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Host-parasite relationships of *Zootoca vivipara* (Sauria: Lacertidae) in the Pyrenees (North Spain)

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Abstract. The helminths infesting the common lizard, *Zootoca vivipara* (Jacquin, 1787), were studied with special attention to the relations between the number of nematodes, *Oswaldocruzia filiformis* (Goeze,1782), and the size, sex and age class of the host. The possible seasonality of the parasite intensity and the relationship with the feeding habits of the host were also tested. Helminth infracommunities of *Z. vivipara* were depauperate with lizards harbouring only two species, the trematode *Plagiorchis molini* (Lent et Freitas, 1940) and the nematode *O. filiformis*. A positive correlation between host size and the number of *O. filiformis* was found for female *Z. vivipara*. However, no correlation was detected between intensity and sex or age class. The feeding habits of *Z. vivipara*, the isolation of the population studied and the low level of interaction with other reptilian or amphibian species are suggested as the causes of the depauperate helminth infracommunities found in this lacertid lizard.

Zootoca vivipara (Jacquin, 1787) is a small ground-dwelling lacertid lizard that ranges in Eurasia from northern Spain to Japan (Böhme 1997). It is one of the few lizards that exhibit reproductive bimodality (Lantz 1927). The only populations laying eggs are found in northern Spain (Braña and Bea 1987) and in French Aquitaine (Heulin et al. 1994), whereas all others are viviparous. One of these oviparous populations, the diet and reproduction of which have previously been analysed (Carretero et al. 1996, Roig et al. 1996, Roig 1998), is the subject of this parasitological study. Little is known about the helminth fauna of this lacertid, and even less about host-parasite relationships. Thirteen species of parasites were identified in the former USSR (Sharpilo 1976) and seven species were recorded in Poland (Lewin 1992a). In Spain, only one parasite species has been recorded (García-Adell and Roca 1988) from a small number of hosts. In this study we analyse the prevalence, intensity and helminth diversity of parasites of common lizard in an alpine meadow habitat, specifically addressing the following questions: (i) What is the helminth fauna of *Z. vivipara* in the Central Pyrenees? (ii) What are the prevalence and intensity of infection of helminths found in the host? (iii) Is there a relationship between the number of specimens of the main helminth species [the nematode *Oswaldocruzia filiformis* (Goeze, 1782)] with lizard size? (iv) Is there a relationship between the helminth intensity (*O. filiformis*) and the sex and size of the host? (v) Does the prevalence of parasites (*O. filiformis*) vary seasonally? (vi) What is the relationship between the feeding habits of the host and infection?

MATERIALS AND METHODS

The study area was an alpine meadow located at 1800 m of altitude, in the Central Pyrenees (Pla de Beret, Salardú, Naut Aran, U.T.M. grid 31T CH3434; 1º01'E, 42º44'N), dominated by heather (*Calluna vulgaris*) and, to a lesser degree, common juniper (*Juniperus communis*). The annual mean temperature is 9.7°C and annual total precipitation 918.9 mm (30 years mean, Panareda and Nuet 1973). *Z. vivipara* was the only lacertid species found at this site although some specimens of *Podarcis muralis* (Laurenti, 1768) were observed in adjacent areas.

From April to October 1995, 129 lizards were collected in a systematic field sampling carried out 15 days apart. An additional sample of eight pregnant females was captured in the first half of July 1997. Lizards with developed gonads during the reproductive period were considered adults and the minimum sizes of these reproductive lizards were determined for each sex. Outside the reproductive period, only those lizards with body size larger than these minima were included in the adult class (Carretero and Llorente 1997).

All lizards captured were killed with chloroform and frozen. Once in the laboratory, they were dissected and their digestive tract, heart, lungs, and liver were removed and opened in Ringer's solution for microscopical examination. Helminths were counted, washed in distilled water, fixed, mounted using standard techniques, and identified to species.

The use of descriptive ecological terms follows Bush et al. (1997). Brillouin's index of diversity (Magurran 1988) was calculated for each helminth infracommunity.

