An approach to the knowledge of the helminth infracommunities of Mediterranean insular lizards (*Podarcis* spp.)

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Abstract: Seven lizard species of the genus *Podarcis* living in several islands of the Mediterranean Basin, have been helminthologically searched. Nineteen helminth species have been found: 2 trematodes, 4 cestodes, 12 nematodes, and 1 acanthocephalan. The structure of the helminth infracommunities of the hosts has been analysed. There are a few component species mainly the Pharyngodonidae nematodes and the trematode *Paradistomum mutabile*. Also the larval forms of cestodes, nematodes, and acanthocephalans are qualitatively important in the helminth faunas of Mediterranean lizards. Their presence indicate that these saurians are intermediate hosts when they are taken as prey by small carnivorous or birds of prey. The diversity parameters such as species richness, abundance, and Brillouin's index, indicate that the helminth infracommunities of these lizards are depauperate and isolationist as it occurs in most saurians.

Key words: helminth infracommunities; diversity patterns; trematodes; cestodes; nematodes; acanthocephalans; *Podarcis* lizards; islands; Mediterranean Basin.

INTRODUCTION

The ecological studies of the parasite communities of reptiles are at the present time, scarce and unsystematic. AHO (1990) gives general information on the structure of the helminth communities of several reptiles and amphibians. Recently, DOBSON & PACALA (1992) and DOBSON *et al* (1992) analysed the helminth communities of ten *Anolis* species from seven islands of the Caribbean. In the Palearctic region, this kind of studies has been made only on lizards and gekkoes of the Iberian Peninsula and nearby islands (ROCA, 1993; LAFUENTE & ROCA, 1993; ROCA & HORNERO, 1994).

In the islands and islets of the Mediterranean Basin there exists a great number of lizard species of the genus *Podarcis* Wagler, 1830 probably originated in themselves (ALCOVER, 1988). All these species, together with other continental forms, came from one or very few stocks which colonized the Mediterranean area during the Mesinian period; fossils of the genus *Podarcis* are known from Majorca, Minorca, Eivissa, Formentera, Sardinia, Sicily, Malta, and Crete, so at least one of the species of the genus *Podarcis* was part of the first wave of mesinian colonizings (ALCOVER, 1988). From these *Podarcis* spp., several species occur in restricted areas, as *Podarcis pityusensis* (Boscá, 1883) and *Podarcis lilfordi* (Günther, 1874) being endemic of some islands and islets of the Balearic Islands (Western Mediterranean), or *Podarcis milensis* (Bedriaga, 1882) being endemic of a small number of islands of the Cyclad Archipelago (Eastern Mediterranean). Other species have a great distribution area living in different islands and also in continental lands of the Mediterranean Basin, as it occurs with *Podarcis muralis* (Laurenti, 1768).

In these Mediterranean islands and islets the parasitological studies of the lizards are especially interesting because: (i) the isolation of the host populations; (ii) the peculiar food habits of some of these populations; (iii) the high population densities found in some of the islands (HORNERO, 1991; ROCA, in prep.).

A total of 12 Mediterranean *Podarcis* spp. inhabit islands; some of them are only insular while others have insular and continental populations (ARNOLD & BURTON, 1978; CASTILLA *et al*., 1991): thus, *Podarcis hispanica* (Steindachner, 1870) living in some small islets of the Iberian Mediterranean coast; *Podarcis pityusensis* and *Podarcis lilfordi* in islands and islets of the Balearic Archipelago; *Podarcis sicula* (Rafinesque, 1810) in some islands of the Mediterranean Basin; *Podarcis muralis* also in some islands of the central area of the Mediterranean sea; *Podarcis tiliguerta* (Gmelin, 1789) in Corsica and Sardinia; *Podarcis wagleriana* (Gistel, 1835) in Sicily; *Podarcis filfolensis* (Bedriaga, 1876) in Malta; *Podarcis melisellensis* (Braun, 1877) in some islands of the Adriatic sea; *Podarcis taurica* (Pallas, 1814) in some Ionic islands; *Podarcis erhardii* (Bedriaga, 1876) in some Cyclad islands and in Lesvos island; and *Podarcis milensis* in Milos and nearby islets. Seven of these insular populations have been investigated helminthologically (*P. pityusensis, P. lilfordi, P. tiliguerta, P. muralis, P. sicula, P. erhardii,* and

