

## New Reptile Hosts for Helminth Parasites in a Mediterranean Region

VICENTE ROCA,<sup>1</sup> JOSABEL BELLIURE,<sup>2</sup> XAVIER SANTOS,<sup>3</sup> AND JULI G. PAUSAS<sup>4,5</sup>

<sup>1</sup>Departament de Zoologia, Facultat de Ciències Biològiques, Universitat de València, Dr. Moliner 50, 46100 Burjassot, Valencia, España

<sup>2</sup>Departamento de Ciencias de la Vida, Facultad de Biología, Ciencias Ambientales y Química, Universidad de Alcalá, 28871 Alcalá de Henares, Madrid, España

<sup>3</sup>CIBIO/In BIO, Centro de Investigação em Biodiversidade e Recursos Genéticos da Universidade do Porto, Instituto de Ciências Agrárias de Vairão, R. Padre Armando Quintas, 4485-661 Vairão, Portugal

<sup>4</sup>Centre d'Investigació sobre la Desertificació (CIDE), Carretera Moncada-Náquera km 4.5, 46113 Moncada, Valencia, España

**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, *Psammodromus algirus* and *Psammodromus 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 *Psammodromus 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 por su taxonomía los reptiles se cuentan entre los animales hospedadores que albergan una diversidad depauperada. Entre las explicaciones por la baja diversidad de los helmintos, 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 helmintos parásitos. Analizamos la helmintofauna de dos lagartos, *Psammodromus algirus* y *Psammodromus edwardsianus* (Squamata: Lacertidae) y un esquinco, *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* originarios de áreas montañosas del este de la Península Ibérica. Detectamos tres especies de helmintos, los nematodos *Parapharyngodon echinatus* y *Spauligodon* sp., y el cestodo *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 esquinco que en los dos lagartos, lo que sugiere que el estilo de vida del esquinco (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). Thus, some genera (*Tachygonetria*, *Mehdiella*, *Alaeuris*, *Thaparia*, *Ortleppnema*, *Ozolaimus*, *Travassozolaimus*, and *Mamillomacracis*), 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,

<sup>5</sup>Corresponding author: E-mail: Vicente.roca@uv.es  
DOI: 10.1670/18-133



FIG. 1. Caudal end of a male of *Parapharyngodon echinatus* from *Chalcides bedriagai* showing caudal papillae. Scale bar: 20  $\mu\text{m}$ . (Photo V. Roca.)



FIG. 2. Female of *Spauligodon* sp. from *Psammmodromus algirus*. Scale bar: 1 mm. (Photo V. Roca.)

such as members of the genera *Psammmodromus* 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. edwardsianus*, 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 *Psammmodromus* 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 *Psammmodromus algirus* (50 males, 52 females), 27 of *Psammmodromus edwardsianus* (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 Hornero, 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. edwardsianus* (Table 1). Helminth parasites were not homogeneously distributed across the lizard species; prevalence was 3% for *P. algirus*, 3.7% for *P. edwardsianus* and 39.1% for *C. bedriagai*. Mean intensity of infection was  $3.3 \pm 4$  (1–8) for *P. algirus* and  $2.2 \pm 1.5$  (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. edwardsianus* 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