For each lizard, the snout-vent-length (SVL), together with a number of parameters associated with reproduction (gonad weight, epididymis and oviduct width) and body condition (fat bodies and liver weight, tail base section) were measured in

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both sexes (see Carretero et al. 1996, Roig et al. 1996). Callipers (0.01 mm precision) were used for linear measurement and weights were recorded with a digital balance (0.0001 g precision). Regression residuals between all variables and SVL (both log-transformed) were calculated to standardise variables to animal size (see Carretero et al. 1996, Roig et al. 1996).

Since the intensity of infection (number of helminths per host) was not normally distributed, non-parametric statistics were used when appropriate. For certain analyses, mean size of each helminth sex was calculated for each infected host in order to avoid pseudoreplication.

Log-linear models (Bizquerra 1989, Jobson 1992) were used for analysing simultaneously several categorical variables, including the effects of different host factors (size, sex, season) and the presence of helminths. An automatic procedure was performed (Anonymous 1999). First, a model with no relationships between factors was fitted; if that model did not fit, then a model with all two-way interactions was fitted. If this also failed to fit, then all three-way interactions were fitted, and so on. Finally, non-significant interactions were eliminated. The resulting model included the minimum number of interactions necessary to fit the observed table. The statistical significance was assessed by maximum likelihood and Pearson χ^2 tests (Bizquerra 1989).

RESULTS

The overall prevalence of infection of the *Zootoca vivipara* population in the Central Pyrenees was 39.42%. The prevalence was 37.9% for *Oswaldocruzia filiformis* and 2.2% for *Plagiorchis molini*. No seasonal patterns of occurrence were noted for *O. filiformis* (Fig. 1). No significant correlation was found between the prevalences of *O. filiformis* and monthly rainfall [$R = 0.12$, $F(1,5) = 0.07$, $p < 0.78$, n.s.].

The helminth community was only composed of two helminth species (Table 1). The digenean *P. molini* was found in only three large lizards (2 adult males and 1 adult female collected in August and July). The mean value of Brillouin's index of diversity was 0.0025 (SD = 0.029, range = 0-0.346). Only the nematode *O. filiformis* was abundant enough to be studied in detail. Considering only *O. filiformis*, individual lacertid lizards harboured a mean of 2.4 individual helminths (SD = 2.00, range = 1-10).

A significant correlation between host size and the number of *O. filiformis* was found for female *Z. vivipara* ($R_{\text{Spearman}} = 0.38$, $n = 61$, $p = 0.002$; see Fig. 2) but not for males ($R_{\text{Spearman}} = 0.17$, $n = 76$, $p = 0.13$). A sexual dimorphism in size was detected in adult lizards, with females being larger than males (mean SVL ± standard error in mm: females 50.94 ± 0.49, males 48.25 ± 0.39; $T = 4.13$, 83 d.f., $p = 0.00008$).

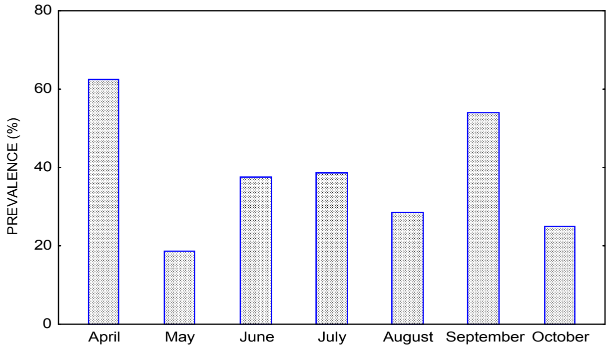

Fig. 1. Monthly prevalence of *Oswaldocruzia filiformis* in *Zootoca vivipara* (1995).

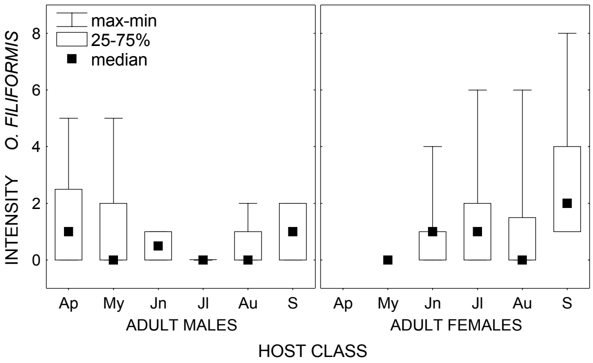

Fig. 2. Number of helminths (*Oswaldocruzia filiformis*) found throughout the year in adult *Zootoca vivipara*, according to the sex of the host.

