

## Relationships between helminth communities and host traits in *Podarcis bocagei* and *Podarcis carbonelli* from NW Portugal

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### Abstract

A parasitological survey was carried out to determine the relationships between helminth fauna and some biological traits of two host species of lacertid lizards. Size, sex, diet, and season of collection, as well as infracommunities and component communities of *Podarcis bocagei* and *P. carbonelli* from Douro litoral (northwest Portugal), have been analysed. In both host species, we found low values of parasite infection parameters and diversity. These findings were in accordance with their feeding habits, eating only animal prey and no plant matter. Evidences suggest a relationship between the presence of *Brachylaima* sp (Trematoda: Brachylaimidae) and the ingestion of snails by both lizard species. *Spauligodon carbonelli* (Nematoda, Pharyngodonidae), a specialist in *Podarcis* hosts, was the most important parasite, affecting mainly adult males with a prevalence of infection showing seasonal variation.

**Keywords:** *Podarcis bocagei*, *Podarcis carbonelli*, *helminths*, *Lacertidae*, Portugal

### Introduction

Among the species of the lizard genus *Podarcis* (Reptilia, Lacertidae) currently recognized in the Iberian Peninsula, two are endemic to the Western part of this region: *Podarcis bocagei* (Seoane 1884) and *Podarcis carbonelli* (Pérez-Mellado 1981) (Pleguezuelos et al. 2002). Both were considered conspecific (Pérez-Mellado 1981) but morphological (Harris & Sá Sousa 2001; Kaliontzopoulou et al. 2005), genetical (Harris & Sá Sousa 2001, 2002; Harris et al. 2002), and behavioural evidences (Barbosa et al. 2005) support the specific status of *P. carbonelli* (Sá Sousa & Harris 2002). Both species are in contact in one locality of the Douro Litoral province, northwest Portugal (Sá Sousa 2001), in which they are found in strict syntopy (Carretero et al. 2002).

Although some studies on helminth communities of both lizard hosts have been carried out (Roca et al. 1989; Galdón et al. 2006), none of them deals with

the relationships between the parasites and the host traits as examined for insular lacertid lizards such as the Balearic members of *Podarcis* (Roca & Hornero 1994; Roca 1996) and the Canarian lizards genus *Gallotia* (Martin et al. 2005; Roca et al. 2005). Here, our aim was to investigate the relationship between the structure and composition of helminth communities and host traits in both *Podarcis* species, specifically addressing if the structure of the helminth communities: (i) is related with the general patterns of the diet of both hosts; (ii) changes with the host species; (iii) varies with the locality; and (iv) is affected by the size and sex of the host, and by the season of collection.

### Materials and methods

Sampling was carried out in three coastal localities from Douro litoral, northwest Portugal: Espinho-Granja, UTM squares 29T NF24 and NF34, for

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both hosts; Torreira, near Aveiro, 29T NF21, for *P. carbonelli* and Mindelo-Vila Chã, 29T NF27, for *P. bocagei*. All three sites were geographically close (within a range of 40 km) and harboured similar habitats, humid dunes covered by psammophile vegetation (see Carretero et al. 2002 for a more detailed description). Climate regime was maritime Atlantic with warm mid-summers and mild, rainy winters; annual temperature averaged 12°C and total annual precipitation was 1000–1200 mm (Direcção Geral do Ambiente 1995).

Whenever possible, eight adult lizards (four males and four females) and four juvenile lizards of each species were captured on each month (within a period of one week maximum) and locality. This rate of collection was unlikely to have had an adverse effect on these populations. In all, 249 specimens of *P. bocagei* and 257 of *P. carbonelli* were collected. Lizards were immediately transported to the laboratory, humanely sacrificed and frozen. These specimens were used not only for this study, but also to analyse the gonads and fat reserves cycles (Carretero et al. 2006), as well as morphometrics (Kaliotzopoulou et al. 2005), and trophic ecology (Marques et al. unpublished data).

