was determined for each trip. We are aware that small, elongate prey like centipedes and very small frogs and lizards may go undetected by this method, and thus the contribution of passerine birds (which are a bulky prey, even the smallest species) in the diet of adult *B. insularis* may be overestimated.

Results

Comparable data on seasonal abundance of passerine birds at QGI are available for 1049 records of 34 species (Table 1). Seven additional species were recorded off the census, which results in a total of 41 species of perching birds recorded on the island throughout our study. The most abundant species was the southern house wren (*Troglodytes musculus*), making up about 50% of all records (534/1049). The seasonal relative abundance of the wren was higher than those of all other species throughout the year (Figure 2) and ranged from 0.34 to 0.86 (June 2007 and December 2007, respectively; see Table 1). Vocal activities of breeding individuals indicate that the wren is a resident on the island. Another passerine for which we recorded reproductive

Table 1. Number of passerine bird individuals recorded in each field trip to Queimada Grande Island (see methods in text). Numbers in parentheses are relative frequencies (≥ 0.08 in bold). Families, genera, and species in alphabetical order.

Species	April 1996 (autumn)	July 1996 (winter)	October 1996 (spring)	February 1997 (summer)	February 2007 (summer)	June 2007 (winter)	August 2007 (winter)	December 2007 (summer)	March 2008 (autumn)	July 2008 (winter)
Coerebidae (bananaquit)										
Coereba flaveola	**4 (0.08)**	2 (0.03)	3 (0.05)	1 (0.02)	**21 (0.16)**	20 (0.15)	8 (0.06)	**7 (0.10)**	5 (0.04)	8 (0.06)
Cotingidae (cotinga)										
Procnias nudicollis										5 (0.03)
Emberizidae (seedeaters)										
Sporophila caerulescens	1 (0.02)				1					
Volatinia jacarina				1						
Hirundinidae (swallows)										
Pygochelidon cyanoleuca						2 (0.015)				
Stelgidopteryx ruficollis	**7 (0.14)**		**12 (0.18)**							
Tachycineta leucorrhoa							1 (0.01)			
Parulidae (warbler)										
Basileuterus culicivorus						1				1 (0.01)
Thraupidae (tanagers)										
Hemithraupis ruficapilla			1 (0.02)							**2 (0.14)**
Tachyphonus coronatus		5 (0.07)				6 (0.04)	6 (0.05)			**16 (0.11)**
Tangara peruviana						5 (0.04)				**2 (0.14)**
Tersina viridis							5		1 (0.01)	
Thraupis sayaca	1 (0.02)	1 (0.01)	**5 (0.08)**	2 (0.03)		2 (0.02)	2 (0.02)		1 (0.01)	4 (0.03)
Tityridae (tytiras)										
Pachyramphus polychopterus			1 (0.02)							
Pachyramphus validus									1 (0.01)	
Troglodytidae (wren)										
Troglodytes musculus	**28 (0.57)**	**33 (0.49)**	**33 (0.52)**	**49 (0.75)**	**95 (0.73)**	**47 (0.34)**	**49 (0.37)**	**61 (0.86)**	**72 (0.57)**	**67 (0.46)**

Turdidae (thrushes)										
Turdus albicollis	2 (0.04)	9 (0.13)		1 (0.02)		22 (0.16)	13 (0.10)	1 (0.01)	1 (0.01)	16 (0.11)
Turdus amaurochalinus		5 (0.07)		1 (0.02)		1 (0.01)	7		3 (0.03)	14 (0.10)
Turdus flavipes		13 (0.19)		5 (0.08)	2 (0.02)	11 (0.08)	29 (0.21)			2 (0.14)
Tyrannidae (flycatchers)										
Attila rufus						1 (0.01)	2 (0.02)			
Cnemotriccus fuscatus				2 (0.03)						
Elaenia chilensis	2 (0.04)				2 (0.02)				34 (0.27)	
Elaenia mesoleuca			2 (0.03)							
Legatus leucophaius			2 (0.03)							
Leptopogon amaurocephalus										1 (0.01)
Myiarchus tyrannulus					1 (0.01)			1 (0.01)	1 (0.01)	
Myiodynastes maculatus					2 (0.02)					
Myiophobus fasciatus							1 (0.01)			
Myiozetetes similis						6 (0.04)			2 (0.02)	1 (0.01)
Pitangus sulphuratus			1 (0.02)	5 (0.04)		9 (0.07)	6 (0.05)	1 (0.01)	3	6 (0.04)
Satrapa icterophrys									1 (0.01)	
Tyrannus melancholicus	3 (0.06)		2 (0.03)	1 (0.02)	1 (0.01)				1 (0.01)	
Tyrannus savana			1 (0.02)	2 (0.03)						
Vireonidae (vireo)										
Vireo olivaceus	1 (0.02)		1 (0.02)	1 (0.02)					1 (0.01)	
Total	49	68	64	129	130	135	132	71	127	144

