J. Parasitol., 90(2), 2004, pp. 266–270

HELMINTH INFRACOMMUNITIES OF *GALLOTIA CAESARIS CAESARIS* AND *GALLOTIA CAESARIS GOMERAE* (SAURIA: LACERTIDAE) FROM THE CANARY ISLANDS (EASTERN ATLANTIC)

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ABSTRACT: A survey of gastrointestinal helminth communities of *Gallotia caesaris caesaris* (Lehrs, 1914) and *G. c. gomerae* (Boettger and Müller, 1914), from the islands of El Hierro and La Gomera, respectively, in the Canary Archipelago, Spain, was conducted to determine the prevalence, intensity, and diversity of intestinal parasites of these lacertid lizards. Larval forms of cestodes, nematodes, and acanthocephalans were found in the body cavity of *G. c. caesaris*; this lizard is the intermediate or paratenic host in the life cycle of these helminths. Pharyngodonid nematodes were the most common intestinal helminths in both hosts, 4 of them being *Gallotia* spp. specialists. Helminth infracommunities of both hosts were depauperate and isolationist, according to the low values of helminth diversity.

The Canarian Archipelago, located off the northwest coast of Africa, at 27°37′–29°24′N, 13°37′–8°10′W, comprises 7 main islands and a number of peripheral islets. Lacertids living in this archipelago belong to endemic species *Gallotia* (Arnold, 1973). El Hierro and La Gomera islands are inhabited by different subspecies of *Gallotia caesaris*: *G. c. caesaris* on El Hierro and *G. c. gomerae* on La Gomera (Thorpe et al., 1993; Barahona et al., 2000; Mateo and García-Márquez, 2002).

Although several recent ecological studies are available on helminth communities of reptiles (Dobson and Pacala, 1992; Dobson, Pacala, Rougharden et al., 1992; Goldberg and Bursey, 1998; Goldberg et al., 1999), there is a paucity of data on the structure of the helminth communities of European reptiles (Roca and Hornero, 1994; Roca, 1995; Sanchis et al., 2000). For the Canary Islands, data are available for 2 subspecies of *G. galloti* living on the islands of Tenerife and La Palma (V. Roca, unpubl.).

In this article, we analyze the prevalence, intensity, and diversity of helminths from *G. c. caesaris* and *G. c. gomerae*, specifically addressing the following issues: (1) characterization of the patterns of helminth community richness and diversity, (2) evaluation of the exchange of helminths between both lizard subspecies, (3) characterization of the helminths parasitizing both hosts as either specialists or generalists, and (4) comparison of the helminth fauna of *G. caesaris* with that of other continental and insular lacertid hosts.

MATERIALS AND METHODS

El Hierro is a volcanic island (269 km^2; maximum elevation of 1,500 m) with a peripheral position in the Canarian Archipelago (Fig. 1). The island is microclimatically and ecologically heterogeneous because of the interaction of its surface relief with wet air masses carried by trade winds from the northeast and the presence of ancient volcanic soils that provide multiple opportunities for plant colonization (García-Márquez, López-Jurado et al., 1999). In all, 318 lizards were caught in several localities from this island (Fig. 1) during March–November 1995.

La Gomera is also a volcanic island (378 km^2; 800 m). As for El Hierro, the combination of geomorphological features and climate has given rise to numerous ecological habitats and a diverse flora and fauna. Twenty-one lizards were caught in San Antonio (Fig. 1) in July 1995.

All lizards captured were killed with an overdose of chloroform. The body cavity, digestive tract, heart, lungs, and liver were removed, opened, and placed in Ringer's solution for examination. Helminths were removed, washed in distilled water, fixed, and mounted according to standard techniques. Parasites were identified, when possible, to species, and the number and location of individuals of each species were recorded.

The use of descriptive ecological terms follows Bush et al. (1997). Brillouin's index was used for calculating diversity according to Magurran (1988).

RESULTS

A total of 12 helminth species was found (10 Nematoda, 1 Cestoda, and 1 Acanthocephala). Nine of the nematode species were recorded as adults and 1 as a larval stage. Only larval specimens of Cestoda and Acanthocephala were found.

Mesocestoides sp., *Centrorhynchus* sp., and Spirurida gen. sp. (all as larvae) were located in the body cavity, whereas the remaining nematodes were found in the digestive tract. The total number of parasite species and the infection parameters for each host subspecies are shown in Tables I, II. The overall prevalence of infection in *G. c. caesaris* from El Hierro was 85.2%, whereas it was 81.0% in *G. c. gomerae* from La Gomera (Table III).