For each lizard, snout–vent length (SVL) was measured with a calliper ( $\pm 0.01$  mm). Digestive tracts were extracted and fixed in 70% alcohol, and were sent to the laboratory of parasitology for analysis. They were opened and examined. Helminths were removed, washed, fixed, and mounted according to standard techniques (Roca, unpublished data). Parasites were identified, when possible, to species, and the number and location of individuals of each species were recorded. A parallel study on diet of these lizard hosts was carried out.

The use of descriptive ecological terms followed Bush et al. (1997). Brillouin's index was used for calculating diversity, according to Magurran (2004).

## Results

A total of five helminth species were recorded from both lizard hosts (Table I): 1 Trematoda (*Brachylaima* sp.), 1 Cestoda (*Oochoristica gallica* Dollfus, 1954) and 3 Nematoda (*Skrjabinelazia hoffmanni* Li, 1934, *Spauligodon carbonelli* Roca, 1988 and Spirurida gen. sp). All parasite species were found in the small intestine, except for *S. carbonelli*, which was found at the end of the large

Table I. Infection parameters of helminth species considering the host species, locality and host class. Values are given as the mean  $\pm$  SD with the range in parentheses.

| Helminth species                | Host species         | Locality | Host class  | n   | Prevalence | Abundance              |
|---------------------------------|----------------------|----------|-------------|-----|------------|------------------------|
| <b>DIGENEA</b>                  |                      |          |             |     |            |                        |
| <i>Brachylaima</i> sp (larvae)  | <i>P. bocagei</i>    | Espinho  | Pooled      | 87  | 1.15       | 0.02 $\pm$ 0.02 (0–2)  |
|                                 | <i>P. bocagei</i>    | Mindelo  | Pooled      | 162 | –          | –                      |
|                                 | <i>P. carbonelli</i> | Espinho  | Pooled      | 117 | 1.71       | 0.11 $\pm$ 0.10 (0–12) |
|                                 | <i>P. carbonelli</i> | Torreira | Pooled      | 140 | 0.71       | 0.01 $\pm$ 0.01 (0–1)  |
| <b>CESTODA</b>                  |                      |          |             |     |            |                        |
| <i>Oochoristica gallica</i>     | <i>P. bocagei</i>    | Espinho  | Pooled      | 87  | 6.90       | 0.20 $\pm$ 0.10 (0–8)  |
|                                 | <i>P. bocagei</i>    | Mindelo  | Pooled      | 162 | –          | –                      |
|                                 | <i>P. carbonelli</i> | Espinho  | Pooled      | 117 | 2.56       | 0.07 $\pm$ 0.04 (0–4)  |
|                                 | <i>P. carbonelli</i> | Torreira | Pooled      | 140 | –          | –                      |
| <b>NEMATODA</b>                 |                      |          |             |     |            |                        |
| <i>Skrjabinelazia hoffmanni</i> | <i>P. bocagei</i>    | Espinho  | Pooled      | 87  | 14.94      | 0.45 $\pm$ 0.16 (0–9)  |
|                                 | <i>P. bocagei</i>    | Mindelo  | Pooled      | 162 | 7.41       | 0.38 $\pm$ 0.19 (0–27) |
|                                 | <i>P. carbonelli</i> | Espinho  | Pooled      | 117 | 7.69       | 0.12 $\pm$ 0.04 (0–2)  |
|                                 | <i>P. carbonelli</i> | Torreira | Pooled      | 140 | 1.43       | 0.01 $\pm$ 0.01 (0–1)  |
| <i>Spauligodon carbonelli</i>   | <i>P. bocagei</i>    | Espinho  | Pooled      | 87  | 1.15       | 0.01 $\pm$ 0.01 (0–1)  |
|                                 | <i>P. bocagei</i>    | Mindelo  | Pooled      | 162 | –          | –                      |
|                                 | <i>P. carbonelli</i> | Espinho  | Pooled      | 117 | –          | –                      |
|                                 | <i>P. carbonelli</i> | Torreira | Pooled      | 140 | 14.29      | 1.26 $\pm$ 0.38 (0–32) |
|                                 | <i>P. carbonelli</i> |          | Ad. Males   | 54  | 25.93      | 2.44 $\pm$ 0.86 (0–32) |
|                                 | <i>P. carbonelli</i> |          | Ad. Females | 46  | 8.70       | 0.35 $\pm$ 0.23 (0–10) |
|                                 | <i>P. carbonelli</i> |          | Immatures   | 40  | 5.00       | 0.70 $\pm$ 0.59 (0–23) |
| Spirurida gen. sp (larvae)      | <i>P. bocagei</i>    | Espinho  | Pooled      | 87  | –          | –                      |
|                                 | <i>P. bocagei</i>    | Mindelo  | Pooled      | 162 | 0.62       | 0.01 $\pm$ 0.01 (0–1)  |
|                                 | <i>P. carbonelli</i> | Espinho  | Pooled      | 117 | –          | –                      |
|                                 | <i>P. carbonelli</i> | Torreira | Pooled      | 140 | –          | –                      |