Seven additional species: *Haplospiza unicolor* and *Sicalis flaveola* (Emberizidae), *Parula pitiayumi* (Parulidae), *Pipraeidea melanonota* (Thraupidae), *Turdus leucomelas* (Turdidae), and *Mionectes rufiventris* and *Elaenia flavogaster* (Tyrannidae) were recorded on the island but off the fixed sampling points and in small numbers (one to two individuals).
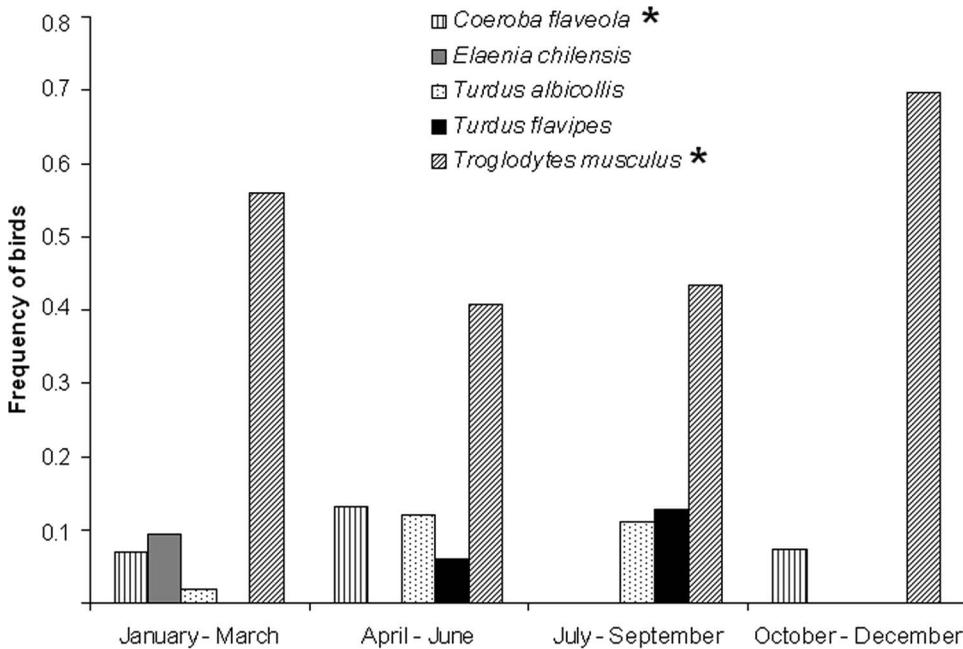
Figure 2. Average relative abundance of the five most common bird species, based on samples obtained in different years (see text). Asterisks indicate residents.

activity on QGI was the bananaquit (*Coereba flaveola*), although its abundance was lower than that of the preceding species (Figure 2), and its relative abundance ranged from 0.02 to 0.16 (February 1997 and February 2007, respectively; see Table 1). The remaining passerine species recorded on the island seem to be migrants or very rare, and were not observed displaying any reproductive activity (Macarrão 2010). Seasonal abundances indicate migratory peaks for some of these migrants (Figure 2). Relative abundance of two of the three recorded thrushes, *Turdus albicollis* and *T. flavipes*, was highest in the austral winter (June–September, see Table 1 and Figure 2). Relative abundance of *T. flavipes* was ~0.20 in July 1996 and August 2007, and was surpassed only by the wren *T. musculus* (Table 1). Another high relative abundance (0.27) was recorded for *Elaenia chilensis* in March 2008 (Table 1). This tyrannid was unrecorded in the remaining nine field trips except for two individuals in February 2007 (Table 1).