Intestinal infracommunities of both host subspecies comprised mainly pharyngodonid nematodes. Prevalences of these nematodes were less than 30% for 12 of the 17 helminth–host species pairs. Only 2 species infected more than 50% of the host populations. The 3 species that used lizards as intermediate hosts (*Mesocestoides* sp., *Centrorhynchus* sp., and Spirurida gen. sp.) each infected less than 3% of their host populations.

Table IV shows the diversity parameters for helminth infracommunities in both hosts. Helminth richness and proportion of lizards with 0 or 1 helminth species were similar in both hosts. The number of helminths per host (abundance) and Brillouin's index (diversity) were lower in *G. c. caesaris* than in *G. c. gomerae*.

DISCUSSION

The most common nematodes in the infracommunities of *G. c. caesaris* and *G. c. gomerae* are members of the Pharyngodonidae, of which *Thelandros galloti*, *T. filiformis*, *T. tinerfensis*, *Spauligodon atlanticus*, and *Alaeuris numidica canariensis* are endemic species or subspecies on the Canary Islands. *Thelandros galloti*, *T. filiformis*, *S. atlanticus*, and *A. n. canariensis* can be considered as *Gallotia* specialists (sensu Edwards and

Received 6 February 2003; revised 6 October 2003; accepted 6 October 2003.

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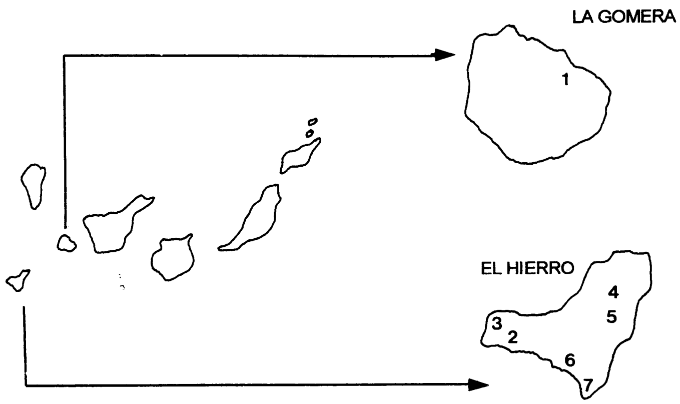

FIGURE 1. Location of El Hierro and La Gomera islands in the Canarian Archipelago. Prospected localities for lizards in both islands: 1. San Antonio; 2. Los Llanillos; 3. La Dehesa; 4. Nisdafe; 5. San Andrés; 6. El Risco; and 7. El Gaterón.

Bush [1989], but also see Roca and Hornero [1994]) but not for other European lizards. *Thelandros tinerfensis* is not a *Gallotia* specialist because it was also found in the scincid *Chalcides viridanus* (Solera-Puertas et al., 1988). The remaining helminths parasitizing both hosts appear to be generalist species.

The presence of larval forms of helminths infecting *G. c. caesaris* suggests that this lizard may be an intermediate or paratenic host in the life cycles of *Mesocestoides* spp., *Centrorhynchus* sp., and Spirurida gen. sp. For species of *Mesocestoides*, several reptile species have been identified as paratenic hosts (Soldatova, 1944; Mankau and Widmer, 1977), including some insular and continental European lacertid lizards (Roca et al., 1986; Roca and Hornero, 1991) and also geckoes from the Canary Islands (Roca et al., 1987). Feral cats, and birds of prey, have been identified as definitive hosts for species of *Mesocestoides* (Voge, 1955; Roca et al., 1987), and may be definitive hosts for *Mesocestoides* sp. found in *G. c. caesaris*, because feral cats are important predators of this lacertid lizard on El Hierro island (García-Márquez, Caetano et al., 1999). According to Poinar (1983), the life cycles of most species of Spirurida use insects or other invertebrates as first intermediate hosts. In addition, larval forms of Spirurida have been found in lacertid lizards (Roca et al., 1986; Roca and Hornero, 1994). In fact, Roca and Hornero (1991) suggested that lizards probably are paratenic hosts in the life cycle of these larval forms, with lizard-eating birds as their definitive hosts. Thus, because *G. c. caesaris* harbors larvae of Spirurida, it may be its paratenic host. Birds of prey (*Falco tinnunculus*) (García-Márquez, López-Jurado et al., 1999) would be definitive hosts on El Hierro Island. Because many reptiles are intermediate hosts in the life cycles of acanthocephalans (Goldberg et al., 1996), it is not surprising to find larvae of these parasites in lizards from the Canary Islands. Larvae of *Centrorhynchus* sp. have also been found in lizards from the Balaearic Islands (Roca and Hornero, 1991; Hornero and Roca, 1992) and geckoes from the Canary Islands (Roca, Martin, and Carbonell, 1999); birds of prey may also serve as definitive hosts for these larval forms (Yamaguti, 1963; Hornero and Roca, 1992).