Table II. Global infection and diversity parameters in both host species in the study areas. Diversity was calculated using the Brillouin index only with the parasitized hosts. Values are given as the mean  $\pm$  SD with the range in parentheses.

| Host species         | Locality | <i>n</i> | Prevalence | Abundance             | Richness              | Diversity                |
|----------------------|----------|----------|------------|-----------------------|-----------------------|--------------------------|
| <i>P. bocagei</i>    | Espinho  | 87       | 24.14      | $0.68 \pm 0.2$ (0–9)  | $0.24 \pm 0.05$ (0–1) | $0 \pm 0$ (–)            |
| <i>P. bocagei</i>    | Mindelo  | 162      | 8.02       | $0.39 \pm 0.2$ (0–27) | $0.08 \pm 0.02$ (0–1) | $0 \pm 0$ (–)            |
| <i>P. carbonelli</i> | Espinho  | 117      | 11.97      | $0.3 \pm 0.1$ (0–12)  | $0.12 \pm 0.03$ (0–1) | $0 \pm 0$ (–)            |
| <i>P. carbonelli</i> | Torreira | 140      | 15.71      | $1.28 \pm 0.4$ (0–32) | $0.16 \pm 0.03$ (0–2) | $0.01 \pm 0.00$ (0–0.15) |

intestine (rectum). The trematode *Brachylaima* sp. and the nematode Spirurida gen. sp. were recorded as larval forms, whereas the other species were adults.

Abundance, richness and diversity of helminth species in the communities of both hosts in all three localities was very low (Table II). The only Pharyngodonidae nematode found was *S. carbonelli*. This nematode displayed the most biased distributions among hosts, since it was absolutely absent from the populations of *P. carbonelli* from Espinho and *P. bocagei* from Mindelo, and very scarce in *P. bocagei* from Espinho. In contrast, it was found more frequently and abundantly in *P. carbonelli* from Torreira.

In fact, the infection by this nematode affected mainly adult males (ANOVA  $F_{2,137}=3.15$ ,  $P=0.04$ , Scheffé *post hoc* tests  $P<0.05$ ). Moreover, its prevalence showed seasonal variation, with the highest values concentrated between July and September (Figure 1). Furthermore, a significant relationship between host size and the number of *S. carbonelli* was found for males of *P. carbonelli* in the same locality (males  $R^2=0.26$ ,  $n=73$ ,  $P=0.03$ ; females  $R^2=0.12$ ,  $n=67$ ,  $P=0.31$ ; Figure 2). No sexual dimorphism in size was detected in adult lizards (males  $49.67 \pm 0.61$ , females  $48.57 \pm 0.54$ ,  $t_{98}=1.31$ ,  $P=0.19$ ). *Skrjabinelazia hoffmanni* was also abundant, but its distribution was less variable

between host populations and classes. Nevertheless, it appeared to be more frequent and abundant in *P. bocagei* from Espinho and very scarce in *P. carbonelli* from Torreira (Table I).