   Elaenia chilensis was the most common prey of the golden lancehead in February 1997 and 2007 (Figures 3 and 4). The low frequency of this bird in February 1997 (see Table 1) is strongly suggestive of a very brief stay of this bird on the island. Probably the snakes had eaten these birds before our trip when such passerines were still abundant on the island. *Bothrops insularis* is most commonly found on the ground (Figure 5). However, during the peak of abundance of *E. chilensis* on the island in March 2008 (early autumn) detected by us (Table 1), more snakes were found on vegetation (Figure 4) than on the ground. This difference (in March, early autumn) was not statistically significant ($n = 58$, $\chi^2 = 1.72$, $p = 0.19$) but in other periods the number of snakes found on the ground was significantly ($52 \leq n \leq 55$, $\chi^2 \geq 8.32$, $p < 0.05$) higher than on vegetation (except for December 2007, $n = 37$, $\chi^2 = 3.27$, $p = 0.07$) (Figure 5).
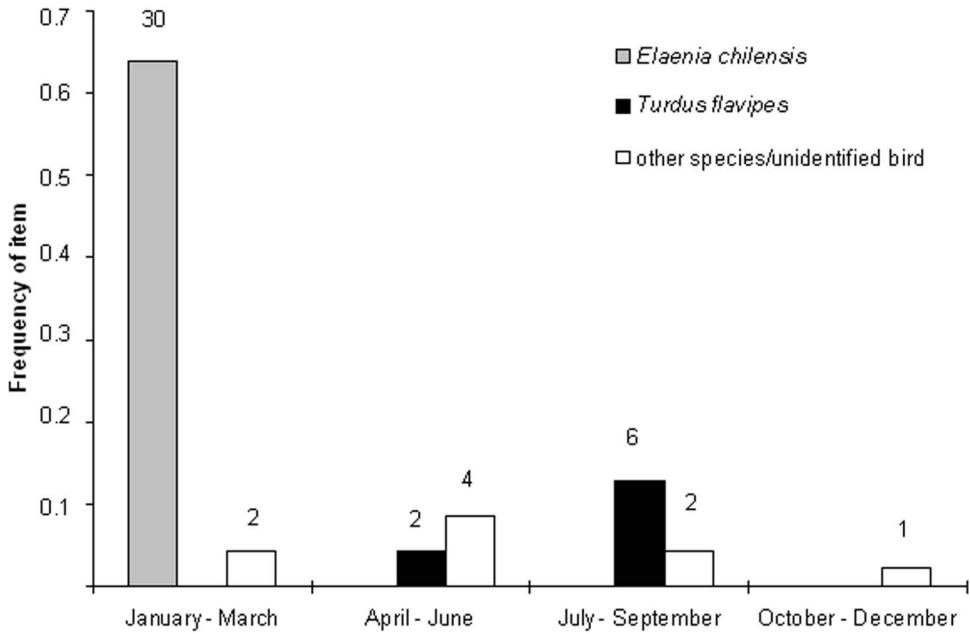
Figure 3. Frequency and number of passerine birds recorded as prey of *Bothrops insularis* ($n =$ 47, sum of 10 field trips to Queimada Grande Island).