Although samples of hosts from the 2 islands were heterogeneous with respect to sample sizes and sampling times, we suggest that the helminth fauna of *G. c. caesaris* and *G. c. gomerae* is very similar. The most common helminths (*T. galloti*, *T. filiformis*, *T. tinerfensis*, and *S. atlanticus*) were present on both islands, as has been found in other similar archipelagos (Dobson, Pacala, Rougharden et al., 1992; Roca and Hornero, 1994).

One of the effects of the insularity on the helminth fauna of some hosts, noted by Mas-Coma and Feliu (1984) and Mas-Coma et al. (1987), is a higher prevalence of infection in hosts as compared with hosts living on continents. In general, when hosts occur at high densities (as in the case of lizards on the Canary Islands), they show elevated prevalences. The insular physiography may be of great importance in this context because it determines the behavior of free-living species regarding

TABLE I. Infection parameters of the helminths parasitizing *Gallotia caesaris caesaris* from El Hierro.

Helminth species	Site of infection	Prevalence*	Intensity of infection: Range	Intensity of infection: $\bar{x}$	Mean abundance
Cestoda					
Mesocestoides sp.	Body cavity	1 (0.3)	—	—	—
Nematoda					
Thelandros galloti	Cecum	159 (50.0)	1–108	14.6 ± 17.5	7.3 ± 14.3
T. filiformis	Cecum	56 (17.6)	1–348	33.1 ± 66.7	5.8 ± 28.8
T. tinerfensis	Cecum	6 (1.9)	6–27	18.0 ± 7.3	0.3 ± 2.7
Parapharyngodon micipsae	Cecum	49 (15.4)	1–97	8.4 ± 14.5	1.3 ± 4.3
Spauligodon atlanticus	Cecum	113 (35.5)	1–186	26.1 ± 32.7	9.3 ± 17.8
Alaeuris numidica canariensis	Cecum	2 (0.6)	3–15	9.0 ± 12.6	0.1 ± 4.1
Tachygonetria dentata	Cecum	1 (0.3)	—	—	—
T. macrolaimus	Cecum	1 (0.3)	—	—	—
Skrjabinelazia pyrenaica	Digestive tract	42 (13.2)	1–10	1.7 ± 1.6	0.2 ± 3.5
Spirurida gen. sp.	Body cavity	8 (2.5)	1–6	2.0 ± 1.8	0.1 ± 2.1
Acanthocephala					
Centrorhynchus sp.	Body cavity	1 (0.3)	—	—	—

* Number of hosts parasitized divided by the number of hosts sampled (n = 318). Values in parentheses are in percentages.

TABLE II. Infection parameters of the helminths parasitizing *Gallotia caesaris gomerae* from La Gomera.

Helminth species	Site of infection	Prevalence*	Intensity of infection: Range	Intensity of infection: $\bar{x}$	Mean abundance
Nematoda					
Thelandros galloti	Cecum	8 (38.1)	3–88	29.5 ± 28.8	11.2 ± 22.5
T. filiformis	Cecum	7 (33.3)	2–89	30.1 ± 31.1	10.1 ± 22.4
T. tinerfensis	Cecum	2 (9.5)	16–31	23.5 ± 10.6	2.2 ± 7.5
Spauligodon atlanticus	Cecum	11 (52.4)	3–237	55.5 ± 66.9	29.1 ± 55.2
Skrjabinelazia pyrenaica	Digestive tract	1 (4.8)	—	—	—

* Number of hosts parasitized divided by the number of hosts sampled (n = 21). Values in parentheses are in percentages.

feeding, cohabitation with other species, and choice of biotopes different from those that are usual on the mainland. Roca (1995) noted that this effect should not be generalized in lizards, although in his study, prevalences of infection in insular lizards were usually higher than in continental hosts (Table III). Both *G. c. caesaris* and *G. c. gomerae* show higher prevalences than other continental Mediterranean lacertid lizards (Roca, 1995), which is probably due to greater host population densities and island physiography (Mas-Coma and Feliu, 1984). But they also show higher prevalences than other insular lizards (Roca, 1995) (Table III). This may be explained in 2 nonexclusive ways. First, the increase in prevalence is more marked on oceanic islands, e.g., Canary Islands, than on continental or ''land bridge'' islands, e.g., Balearic and other Mediterranean islands (see Roca, 1995). Second, the tendency toward herbivory in saurians (higher in canarian lizards; see Roca, 1999) will increase their prevalence of infection, mainly in pharyngodonid nematodes, as noted by Roca (1999).