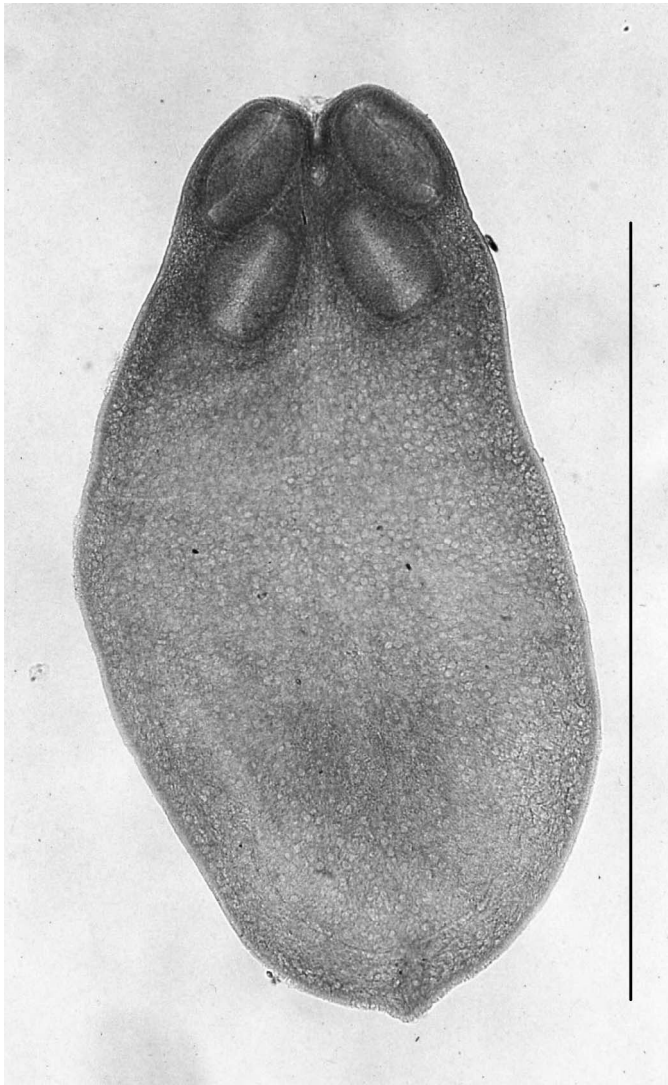


FIG. 3. *Mesocestoides* sp. (larvae) from *Psammodromus edwardsianus*. Scale bar: 1 mm. (Photo V. Roca.)

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. edwardsianus* 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. edwardsianus* provided here corroborates the fact that this lizard acts as intermediate or paratenic host for this helminth species. Predators of *P. edwardsianus* 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 Canary 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. edwardsianus* 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 spinicauda*) 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 *Psammodromus*. 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 1. Helminths from the different lizard species searched. Host references belong to individuals in which parasites were found.

Helminth species	<i>Psammodromus algirus</i>	<i>Psammodromus edwardsianus</i>	<i>Chalcides bedriagai</i>
Cestoda			
<i>Mesocestoides</i> sp.		A1C4-3100 (adult female)	
Nematoda			
<i>Spauligodon</i> sp.	16145 (feces) TNB64 (feces)		
<i>Parapharyngodon echinatus</i>	COA.4-3106 (adult male)		AZ0.2-2018 (adult male) AZ0.2-2021 (adult female) A3ANE-3065 (adult female) A2B4-3085 (adult male) AZ32-1401 (adult female) M2A1 (juvenile female) M3A2 (adult male) C0A4-CHB1 (adult male) C2B4 (adult male)
	CZ2.2-2047 (adult male)		
	COA4 (adult female)		

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.

*Acknowledgments.*—We thank the FILAS project (CGL2015-64086-P) from the Spanish government for funding. Permits for traps were provided by the Consellería de Infraestructuras, Territorio y Medio Ambiente (Generalitat Valenciana): 630/12(FAU12\_052). The handling of the animals was in accordance with the rules of the Animal Experimentation and Animal Welfare Committee of the University of Valencia (Spain). Lizard carcasses are deposited in the Museo de la Universitat de València de Historia Natural.

