New Reptile Hosts for Helminth Parasites in a Mediterranean Region

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ABSTRACT.—Parasitic helminths are an almost universal feature of vertebrate animals, but reptiles are among the hosts with the most depauperate parasite communities. Biological traits of reptiles are considered to be among the key reasons that explain low helminth diversity; therefore, insights from a wide range of reptile hosts are helpful to understanding the ecology of parasitic helminths. We analyzed helminth fauna in two lacertids, Psammomodromus algirus and Psammomodromus edwardsianus (Squamata: Lacertidae), and one skink, Chalcides bedriagai (Squamata: Scincidae), three common species of Mediterranean woodlands that differ in their ecological conditions and in lifestyles that are linked to habitat use. We examined a total of 102 P. algirus, 27 P. edwardsianus, and 23 C. bedriagai from mountain landscapes in eastern Iberia. We found three helminth species, the nematodes Parapharyngodon echinatus and Spauligodon sp., and the cestode Mesocestoides sp. We report new reptile hosts for two helminth species: the skink C. bedriagai for the nematode P. echinatus and the lizard Psammomodromus algirus for the nematode Spauligodon sp. We also provide the second record of the larval forms of the cestode Mesocestoides sp. in the lizard P. edwardsianus from the Iberian Peninsula. Interestingly, prevalence of infection was much higher in the skink than it was in the two lacertid lizards. Therefore, a subterranean skink lifestyle may determine the incidence of helminth parasites when compared to the ground-dwelling lizard species. Similar to other reptile hosts, the helminth fauna of our focal lizard species was poor and mainly composed by Pharyngodonidae nematodes that are often detected in insectivorous reptiles.

Resumen.—Los helmintos parásitos son una característica casi universal de los vertebrados, pero su taxonomía los reptiles se cuentan entre los animales hospedadores que albergan una diversidad depauperada. Entre las explicaciones por la baja diversidad de los helminthos, se consideran razones claves varias características biológicas de los reptiles; por eso las investigaciones sobre diversas especies de reptiles son siempre útiles para entender la ecología de los helminthos parásitos. Analizamos la helmintofauna de dos lagartos, Psammomodromus algirus y Psammomodromus edwardsianus (Squamata: Lacertidae) y un escinco, Chalcides bedriagai (Squamata: Scincidae), tres especies de reptiles que a pesar de ser típicas de los bosques mediterráneos, difieren en sus condiciones ecológicas y estilo de vida, de acuerdo con su uso del hábitat. Hemos examinado un total de 102 P. algirus, 27 P. edwardsianus y 23 C. bedriagai de áreas montañosas del este de la Península Ibérica. Detectamos tres especies de helmintos, los nematodos Parapharyngodon echinatus y Spauligodon sp., y el cestode Mesocestoides sp. Señalamos como nuevos hospedadores al C. bedriagai para el nematodo P. echinatus y al P. algirus para el nematodo Spauligodon sp. También ofrecemos la segunda cita de larvas del cestodo Mesocestoides sp. en el lagarto P. edwardsianus oriundo a la Península Ibérica. La prevalencia de infección fue mucho más alta en el escinco que en los dos lagartos, lo que sugiere que el estilo de vida del escinco (especie más subterránea) pudo influir en la mayor incidencia de helmintos en comparación con los lagartos (especies más de superficie). Al igual que ocurre en otras especies de reptiles, la helmintofauna de los reptiles hospedadores estudiados fue pobre y principalmente compuesta por nematodos Pharyngodonidae, que son un grupo frecuente entre los reptiles insectívoros.

Reptiles are parasitized by various helminth species but typically in depauperate parasite communities (Aho, 1990). Several factors have been proposed as responsible for the simplicity of the helminth communities in reptiles, including such characteristics of the hosts as ectothermy, the simplicity of the alimentary canal, their low vagility, a nonspecialized diet, and characteristics of the parasites such as low helminth species diversity and direct life cycles (Kennedy et al., 1986; Roca and Hornero, 1994). Other ecological (host independent) characteristics may also contribute to these depauperate helminth communities, such as ecological isolation, infrequent interactions with other reptile species (Sanchis et al., 2000; Galdón et al., 2006), and low opportunities for parasite recruitment because of habitat conditions (Roca et al., 2016).

Largely herbivorous reptiles, such as tortoises, often show higher helminth diversity and prevalence of infection than strict insectivores such as many lizards (Roca, 1999). Furthermore, some nematode genera belonging to the family Pharyngodonidae are indicative of the feeding habits of their reptile hosts (Petter, 1966). Some genera (Tachygonetria, Mehdiella, Alaeuris, Thaparia, Ortellepomma, Ozolaimus, Travauszolaimus, and Mamillonacrus), typically parasitize herbivorous reptiles, whereas other genera (Pharyngodon, Spauligodon, Skrjabinodon, Parapharyngodon) infect insectivorous reptile species (Petter and Quentin, 1976; Roca, 1999).