The low values of helminth richness and abundance (Table IV) indicate that many members of the helminth infracommunities occurred only irregularly and occasionally. This agrees with the typical pattern of helminth infection in many reptiles, i.e., few species occur frequently, few species occur with moderate prevalence, and many species are rare (Roca and Hornero, 1994).

Gallotia caesaris caesaris and *G. c. gomerae* have diversity patterns of intestinal helminth infracommunities (Table IV) that are similar to those of other insular saurians. Thus, *Podarcis pityusensis* and *P. lilfordi*, both from the Balearic Islands (western Mediterranean), show values of Brillouin's diversity index of $\bar{x}H = 0.242$, range 0–1.211 and $\bar{x}H = 0.108$, range 0–0.815, respectively (Roca and Hornero, 1994). *Gallotia galloti galloti* from Tenerife Island, shows values of $\bar{x}H = 0.160$, range 0–0.94 (V. Roca, unpubl.). Such low diversity values agree with values observed in most reptiles (Aho, 1990) and suggest that the helminth infracommunities of *G. c. caesaris* and *G. c. gomerae* are depauperate and isolationist, a pattern probably widespread among lizards. Some characteristics of the reptile hosts, i.e., ectothermy, simplicity of the alimentary canal, and low vagility (Kennedy et al., 1986; Roca and Hornero, 1994), may be responsible for this pattern.

The total number of helminth species in the populations of *G. c. caesaris* and *G. c. gomerae* greatly exceeded both the average and the maximum number of species per individual lizard; thus, no single infracommunity included all species locally available. This upper limit on species richness is not usually realized (Poulin, 1998). This agrees with the results obtained for *Gallotia galloti* (V. Roca, unpubl.) and seems to be a pattern typical of many lacertid lizards (Roca and Hornero, 1994; Roca, 1999).

TABLE III. Comparison of the prevalences of different species of lacertid lizards from the Iberian Peninsula and several Mediterranean islands, and the hosts from La Gomera and El Hierro. Source of data of Mediterranean hosts is from Roca (1995).

	Locality	Prevalence (%)
Canarian insular hosts		
Gallotia caesaris caesaris	El Hierro (Spain)	85.2
G. c. gomerae	La Gomera (Spain)	81.0
Mediterranean insular hosts		
Podarcis pityusensis	Ibiza–Formentera (Spain)	79.4
P. litfordi	Mallorca–Menorca islets (Spain)	72.2
P. muralis	Rioux archipelago (France)	65.8
P. sicula	Corsica (France)	62.3
P. milensis	Milos (Greece)	71.4
P. erhardii	Lesvos (Greece)	73.1
Mediterranean continental hosts		
P. hispanica	Iberian Peninsula	66.1
P. muralis	Iberian Peninsula	45.7
P. bocagei	Iberian Peninsula	66.1
Lacerta lepida	Iberian Peninsula	53.5

TABLE IV. Overall diversity parameters of helminth infracommunities from both hosts.

Host	n	Species richness*	Helminth abundance*	Diversity*	Proportion of sample with 0 or 1 helminth species
Gallotia caesaris caesaris	318	1.4 ± 1.0 (0–5)	30.0 ± 44.3 (0–350)	0.2 ± 0.3 (0–1.1)	0.6
G. c. gomerae	21	1.4 ± 1.0 (0–3)	52.6 ± 84.2 (0–326)	0.3 ± 0.4 (0–1.0)	0.6

* Values are given as the mean ± SD, with the range in parentheses.

ACKNOWLEDGMENTS

We thank those who helped us with fieldwork in the Canary Islands: Gustavo Llorente, Albert Montori, Nuria Orrit, Silvia Lope, and Xavier Santos (University of Barcelona, Spain), Miguel Angel Carretero (CIBIO, Portugal); also people who helped us in the laboratory: José V. Sánchez-Mut, Joana Muniesa, and Mª Angeles Galdón (University of Valencia, Spain); and also Enrique Font (University of Valencia) who reviewed the English. This study was financed by Project PB98-1450 of the DGCYT (Spain). Permits (04/07/JVJ/JLRL and 04/07/TAB/JLR) for collecting living specimens were granted by the Viceconsejería de Medio Ambiente of the Canarian Government.

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