# Infection patterns of *Paradollfusnema amphisbaenia* (Nematoda: Cosmocercidae) in a population of *Amphisbaena wuchereri* (Squamata: Amphisbaenidae) from Minas Gerais state, south-eastern Brazil, and its relations with host size, sex and fat body mass

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## Abstract

Specimens ($n = 41$) of the amphisbaenid *Amphisbaena wuchereri* taken from a population in Minas Gerais state, south-eastern Brazil, were examined for gastrointestinal parasites. A single nematode species was found, *Paradollfusnema amphisbaenia*. This was a new host record for this nematode species. This parasite was encountered in the large intestine (prevalence of 100%), in the stomach (prevalence of 2%) and in the small intestine (prevalence of 7.3%). The intensity of infection ranged from 1 to 457 individual parasites per host and was positively correlated with body size of both male and female amphisbaenians. The discrepancy index ($D$) indicated that *P. amphisbaenia* tended to an even distribution in this host population. The nematode, which did not affect fat body mass, induced inflammatory infiltrations in the small intestine, indicating that the parasites might injure the host's organs.

## Introduction

Ecological interactions between parasites and neotropical reptiles have been the subject of a number of recent studies (e.g. Anjos *et al.*, 2005; Almeida *et al.*, 2007, 2008; Ávila & Silva, 2010). In general, the number of parasites infecting a single host (i.e. intensity of infection) is related to individual body size, with larger individuals having higher parasite loads, possibly because of increased chances of infection during longer lifespans or due to niche divergences between juveniles and adults (Rocha, 1995). Differences in prey selection may also be a reason to explain any sex-based

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differences in prevalence and intensity of infection in reptiles (Ribas *et al.*, 1995).

Endoparasites obtain all their nutrients from their hosts, and nematodes may feed on the intestinal contents or on the host tissues (Quinnell *et al.*, 1990), which may induce energetically costly immunological responses (Lochmiller & Deerenberg, 2000) leading to deficits in energy budgets of their hosts. Thereby, parasitized individuals might have less energy to invest in reproduction (Polack, 1998; Bollache *et al.*, 2001), physiology (Hernández-Bello *et al.*, 2010), behaviour (De Jong-Brink & Koene, 2005) and ultimately survival (Fuller & Blaunstein, 1996), affecting the overall fitness of hosts (Schüpbach & Baur, 2008; Thomas *et al.*, 2010). For reptiles, authors have found different responses of hosts to parasites. For example, Hidalgo-Vila *et al.* (2011) reported that the nematode *Serpinema microcephalus* caused pancreatitis in red-eared slider turtles, *Trachemys scripta elegans*, with tissue destruction and inflammation. Madsen *et al.* (2005) found that the intensity of infection of a hematozoan blood parasite is negatively correlated with growth and condition in water pythons, *Liasis fuscus*. On the other hand, in the lizard *Lacerta vivipara*, blood parasite load was positively related to the relative clutch mass and investment per young in female lizards (Sorci *et al.*, 1996).

Amphisbaenians are fossorial reptiles and their burrowing habit presents difficulties when collecting large series of individuals from their natural environment. Hence, information regarding infection patterns for this reptile group is scarce. Nevertheless, studies have demonstrated that amphisbaenians may have an important role as hosts in the life cycle of some parasite species. For example, the species *Amphisbaena alba* is the final host of the pentastomid *Raillietiella gigliolii* (Winch & Riley, 1985), and may show high prevalences of this nematode species (from 55% (Almeida *et al.*, 2009) to 86% (Winch & Riley, 1985)) and an intensity of infection from 1 to 13 parasites (Almeida *et al.*, 2009).

The aim of the present study was to analyse the gastrointestinal helminth infection patterns in a population of the shovel-snouted amphisbaenid *Amphisbaena wuchereri* by measuring the level of aggregation (i.e. aggregation of parasites within the host population; Poulin, 1993), the prevalence and mean intensity of infection of parasites. Since females are larger than males in *A. wuchereri* (Filogonio *et al.*, 2009), we compared the relative parasite load between the sexes. Additionally, we tested the effect of helminth loads on the storage of fat in the amphisbaenians. Reptiles typically have coelomic fat bodies and their size may represent the stored energy remaining from that spent on maintenance metabolism and growth, indicating the condition of the organism (Hayes & Shonkwiler, 2001).