Figure 4. A golden lancehead (*Bothrops insularis*) holds in its jaws a tyrannid flycatcher (*Elaenia* sp.) it caught on vegetation.
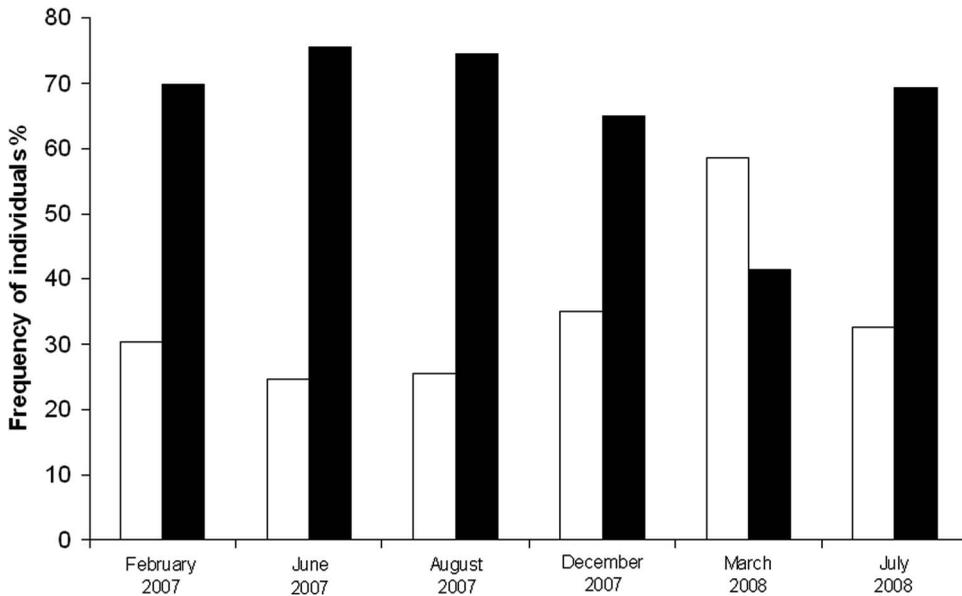
Figure 5. Percentage of *Bothrops insularis* individuals ($n = 493$) found on vegetation (white) and on the ground (black) in six field trips to Queimada Grande Island.

Additionally, during a recent trip to QGI in early autumn (8 April 2011) 10 out of 15 snakes sighted were coiled on vegetation (K. Kasperoviczus pers. com.).

We found 50 prey items in the gut contents of 493 golden lanceheads (488 adults and five juveniles) we palpated. Forty-seven ($\sim$95%) prey items were perching birds, predominantly the two most abundant visitors to the island, the thrush *Turdus flavipes* and the tyrant *Elaenia chilensis* (Table 1 and Figures 2 and 3). Additional migrant bird species were recorded as prey very occasionally, whereas the two resident bird species were never recorded as prey of the golden lancehead. One of the resident bird species, the wren *Troglodytes musculus*, was the most abundant passerine on the island (Table 1 and Figure 2). It is an agile bird that forages mostly on the ground, and seems to be able to avoid predation by *B. insularis*. In one instance, a wren foraging on the ground suddenly stopped moving, stared at a coiled viper, and made a long turn apparently to avoid getting close to the snake. The percentage of snakes with birds in the gut ranged from 0 to 22.2%. Higher values ($\sim$20%) occurred only in late summer and early autumn (February and March), decreasing in winter and more so in other seasons (Figure 6). Prey other than birds were centipedes (*Otostigmus scabricauda*, $n = 2$) and a lizard (*Colobodactylus taunayi*, $n = 1$).

Discussion

We found that the diet of *Bothrops insularis* is weighted heavily towards only two out of the 41 perching bird species recorded on QGI. These two birds are altitudinal or latitudinal migrants (Sick 1997). On the mainland, *Turdus flavipes* occurs in the highlands during the rainy season (austral spring and summer), but migrates to lowland areas
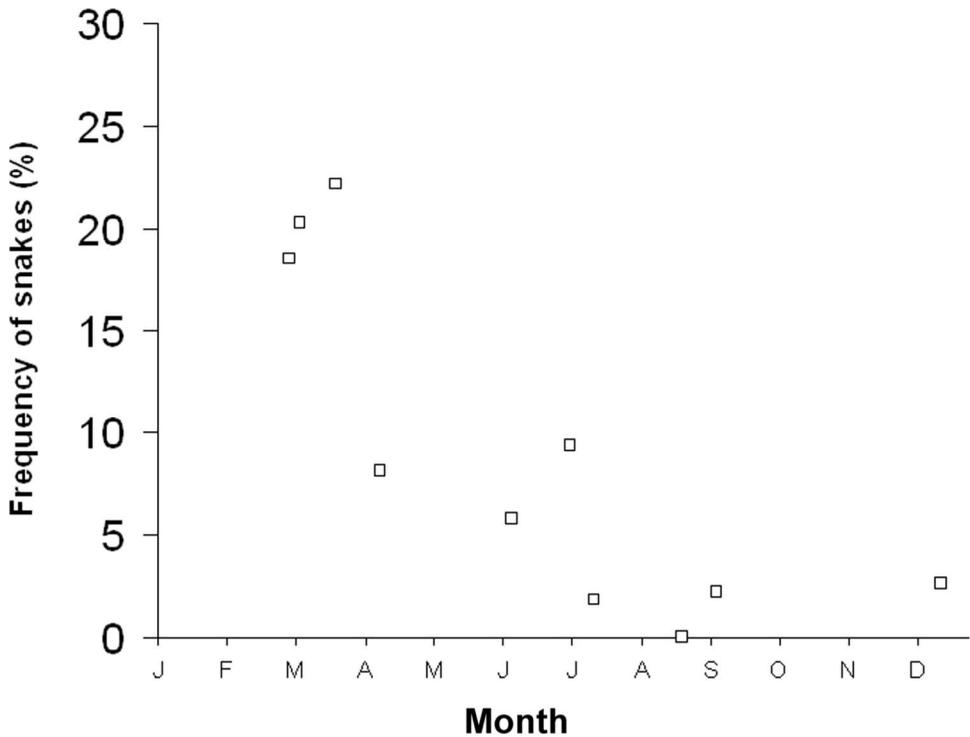
Figure 6. Frequency of *Bothrops insularis* with birds in their guts found in 10 field trips to Queimada Grande Island.