## Discussion

It has been suggested (Roca 1999; Martin et al. 2005) that carnivorous reptiles harbour poorer helminth communities than herbivorous ones, and lack Pharyngodonidae nematodes typical of the evolutionary lineage of the herbivorous reptiles. Thus, these Pharyngodonidae are good indicators of the degree of herbivory of the reptiles (Petter & Quentin 1976; Martin, unpublished data). Since the studied hosts eat only animal matter (none of the 506 stomachs had plant remains; Marques et al. unpublished data), have poor and isolationist communities (see Aho 1990; Martin & Roca 2004), and have no Pharyngodonidae nematodes belonging to the lineage of herbivorous reptiles, the pattern of poor helminth fauna in carnivorous lizards is corroborated. We can thus place *P. bocagei* and *P. carbonelli* near the end of carnivory in a continuum herbivory–carnivory of the food type strategy (Roca 1999; Martin, unpublished data), and near the end of isolationist in a continuum of the isolationist (poor)–interactive (rich) helminth communities (Figure 3).

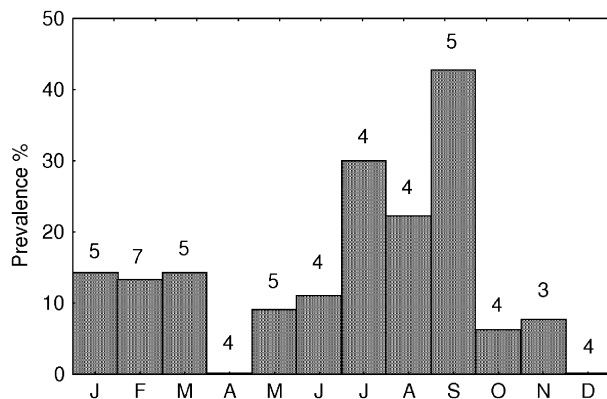


Figure 1. Monthly prevalence of *Spauligodon carbonelli* in *Podarcis carbonelli* from Torreira. Numbers indicate hosts sampled.

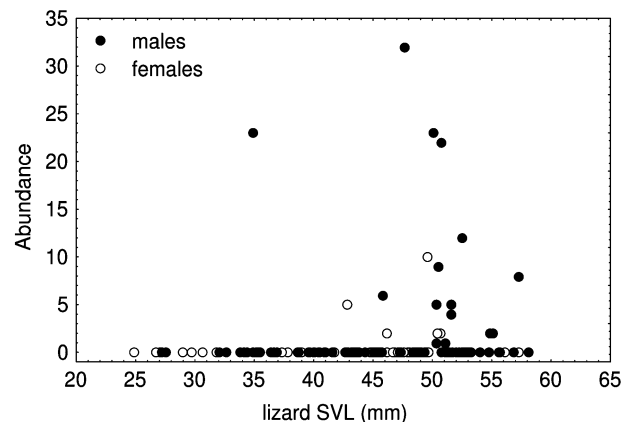


Figure 2. Variation in the abundance of *Spauligodon carbonelli* with size and sex of the host, *Podarcis carbonelli* from Torreira.