## Materials and methods

### Collection and examination of reptiles

Amphisbaenians in this study were collected by animal rescue groups, in October and November 2001, during the flooding process leading to the construction of the Santa Clara hydroelectric power plant in the municipalities of Nanuque and Serra dos Aimorés, Minas Gerais state,

south-eastern Brazil (17°50′S, 40°21′W). This site is situated within the Atlantic rainforest biome and possessed forest fragments that were damaged as a result of timber extraction. Captured animals were transported to the hydroelectric laboratory and maintained in a ventilated wooden collection box (40 × 20 × 20 cm) for 2–3 days and were not fed during this period. Wet cotton pads were placed in the box to maintain humidity. Individuals were subsequently euthanized, fixed in 10% formalin, kept in a storage solution of 70% alcohol, and deposited at Museu de Ciências Naturais, Pontifícia Universidade Católica de Minas Gerais (MCNR 279-425), Brazil.

Prior to dissection in the laboratory, we measured the snout to vent length (SVL), subtracting tail length (measured with a caliper to the nearest 0.05 mm from the extreme posterior point of the cloacal flap to the tip of-the tail) from total length (measured with a measuring tape to the nearest 1 mm). Individuals were sexed by verifying the presence or absence of the everted hemipenis. The gonads were examined in individuals in which the hemipenis was not present in order to positively assign a sex to each individual. During dissections, we first removed the fat bodies located within the body cavity and dried them with paper towels for *c.* 30 min prior to weighing with a precision balance to the nearest 0.1 mg. Since fat body mass (FBM) can be affected by reproductive stage in squamate reptiles (e.g. Van Sluys *et al.*, 2002; Galdino *et al.*, 2003) we inspected gonads in order to verify reproductive condition of *A. wuchereri*. The gonads showed no overt sign of reproductive activity (see Filogonio *et al.*, 2009). Hence, we are confident that all individuals of *A. wuchereri* were non-reproductive and, consequently, that FBM was not influenced by differences in reproductive state between individuals.

The gastrointestinal tract (stomach and small and large intestines) were removed and checked under a stereomicroscope for the presence of helminths. The taxonomic determination of helminths was carried out by morphological characters following Vicente *et al.* (1993) and Bursey (2002). Parasites were cleared with lactophenol and analysed under a light microscope with the Leica Application Suite (LAS V5) computerized system (Leica Microsystems, Wetzlar, Germany). For each helminth species, we calculated the prevalence [(infected amphisbaenians/examined amphisbaenians) × 100] (Bush *et al.*, 1997) and the mean intensity of infection (arithmetic mean number of worms from infected amphisbaenians) (Bush *et al.*, 1997). Voucher specimens of the helminths were deposited at the Coleção Helmintológica do Instituto de Biociências (CHIBB, no. 5098-5099), Universidade Estadual Paulista – UNESP, Brazil.

### Data analysis

Preliminary analyses were performed to test the normality and homoscedasticity of data and to choose the appropriate statistical tests. Descriptive statistics are presented as mean ± standard error (according to Bush *et al.*, 1997). The Spearman's Rank Correlation and Pearson's Correlation (Zar, 1999) were used to evaluate the association between host size (SVL) and infection intensities in males and females, respectively. Differences

in intensity of infection between sexes were tested using Mann–Whitney *U*-test. The discrepancy index (*D*), used to measure the level of aggregation, was calculated according to the equation:

$$D = 1 - \frac{2\sum_{i=1}^{N}\left(\sum_{j=1}^{i} x_j\right)}{\bar{x}N(N+1)}$$

where *x* is the number of parasites in host *j* (hosts are ranked from the least to most infected) and *N* is the total number of hosts (Poulin, 1993). The index has a minimum value of zero (*D* = 0) if all hosts harbour the same number of parasites, and a maximum value (*D* = 1) if all parasites were found in a single host. This index was calculated with the software Quantitative Parasitology 3.0 (Rózsa *et al.*, 2000).

Mass is a function of body size (Le Cren, 1951; Hayes & Shonkwiler, 2001) and parasite intensity has been positively correlated with body size in a number of reptile species (e.g. Van Sluys *et al.*, 1994, 1997; Vrcibradic *et al.*, 2000, 2002). Thus, comparisons between FBM and parasite intensity can be confounded by variations in body size. In order to minimize the effect of size on the relationship between parasite load and FBM only the 10 longest individuals of each sex were used to perform a linear regression of these variables. We used this methodology to meet the assumption of independency between size and mass pointed out by Green (2001) for body condition analysis (see Results). Prior to analysis, FBM was cubic root transformed. The effect of parasites on FBM was tested for males and females separately.

## Results

The study utilized 41 individuals of *A. wuchereri*. From these, 23 individuals were males (290 ± 15.0 mm SVL) and 18 females (352.1 ± 11.1 mm SVL). The only parasite found in the gastrointestinal tract of *A. wuchereri* was the nematode *Paradollfusnema amphisbaenia* (Nematoda: Cosmocercidae). All amphisbaenians were parasitized by at least one individual of *P. amphisbaenia* (overall prevalence = 100%). The mean intensity of infection was 116.2 ± 16.6 (range 1–467). The male hosts' mean intensity of infection was 110.7 ± 24.6 (range 1–467) and the females' mean intensity of infection was 130.0 ± 21.9 (range 11–317). However, this difference was not statistically significant (Mann–Whitney; *U* = 174; *P* = 0.2). We also checked for differences in intensity of infection between the ten longest individuals of each sex and we found no intersexual difference (*t* = −1.23, df = 18, *P* = 0.23).