Differences exist among insectivorous reptiles in terms of their endoparasitic helminth communities. For instance, European insular lizards showed higher values for both diversity and prevalence of helminths than did continental species, which is probably because of unusual insular conditions concerning hosts, as well as ecological conditions that are related to parasite recruitment opportunities (Roca et al., 2016). Species of European continental lizards belonging to the genera Podarcis, Zootoca, and Darevskia have been recorded as having among the lowest values for helminth diversity and prevalence (Roca et al., 2015, 2016). Low helminth diversity and prevalence values for helminth communities in other Mediterranean lizard species,
such as members of the genera *Psammodromus* and *Chalcides*, could be expected.

The aim of our study was to contribute to the list of parasite interactions in reptiles, and specifically helminth species that parasitize European lizards. We compared the incidence (diversity and prevalence) of helminth parasites in three Mediterranean reptile species from eastern Iberian Peninsula that share habitat but differ in lifestyle: the lacertids *P. algirus* and *P. edwarsianus*, and the skink *Chalcides bedriagai*. The three lizard species live in the same habitats and share some traits, such as small size, low vagility, and carnivorous feeding habits, but they show differences in activity patterns and microhabitat preferences. The two *Psammodromus* species are ground-dwelling lizards that shuttle among shaded and sunlit spaces and remain away from their refuges for long periods of the day. In contrast, the *Chalcides* skink remains under the soil surface or under rocks (López-Jurado et al., 1978). Although low-diversity helminth communities are expected due to the habitat conditions (i.e., dry habitats and with low interactions with other hosts) and the species biological traits (i.e., ectothermy, low vagility, simple diet), we predict an influence of the lifestyle (see above) in the prevalence of helminths.

**MATERIALS AND METHODS**

We conducted our study in eastern Spain, in the Valencia region (39°30′N, 0°45′E), during spring–summer 2013, 2014, and 2016. Specimens were collected in two shrubland areas, that were dominated by *Quercus coccifera*, *Cistus* sp. pl., *Rosmarinus officinalis*, *Juniperus oxycedrus*, and *Brachypodium retusum*, that sometimes alternated with pine woodlands (*Pinus halepensis*) and some evergreen oak patches (*Quercus ilex*). A total of 48 traps (pitfalls) were set in each area for invertebrate sampling linked to another study (Pausas et al., 2018), and we took advantage of the reptile specimens cited above that accidentally fell to analyze the occurrence of helminth parasites.

In all, 102 specimens (from pitfalls) of *Psammodromus algirus* (50 males, 52 females), 27 of *Psammodromus edwarsianus* (15 males, 12 females), and 23 of *Chalcides bedriagai* (12 males, 11 females) were examined for helminths. In the field, lizards were fixed and stored in 70% ethanol. We dissected each specimen in the laboratory and inspected their digestive tracts using a stereomicroscope. Helminths were removed, washed, fixed, and mounted according to standard techniques (for details see Roca and Horner, 1994). All the parasites were identified, to species level when possible, following the descriptive ecological terms provided by Bush et al. (1997). Thus, prevalence is the number of infected hosts divided by the total number of hosts; intensity of infection is the total number of parasites divided by the number of infected hosts; diversity is calculated using Brillouin’s index.

**RESULTS**

We found a total of three helminth species at the study: two nematodes *Parapharyngodon echinatus* (Fig. 1) and *Spauligodon* sp. (Fig. 2) and one cestode, *Mesocestoides* sp. (Fig. 3). *Parapharyngodon echinatus* was found in the rectums of three specimens of *P. algirus* and of nine specimens of *C. bedriagai*. *Spauligodon* sp. was found in the feces of two *P. algirus* and *Mesocestoides* sp., in various larval stages, was found in the body cavity of a single specimen of *P. edwarsianus* (Table 1). Helminth parasites were not homogeneously distributed across the lizard species; prevalence was 3% for *P. algirus*, 3.7% for *P. edwarsianus* and 39.1% for *C. bedriagai*. Mean intensity of infection was 3.3 ± 4 (1–8) for *P. algirus* and 2.2 ± 1.5 (1–4) for *C. bedriagai*. We never found more than one helminth species per host.