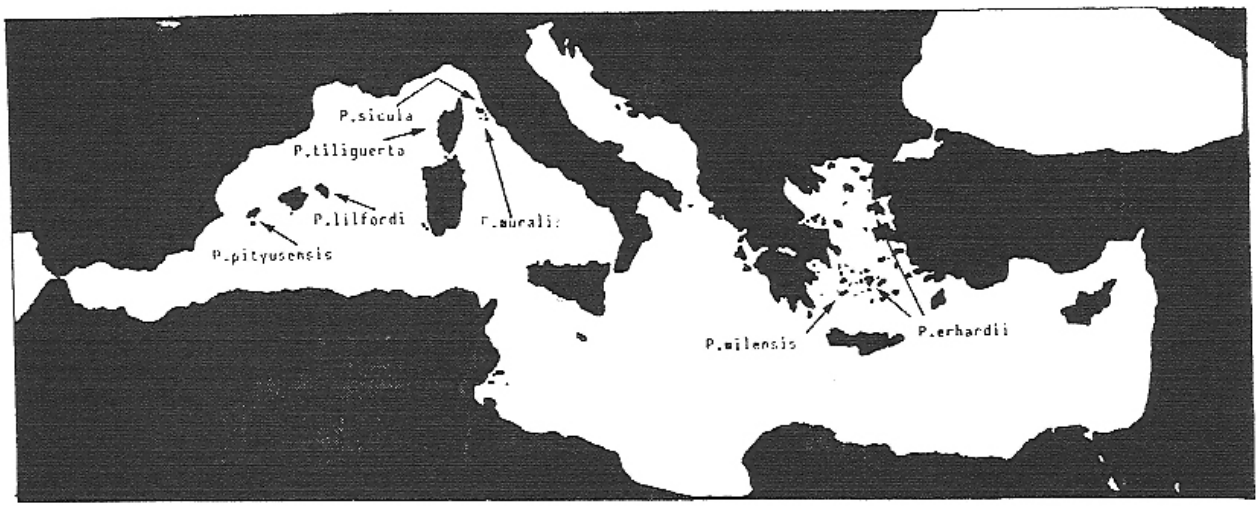

Figure 1: Sampled lizards from different islands of the Mediterranean Basin.

P. milensis) (Fig. 1) while for the other five species no data are known of their insular populations (*P. hispanica, P. wagleriana; P. filfolensis, P. melisellensis*, and *P. taurica*).

The present work includes some published data from *Podarcis pityusensis* and *Podarcis lilfordi* (ROCA, 1993; ROCA & HORNERO, 1994) and offers unpublished data on the remainder hosts.

MATERIAL AND METHODS

Some of the hosts were collected by hand. Also specimens from museums and private collections were studied after the following distribution. *Podarcis pityusensis*: -110 specimens caught by the author in the years 1987, 1988, and 1989; - 242 specimens from the private collection of Dra. Antonia Mª Cirer; -212 specimens from the private collection of the author. *Podarcis lilfordi*: - 20 specimens caught by the author in 1989; 408 specimens from the collection of Museo Nacional de Ciencias Naturales de Madrid (Spain); -113 specimens from the private collection of the author. *Podarcis tiliguerta*: -17 specimens handed over by Dr. Pierre Bartoli from the Université d'Aix-Marseille III. *Podarcis muralis*: -73 specimens from the collection of the Museo Zoologico "La Specola" di Firenze. *Podarcis sicula*: -77 specimens from the same collection. *Podarcis erhardii*: - 8 specimens handed over by Dr. Efstratios Valakos from the University of Athens; -18 specimens caught by the author in 1990. *Podarcis milensis*: -21 specimens caught by the author in 1990. All the captures were made with the appropriate permits. The provenance of the hosts is reflected in figure 1. For more detailed information see HORNERO (1991) AND ROCA & HORNERO (1990).

Helminths were collected, fixed and mounted according to routine techniques (ROCA, 1985; HORNERO, 1991). The terms referring to infestation parameters (prevalence, intensity and abundance) follow the definitions of MARGOLIS *et al.* (1982). Ecological terms referring to the parasites such as infrapopulation, infracommunity, component community, etc. are in accordance with ESCH *et al.* (1990). We chose Brillouin's index of diversity because it is especially recomended for fully censed communities (MAGURRAN, 1988) to produce results comparable with other parasitological studies (e.g. BALBUENA & RAGA, 1993; ROCA & HORNERO, 1994).

RESULTS

Systematics

TREMATODA
Family Dicrocoeliidae (Looss, 1899)
Genus *Paradistomum* Kossack, 1910
Paradistomum mutabile (Molin, 1859)
Family Brachylaimidae Joyeux et Foley, 1930
Genus *Brachylaima* Dujardin, 1843
Brachylaima sp. (*metacercariae*)
CESTODA
Family Linstowiidae Mola, 1929
Genus *Oochoristica* Lühe, 1898
Oochoristica gallica Dollfus, 1954
Family Nematotaeniidae Lühe, 1910
Genus *Nematotaenia* Lühe, 1899