along the coast during the austral winter (Develey 2004; Alves 2007), some individuals reaching QGI (Macarrão 2010). *Elaenia chilensis* migrates from southern to northern South America, appearing in coastal south-eastern Brazil at the end of summer and the onset of autumn (Marini and Cavalcanti 1990; Pacheco and Gonzaga 1994). Both species were among the most abundant passerine birds during the period they spent on the island.

The population of the resident wren *Troglodytes musculus* on the island is unusually large for an Atlantic Forest site (Sick 1997), which may be related to its presumed avoidance of snake predation on QGI. It is possible that this naturally agile bird benefits from this ability to avoid predation and has expanded its population on the island to unusually high densities (Macarrão 2010). Other factors related to an insular environment (e.g. absence of predators other than the viper) may also favour the abundance of this passerine on QGI.

During peak abundance of the tyrannid *Elaenia chilensis* on QGI most snakes were found on vegetation, and we suggest that this may reflect the fact that species of *Elaenia* forage for fruits and insects mostly on vegetation (cf. Crowell 1968; Fitzpatrick 1980; Gomes et al. 2008). Thus, the arboreal foraging habits of these birds likely caused the snakes to search for prey on this substratum. Activity of other island vipers (*Gloydius shedaoensis* and *Macrovipera schweizeri*) which also feed upon migratory passerine seems driven primarily by prey availability (Nilson et al. 1999; Sun et al.

2001). Rainfall, wet ground, and temperature gradients (for thermoregulation activity) may be alternative explanations or additional causes for this trend for *B. insularis*, but we have no evidence that these variables influence substratum use by this viper. We found other forest-dwelling *Bothrops* species on moist ground (pers. obs) and a study on thermoregulation of *B. insularis* (Bovo 2008) does not indicate thermoregulatory differences between individuals found on the ground and on the vegetation. On the other hand, arboreal and terrestrial ambush sites may differ in thermal backgrounds available to the snakes. On Shedao Island, where *G. shedaoensis* lives, thermal backgrounds of arboreal perches were cooler (thus providing more thermal contrast against an endothermic prey such as birds), than were backgrounds available in terrestrial ambush sites (Shine et al. 2002). The same relationship between arboreal versus ground hunting sites may hold true for *Bothrops insularis*. Arboreal ambush sites could be more advantageous in warmer periods, and we recorded higher temperatures on QGI at the onset of autumn (March and April).

It seems that adult *B. insularis* feed mostly in late summer and early autumn, when *Elaenia chilensis* is the most abundant bird prey on the island, and, to a lesser extent, in the winter, when *Turdus flavipes* fills a similar role. Thus, the remaining seasons of the year could be a fasting period for adult vipers, as no migratory birds are found on the island in large numbers, and other prey types are much less important in the diet of this snake. Indeed, the relatively low reproductive frequency recorded for *B. insularis*, as compared to its mainland sister species, *B. jararaca*, may be an additional indication of a short food supply for the golden lancehead on its island habitat throughout much of the year (Kasperoviczus 2009).

Acknowledgements

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