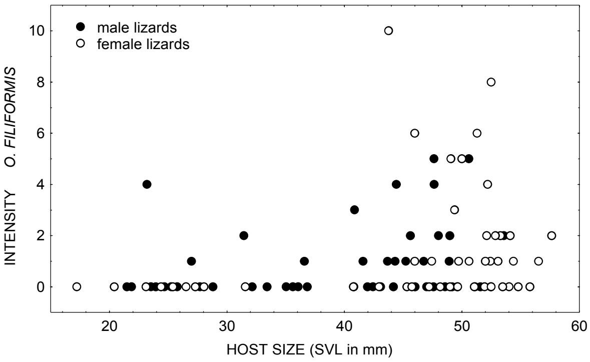

Fig. 3. Variation in the intensity of *Oswaldocruzia filiformis* with size and sex of the host, *Zootoca vivipara*.

After restricting the study to the adult lizards, the intensity of infection by *O. filiformis* was found to be unrelated to gonad development and the body condition of the host (R_{Spearman}). Furthermore, in female lizards infection was not affected by pregnancy. An apparent annual variation in the number of parasites was observed (Fig. 3). For instance, all seven adult females collected in September were infected. However, no statistical differences were found in either males or females (Kruskal-Wallis tests).

Table 1. Prevalence and intensity of the helminths infecting *Zootoca vivipara,* according to host sex, age class, and month of sampling.

				Intensity of infection		
Helminth species	Host class	Host sample	Prevalence[1]	Mean	Median	Range
Oswaldocruzia filiformis	Adult males	38	14 (36.8)	0.8	0	0-5
	Adult females	47	28 (59.6)	1.4	1	0-8
	Adults	85	42 (49.4)	1.2	0	0-8
	Immature males	38	9 (23.7)	0.5	0	0-8
	Immature females	14	1 (7.1)	0.7	0	0-10
	Immatures	52	10 (19.2)	0.5	0	0-10
	Pooled	137	52 (37.9)	0.9	0	0-10
Plagiorchis molini	Pooled	137	3 (2.18)	0.03	0	0-3

[1] Number of infected hosts divided by the number of hosts sampled. Values in parentheses are percentages.

A log-linear analysis was performed to distinguish simultaneously between the effects of sex and size class and the month of sampling on the presence of parasites (Table 2). The hierarchical model obtained showed that intensity was associated only with host size (immature hosts less than 45 mm SVL are less heavily infected than adult hosts), and not with the other factors which were arranged in pairs. A second model which forced associations between pairs of factors into one group while conserving the intensity-lizard size factor increased the significance of associations considerably (Table 2).

DISCUSSION

Although Rocha (1995) showed that the correlation between monthly prevalence of the nematode *Physaloptera retusa* Rudolphi, 1819 and monthly rainfall was positive in the tropidurid lizard *Liolaemus lutzae* Mertens in a "restinga" ecosystem from Rio de Janeiro State, Brazil, such coastal sandy habitats could be considered physiologically "dry" for helminths due to high salinity. In this instance, the rainfall determines the infection of the host. However, *Zootoca vivipara* inhabits very moist, freshwater habitats which remain humid throughout the year (see above), and it would therefore seem reasonable that rainfall has no influence on the infection rates. Thus, as occurs in other nematodes from reptile hosts (Bursey and Goldberg 1991), no seasonal patterns of occurrence were noted in *Oswaldocruzia filiformis* from *Z. vivipara*.

Infracommunities of *Z. vivipara* in the Central Pyrenees are highly depauperate. In fact, only three hosts harboured infracommunities composed of two infrapopulations (specimens of *O. filiformis* and *Plagiorchis molini*), whereas most lacertid lizards only harboured one infrapopulation (specimens of *O. filiformis*). Although Brillouin's index of diversity is low or very low in helminth infracommunities of saurian reptiles (Roca 1995, Roca and Hornero 1994) in comparison with other hosts such as fish (Kennedy et al. 1986) or birds (Roca et al. 1999), the value calculated for helminth infracommunities of *Z. vivipara* is the lowest known in any reptile species. This result suggests that helminth infracommunities are isolationist (Holmes and Price 1986), as in most reptiles (Aho 1990, Roca and Hornero 1994). We agree with Lewin (1992a) that the poor parasite fauna of *Z. vivipara* in comparison with other lacertid lizards is probably due to the habitat, together with small body size and different behaviour of *Z. vivipara*.