Regarding the infection sites, parasites were located in the large intestine of all host specimens (i.e. a prevalence of 100%). The mean intensity of infection in this site was 113.6 ± 16.8 (range 1–467). An infection range of 5–12 was found in the small intestine (prevalence of 7.3%), and one parasite was found in the stomach (prevalence of 2%). The body size of the amphisbaenian host had a positive influence on the intensity of infection (Spearman's rank correlation, $r_s = 0.70$, *P* < 0.0001, *n* = 41), in both male hosts (Spearman's rank correlation, $r_s = 0.78$, *P* < 0.0001, *n* = 23) and female hosts (Spearman's rank correlation, $r_s = 0.57$, *P* < 0.01, *n* = 18) (fig. 1). The discrepancy index

(*D*) for male hosts was *D* = 0.51 and for female hosts, *D* = 0.39. Overall discrepancy was *D* = 0.47.

In the ten longest individuals of each sex (body size range 310.90–388.85 mm, 359.10 ± 23.33, SVL of males; body size range 337.10–432.05 mm, 373.54 ± 28.8, SVL of females), SVL was not correlated with FBM ($r^2 = 0.08$, *P* = 0.27, *n* = 20) or parasite intensity ($r^2 = 0.06$, *P* = 0.15, *n* = 20). Hence, our analysis was not confounded by size effects and met the assumption of independency between size and mass for body condition analysis (Green, 2001). Males' FBM ranged from 0.56 to 4.53 g (1.90 ± 1.38 g) and females' FBM ranged from 1.20 to 4.50 g (2.75 ± 1.04 g) and, in both cases, FBM was not associated with parasite intensity (Spearman's rank correlation, $r_s = 0.24$, *P* = 0.28, *n* = 10, for males; Pearson's correlation, *r* = 0.37, *P* = 0.14, *n* = 10, for females).

## Discussion

Although other helminth species are known to infect amphisbaenians (Ávila & Silva, 2010), the nematode
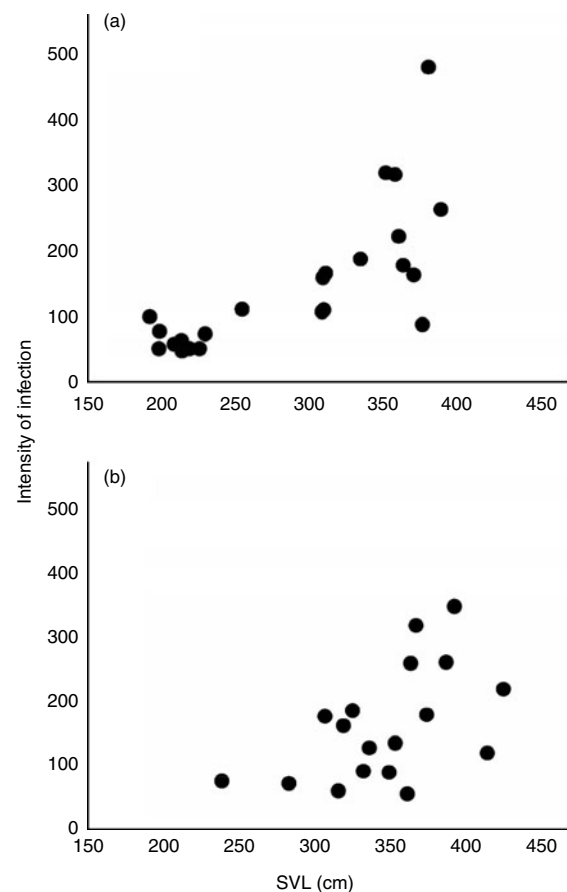


Fig. 1. Correlation between snout to vent length (SVL) and intensity of infection of *Paradollfusnema amphisbaenia* infecting *Amphisbaena wuchereri* at Minas Gerais state, Brazil. Spearman's rank correlation between SVL and intensity of infection to male hosts (a) $r_s = 0.78$, *P* < 0.05, *n* = 23; and to female hosts (b) $r_s = 0.57$, *P* < 0.01, *n* = 18.

fauna found in the sampled population of *A. wuchereri* was composed solely of the species *P. amphisbaenia*. *Paradollfusnema* was created by Baker (1982) as a *nomen novum* replacing *Dollfusnema* Baker, 1981, preoccupied by *Dollfusnema* Caballero, 1974. There are two species in this genus, *P. amphisbaenia*, from the Brazilian amphisbaenian *Amphisbaena microcephala* ( = *Leposternon phocaena* Duméril and Bibron, 1839) (Vicente *et al.*, 1993), and the most recently described species *Paradollfunsnema tellfordi* Bursey, 2002 from the amphisbaenian *Rhineura floridana* from Florida, USA (Bursey, 2002). Hence, this finding constitutes a register of a new host for *P. amphisbaenia* and also extends its range of occurrence through south-eastern Brazil.