## LITERATURE CITED

- AHO, J. M. 1990. Helminth communities of amphibians and reptiles: Comparative approaches to understanding patterns and processes. Pp. 157–195 in G. Esch, A. O. Bush, and J. M. Aho (eds.), *Parasite Communities: Patterns and Processes*. Chapman and Hall, UK.
- BUSH, A. O., K. D. LAFERTY, J. M. LOFT, AND A. W. SHOSTAK. 1997. Parasitology meets ecology on its own terms: Margolis *et al.* revisited. *Journal of Parasitology* 83:575–583.
- GALDÓN, M. A., V. ROCA, D. BARBOSA, AND M. A. CARRETERO. 2006. Intestinal helminth communities of *Podarcis bocagei* and *Podarcis carbonelli* (Sauria: Lacertidae) in Helminthologia NW Portugal). 43: 37–41.
- KENNEDY, C. R., A. O. BUSH, AND J. M. AHO. 1986. Patterns in helminth communities: why are birds and fish different? *Parasitology* 93:205–215.
- LÓPEZ-JURADO, L. F., P. JORDANO, AND M. RUIZ. 1978. Ecología de una población insular mediterránea del eslizón ibérico *Chalcides bedriagai* (Sauria, Scincidae). Doñana, *Acta Vertebrata* 5:19–34.
- MARTIN, J. E., AND V. ROCA. 2005. Helminths of the Atlantic lizard, *Gallotia atlantica* (Reptilia, Lacertidae), in the Canary Islands (Eastern Atlantic): composition and structure of component communities. *Acta Parasitologica* 50:85–89.
- MARTIN, J. E., G. A. LLORENTE, V. ROCA, M. A. CARRETERO, A. MONTORI, X. SANTOS, AND R. ROMEU. 2005. Relationship between diet and helminths in *Gallotia caesaris* (Sauria: Lacertidae). *Zoology* 108:121–130.
- PAUSAS, J. G., J. BELLURE, E. MÍNGUEZ, AND S. MONTAGUT. 2018. Fire benefits flowers beetles in a Mediterranean ecosystem. *PLoS ONE*: 13(6): e0198951.
- PÉREZ-MELLADO, V. 1997. *Psammodromus algirus* (Linnaeus, 1758). Pp. 307–318 in A. Salvador (ed.), *Reptiles. Fauna Ibérica*, vol. 10. Museo Nacional de Ciencias Naturales, CSIC, Spain.
- PETTER, A. J. 1966. Équilibre des espèces dans les populations de nématodes parasites du colon des tortues terrestres. *Mémoires du Muséum National d'Histoire Naturelle, Série A, Zoologie* (Paris) 39: 1–252.
- PETTER, A. J., AND J. C. QUENTIN. 1976. Keys to genera of the Oxyuroidea. Pp. 1–30 in R. C. Anderson, A. G. Chabaud, and S. Willmott (eds.), *CIH Keys to the Nematode Parasites of Vertebrates*. CAB International, UK.
- ROCA, V. 1999. Relación entre la fauna endoparásita de reptiles y su tipo de alimentación. *Revista Española de Herpetología* 13:101–121.
- ROCA, V., AND M. J. HORNERO. 1994. Helminth infracommunities of *Podarcis pityusensis* and *Podarcis lilfordi* (Sauria: Lacertidae) from the Balearic Islands (western Mediterranean basin). *Canadian Journal of Zoology* 72:658–664.
- ROCA, V., J. LLUCH, AND P. NAVARRO. 1986. Contribución al conocimiento de la helmintofauna de los herpetos ibéricos. V. Parásitos de *Psammodromus algirus* (L., 1758) Boulenger, 1887, *Psammodromus hispanicus* Fitzinger, 1826 y *Acanthodactylus erithrurus* (Schinz, 1833) Mertens, 1925 (Reptilia: Lacertidae). *Boletín de la Real Sociedad Española de Historia Natural (Biología)* 81:69–78.
- ROCA, V., F. JORGE, Ç. ILGAZ, Y. KUMLUTAS, S. H. DURMUS, AND M. A. CARRETERO. 2015. Are the helminth communities from unisexual and bisexual lizards different? Evidence from gastrointestinal parasites of *Darevskia* spp. in Turkey. *Acta Zoologica Academiae Scientiarum Hungaricae* 61:279–288.
- ROCA, V., F. JORGE, Ç. ILGAZ, Y. KUMLUTAS, S. H. DURMUS, AND M. A. CARRETERO. 2016. The intestinal helminth community of the spiny-tailed lizard *Darevskia rudis* (Squamata, Lacertidae) from northern Turkey. *Journal of Helminthology* 90:144–151.
- SALVADOR, A. 1997. *Chalcides bedriagai* (Boscá, 1880). Pp. 149–156 in A. Salvador (ed.), *Reptiles. Fauna Ibérica*, Volume 10. Museo Nacional de Ciencias Naturales, CSIC, Spain.
- SANCHIS, V., J. M. ROIG, M. A. CARRETERO, V. ROCA, AND G. A. LLORENTE. 2000. Host–parasite relationships of *Zootoca vivipara* (Sauria: Lacertidae) in the Pyrenees (north Spain). *Folia Parasitologica* 47:118–122.

Accepted: 20 January 2020.

Published online: 16 July 2020.