Of these, host size is the main factor determining the presence and numbers of *O. filiformis* in the intestine. The other apparent associations observed derive from variation in body size (females are larger) and season (differences of activity between adults and immature lizards or between males and females; Carretero et al. 1996, Roig et al. 1996). This seems to reflect the infrequent infection of immature specimens of *Z. vivipara* (which obviously constitute smallest individuals). Poor infection of juveniles has been recorded for other reptile species (see for example, Lewin 1922b, Roca 1996).

We interpret the greater degree of *O. filiformis* infection in female *Z. vivipara* to be an effect of the larger size of female. Sex rarely determines either the presence or the abundance of parasites (Roca 1996, Roca et al. 1990) although Lewin (1922a) noted that male *Z. vivipara* in Poland are generally more heavily infected by *O. filiformis* than females. Furthermore, in the same country, Lewin (1922b) recorded higher infection rates among male *Lacerta agilis* than among females. This may be due to male habit of sniffing faeces of other lizards, even touching them with the tip of the tongue whereas females do not behave in this way (Lewin 1992b). As the population of *Z. vivipara* in the Pyrenean mountains does not live with any other reptile species, and as its helminth fauna is composed of only heteroxenous parasites, we could not expect the same results as those obtained in Poland.

Zootoca vivipara is a strictly carnivorous lizard. In the Central Pyrenees it shows a generalised diet based mainly on Diptera, Araneae and Homoptera (Roig 1998). These prey are actively captured by *Z. vivipara,* making it one of the most widely foraging species

Table 2. Results of the log-linear analysis of infection of *Zootoca vivipara* by *Oswaldocruzia filiformis* according to month (May-October), sex, size (adult/immature) and infection (+/-) of the lizards. Factors in bold are significant.

Factor	d.f.	Partial χ^2	p	Marginal χ^2	p
Month	6	31.28	0.00002	31.28	0.00002
Sex	1	1.37	0.24	1.37	0.24
Size	1	6.64	0.01	6.64	0.01
Parasitisation	1	6.64	0.01	6.64	0.01
period × sex	6	22.09	0.001	19.23	0.004
month × size	6	22.50	0.001	16.15	0.01
month × parasitisation	6	10.59	0.10	6.88	0.33
sex × size	1	8.72	0.003	8.38	0.004
sex × parasitisation	1	1.36	0.24	3.67	0.06
size × parasitisation	1	10.75	0.001	9.55	0.002
month × sex × size	6	8.69	0.19	10.30	0.11
month × sex × parasitisation	6	0.95	0.99	1.87	0.93
month × size × parasitisation	6	3.00	0.81	3.47	0.75
sex × size × parasitisation	1	2.08	0.15	2.37	0.12
Log-linear model (factors)		test	value	d.f.	p
Automatic (month-sex/month-size/ sex-size/size-parasitisation)		Max. likel. χ^2	32.04	32	0.46
		Pearson χ^2	36.61	32	0.26
Simplified (month-sex-size/ size-parasitisation)		Max. likel. χ^2	21.74	26	0.70
		Pearson χ^2	19.78	26	0.80

among the European lacertids (Heulin 1986). Roca (unpubl.) noted that the diet of host and its helminth diversity (species richness and abundance) are related in saurian reptiles; the more carnivorous the reptile is, the lower the helminth diversity it exhibits. Our results agree with the observations made by Roca (unpubl.) since *Z. vivipara* has a very low diversity index in association with its carnivorous feeding habits. Conversely, *Z. vivipara* contradicts previous observations made by Aho (1990) and Roca (unpubl.) who consider that sit-and-wait reptiles exhibit depauperate helminth communities, whereas widely-foraging reptiles have richer, interactive helminth communities. The extremely poor helminth infracommunities found in *Z. vivipara* in Spain do not match with its widely-foraging strategy (Roig et al. 1998). The low parasite recruitment may be due to the small body size of this host species, together with ecological isolation and few interactions with other reptile and amphibian species in the population studied.

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