**DISCUSSION**

The helminth species identified in our study (*P. echinatus*, *Spauligodon* sp., and *Mesocestoides* sp.) are common in reptiles from southwest Europe. Here we provide field evidence of new reptile hosts for two of the helminth species: the skink *C. bedriagai* for the nematode *P. echinatus* and the lizard *P. algirus* for the nematode *Spauligodon* sp. Moreover, we provide the second record of the larval forms of the cestode *Mesocestoides* sp. in the lizard *P. edwarsianus* for the Iberian Peninsula. *Parapharyngodon echinatus* has been recorded in *P. algirus* from the Iberian Peninsula (Roca et al., 1986) and in other European lacertid lizards (Martin and Roca, 2005), but it has never been recorded in *C. bedriagai* (López-Jurado et al., 1978). Some species
of Spauligodon have been recorded in lizard hosts from Europe, but had never been recorded in P. algirus (Roca et al., 1986).

Larval forms of Mesocestoides sp. have been previously recorded in P. edwarsianus from Mediterranean areas of the Iberian Peninsula (Roca et al., 1986) and in Gallotia atlantica and Gallotia caesaris from Canary Islands (Martin and Roca, 2005; Martin et al., 2005); the second observation for P. edwarsianus provided here corroborates the fact that this lizard acts as intermediate or paratenic host for this helminth species. Predators of P. edwarsianus as feral cats or other carnivores are likely to be the definitive hosts for Mesocestoides sp., as has been reported for the Mesocestoides sp. of Canarian lizards (Martin and Roca, 2005).

The observed very low diversity of intestinal helminth communities of P. algirus, Psammodromus hispanicus, and C. bedriagai points to isolationist communities, which is in accordance with the general pattern observed in reptiles (Aho, 1990; Roca and Hornero, 1994). The impoverished communities found in our P. algirus and P. edwarsianus are consistent with previous observations for the same hosts in a nearby geographic area (Roca et al., 1986), and evidence that these lacertid lizards, along with Iberian Podarcis spp. and Caucasian Darevskia spp. (Roca et al., 2015, 2016) are among the European reptiles with the least diverse helminth communities. The skink C. bedriagai showed much higher prevalence, but the helminth community is still very poor (very low diversity), which agrees with data previously recorded in this species (López-Jurado et al., 1978) in which only one nematode (Pharyngodon spinicuadu) was found. Causes of the very low diversity in helminth communities of the three host species could be the potentially low number of interactions they have with other reptile species or infrequent opportunities for parasite recruitment given the habitat conditions (Roca et al., 2016). Nevertheless, prevalence values of infection of C. bedriagai was higher than those of the two species of Psammobromus. Therefore, the idea that lifestyle may influence opportunities for parasite recruitment, together with other ecological conditions that differ between lizards and skinks, including feeding habits, habitat selection, activity periods, or local distribution, was reinforced (Pérez-Mellado, 1997; Salvador, 1997).

In reptiles, poor helminth communities and presence of some particular genera of Pharyngodonidae nematodes are indicative of their feeding habits (tendency to herbivory or carnivory; Roca, 1999). The depauperate helminth communities of P. algirus and C. bedriagai, and the existence of the nematodes P. echinatus and Spauligodon sp. that are typical of carnivorous reptiles (Roca, 1999), could indicate that our lizard species were largely carnivorous opposed to herbivorous. Our observations would be in accordance with the previously reported carnivorous feeding habits of P. algirus and C. bedriagai (Pérez-Mellado, 1997; Salvador, 1997). Moreover, the depauperate helminth communities found in our lizards are better explained by their biotic

<table>
<thead>
<tr>
<th>Helminth species</th>
<th>Psammodromus algirus</th>
<th>Psammodromus edwarsianus</th>
<th>Chalcides bedriagai</th>
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<tbody>
<tr>
<td>Cestoda</td>
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<tr>
<td>Mesocestoides sp.</td>
<td>A1C4-3100 (adult female)</td>
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<td>Nematoda</td>
<td>16145 (feces)</td>
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<tr>
<td>Spauligodon sp.</td>
<td>TNB64 (feces)</td>
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<tr>
<td>Parapharyngodon echinatus</td>
<td>COA.4-3106 (adult male)</td>
<td>AZ0.2-2018 (adult male)</td>
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<td></td>
<td>CZ2.2-2047 (adult male)</td>
<td>A3ANE-3065 (adult female)</td>
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<td></td>
<td>COA4 (adult female)</td>
<td>A2B4-3085 (adult male)</td>
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<td></td>
<td>M2A1 (juvenile female)</td>
<td>AZ32-1401 (adult female)</td>
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<td>C0A4-CHB1 (adult male)</td>
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<td>C2B4 (adult male)</td>
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characteristics (see above), and also abiotic characteristics such as climate and vegetation (Roca et al., 2016) may modify the possibilities of lizard hosts for recruiting parasites. This includes low number of interactions with other reptile species, low prey availability, and low opportunities for parasite recruitment.

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LITERATURE CITED


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