*Amphisbaena wuchereri* presented high prevalence (100%) and intensity of infection when compared to previous studies of parasitism of amphisbaenians. For example, *Blanus strauchi* presented a prevalence of 70% and the intensity of infection varied from one to two gastrointestinal helminths (Düşen *et al.*, 2010); *R. floridana* had a prevalence of 50% and intensity of infection of one parasite per host infected (Telford & Bursey, 2003). The very high prevalence of *P. amphisbaenia* in *A. wuchereri* rules this out as an incidental case of parasitism and suggests that *A. wuchereri* constitutes a specific host for this helminth species.

As for other reptile species, intensity of infection was positively associated with the host's body size, evidencing ontogenetic differences in intensity of infection. Age differences in intensity of infection can be assigned to an increase in the chances of acquiring parasites during the lifetime of larger (i.e. older) lizards (Vrcibradic *et al.*, 1999). Another hypothesis explaining ontogenetic differences in intensity of infection of parasites is that it might emerge as a consequence of segregation in diet between smaller (young) and larger (adults) individuals (Rocha, 1995). Unfortunately, due to the 3-day fasting period prior to killing for preservation, and the bad conservation of stomach contents, we were not able to evaluate dietary composition.

There were no differences in the intensity of parasite infection between males and females despite the females being longer than males (Filogonio *et al.*, 2009). Sexual size dimorphism can lead to different microhabitat utilization (Schoener, 1968) or to segregation in diet between sexes (Gomes *et al.*, 2009). Such ecological segregation is argued in the literature to be an important factor in determining patterns of intensity of infection and prevalence in reptiles (Ribas *et al.*, 1995; Anjos *et al.*, 2005). However, several studies have suggested that other factors might also be involved in determining infection patterns in reptiles. For example, for the lizard species *Eurolophosaurus nanuzae* (Fontes *et al.*, 2003) and *Mabuya frenata* (Vrcibradic *et al.*, 1999), intersexual differences in prevalence were encountered despite the apparent absence of ecological divergences between sexes regarding diet, microhabitat use and active body temperatures (Kiefer, 1998; Vrcibradic & Rocha, 1998). Moreover, for the lizard *Anolis lineatopus*, intersexual differences in intensity of infection were suggested to be a consequence of divergent environment use between sexes, or to different genetic susceptibility of the host population, or a combination of both factors (Vogel & Bundy, 1987). It

seems that if there is any ecological divergence between sexes in this population of *A. wuchereri* as a consequence of sexual dimorphism, it is not expressed in the prevalence or intensity of infection. The scarcity of basic life-history data regarding amphisbaenians, especially *A. wuchereri*, precludes any further ecological inferences.

The habitat for the parasites is not spatially continuous and consists of cells or discrete 'islands' (i.e. the hosts represent patches of favourable habitat in an uninhabitable environment). The parasites are not evenly distributed in these islands, as individual hosts contain very different numbers of parasites. Thus, parasite populations are frequently more aggregated among their hosts than if they were randomly distributed (Poulin, 1993, 2007). *Paradollfusnema amphisbaenia* presented a rather homogeneous distribution in this host sample, with a tendency to be more aggregated in male hosts. According to Poulin (1993), more prevalent parasites show lower $D$ values. Our results support this presumption as in this *A. wuchereri* population the prevalence was high (100%) and the $D$ value indicated an even distribution of parasites. *Amphisbaena wuchereri* is a highly specialized digger (Gans, 1971) and the environment under the soil might be rather homogeneous, which would preclude significant differentiation in individual habitat use and, consequently, infection patterns.

Parasitism can be negatively related to host's life history (e.g. Bosch *et al.*, 2000). However, despite the high infection rates found for *A. wuchereri*, intensity of infection was not associated with its FBM. Nevertheless, we found inflammatory infiltrations in the large intestine of infected individuals of *A. wuchereri* (Rajão, unpublished data). Additionally, we must consider that FBM could be biased by the 3-day fasting period that individuals were submitted to (see Materials and methods), leading us to incur a Type II error. If this is the case, it is possible that *P. amphisbaenia* is harming individuals of *A. wuchereri* to some degree.

## Acknowledgements

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