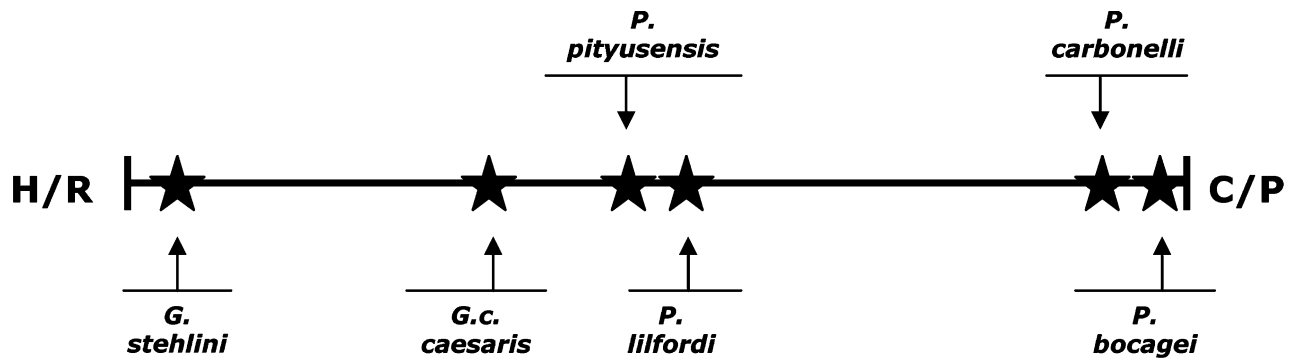


Figure 3. Situation of *Podarcis bocagei* and *Podarcis carbonelli* in the continuum of food type strategy/type of infracommunities. Position of endemic Canarian lizards *Gallotia stehlini* and *Gallotia caesaris* (herbivorous lizards with rich and interactive infracommunities), and *Podarcis pityusensis* and *Podarcis lilfordi*, (omnivorous lizards endemic from Balearic Islands) are noted for comparison. (H: herbivory; C: carnivory; R: rich communities; P: poor communities)

Some authors (Roca et al. 1989; Roca & Hornero 1994) have noted the presence of immature forms of *Brachylaima* sp. in some species of lizards. Lizards are accidental hosts for these parasites, which use small mammals as definitive hosts, and terrestrial gastropods as intermediate hosts (González-Moreno, unpublished data). The presence of these larval forms is scarce in lacertids (Galdón et al. 2006). On the other hand, snails are also rare as a prey of small lacertid species (Carretero 2004), but they were present in 9–26% of the stomachs in the studied populations, depending on the species and site (Marques et al. unpublished data). This evidence strongly suggests a relationship between the presence of *Brachylaima* sp. and the ingestion of snails: lizards eat the first intermediate host of the parasite instead of the usual definitive host, which should be rodents or insectivores (González-Moreno, unpublished data).

*Spauligodon carbonelli* can be considered as a *Podarcis* specialist (Edwards & Bush 1989; Roca & Hornero 1994), since it only parasitizes hosts of this genus (Galdón et al. in press). Remarkably, it was not equally abundant either in both species or in all localities. Since, both lizard species were parasitized but this nematode was absent in one of the localities (Mindelo) and very scarce in another (Espinho), we conclude that the variation observed was due to different local environmental conditions for the parasite between localities and not to host specificity. *S. carbonelli* has a direct life cycle (Roca & García-Adell 1988) and was mainly found in adult male lizards in the summer. These findings suggest that eggs could be taken by male lizards from the substrate during the spring activities related with reproduction such as tongue flicking on conspecific scent marks (Font 1996; López & Martín 2001;

Barbosa et al. 2005) and then develop inside the digestive tract after the breeding season of the host. Such seasonal pattern was not shared by *S. hoffmanni*, which has an indirect life cycle (Roca et al. 1990b). The possible intermediate hosts (arthropods, Chabaud et al. 1988; Roca et al. 1990b) were continuously available in the study sites (Marques et al. unpublished data) so infection, in theory, should not be limited to a period of the year. *O. gallica*, also with a heteroxenous life cycle (Dollfus 1957) could probably follow a similar pattern, which is not so evident because of its scarcity.

Finally, regarding the relationship between parasite infection with the host size (evidenced when sample size is sufficient), it seems to be just an indicator of lizard age and, hence, of time for parasite recruitment (Roca et al. 1990a; Martín, unpublished data). In fact, the greatest differences in parasite infection were between adult (SVL > 40–43 mm in *P. carbonelli*, > 53–57 mm in *P. bocagei*) and immature lizards.

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