Nematotaenia tarentolae López-Neyra, 1944
Family Dypilidiidae Mola, 1929
Genus *Diplopylidium* (Beddard, 1913)
Diplopylidium acanthotetra (Parona, 1886) (*larvae*)
Family Mesocestoididae Perrier, 1897
Genus *Mesocestoides* Vaillant, 1863
Mesocestoides sp. (*larvae*)
NEMATODA
Family Pharyngodonidae Travassos, 1919
Genus *Skrjabinodon* Inglis, 1968
Skrjabinodon medinae (García-Calvente, 1948)
Genus *Spauligodon* Skrjabin *et al.*, 1960
Spauligodon cabrerae Castaño *et al.*, 1988
Spauligodon sp. aff. *saxicolae* Sharpilo, 1961
Spauligodon paratectipenis (Chabaud et Golvan, 1957)
Genus *Parapharyngodon* Chatterjii, 1933
Parapharyngodon bulbosus (Linstow, 1899)
Parapharyngodon micipsae (Seurat, 1917)
Parapharyngodon sp.
Family Seuratidae (Hall, 1916)
Genus *Skrjabinelazia* Sypliaxov, 1930
Skrjabinelazia hoffmanni Li, 1934
Family Strongyloididae Chitwood et McIntosh, 1934
Genus *Strongyloides* Grassi, 1879
Strongyloides ophiusensis Roca et Hornero, 1992
Family Physalopteridae Diesing, 1861
Genus *Abbreviata* Travassos, 1920
Abbreviata abbreviata (Rudolphi, 1819)
Family Acuariidae Seurat, 1913
Genus *Acuaria* Bremser, 1811
Acuaria sp. (*larvae*)
Spirurida gen. sp. (*larvae*)
ACANTHOCEPHALA
Family Gigantorhynchiidae Hamann, 1892
Genus *Centrorhynchus* Lühe, 1911
Centrorhynchus sp. (*larvae*)

All these species are well known (ROCA, 1985; HORNERO, 1991) so they are not morphologically or taxonomically studied in this paper.

Structure of the helminth infracommunities

Podarcis pityusensis (Table 1)

In this host all the helminth groups usually found in lizards, are performed. So we found two trematodes (one as larval form), four cestodes (two as larval form), seven nematodes (two as larval form), and one acanthocephalan as larval form. Only *P. mutabile*, *S. medinae, S. cabrerae, P. bulbosus*, and *P. micipsae* are component species (species found at least in 10% of the hosts, *sensu* BUSH *et al.*, 1990) so they constitute the component community of which four species are Pharyngodonidae nematodes.

Podarcis lilfordi (Table 2)

Its helminth fauna is similar to that of *Podarcis pityusensis* but with some differences. In this host no larval forms of cestodes have been found. The intestinal nematodes are different in both hosts. We found *Strongyloides ophiusensis* in *Podarcis pityusensis* and *Skrabinelazia hoffmanni* and *A. abbreviata* in *Podarcis lilfordi*. Only four species constitute the component community being *S. cabrerae* the species with higher values of infestation parameters.

Podarcis tiliguerta (Table 3)

Only one cestode and two nematodes have been found. The nematodes are the component community. We notice the absence of *S. cabrerae* but the presence of its possible counterpart *Spauligodon* sp. *aff. saxicolae*.

Podarcis muralis (Table 4)

The helminth infracommunity of this lizard is similar to those of the Balearic lizards but with the absences of intestinal nematodes, acanthocephalans and larval forms of *Mesocesotides* sp. The component community is formed by *P. mutabile, S. medinae, S. cabrerae*, and *P. bulbosus* being *S. medinae* the species with higher prevalence, and *S. cabrerae* the one with higher values of intensity and abundance.

Podarcis sicula (Table 5)

Only one trematode, one cestode, and four nematodes (one as larval form) have been found in the Italian Wall lizard. *P. mutabile, S. medinae*, and *S. cabrerae* are component species. Neither larval forms of cestodes, nor intestinal nematodes have been found.

Podarcis milensis (Table 6)

As occurs in *Podarcis tiliguerta*, in *Podarcis milensis* the nematode *S. cabrerae* is replaced by its counterpart *S. paratectipenis*, being the species with higher values of infestation parameters. We also notice the high presence of larval forms of Spirurida gen. sp. (*larvae*) reaching the component species level. *P. mutabile* is not a component species in this lizard.

Podarcis erhardii (Table 7)

All the species of the helminth infracommunity are component species having high prevalences. As it occurs in *Podarcis milensis*, the nematode *S. paratectipenis* is the species with higher values of prevalence, intensity and abundance.

Diversity of the helminth infracommunities of the hosts

Table 8 shows diversity parameters for the helminth infracommunities of all hosts. Values of species richness, helminth richness, and Brillouin's index are low, showing the low diversity of these parasite communities.

Excepting *P. mutabile*, the monoxenous helminths show the highest prevalences and intensities of infection so they make a greater contribution to the infracommunities structure. Thus the Pharyngodonidae *S. medinae, S. cabrerae, P. bulbosus*, and *P. micipsae* in *Podarcis pityusensis*; the same species except for *P. bulbosus* in *Podarcis lilfordi*; *S. medinae*, and *S. saxicolae* in *Podarcis tiliguerta*; *S. medinae*, and *S. cabrerae* in *Podarcis sicula*; *S. medinae*, and *S. paratectipenis* in *Podarcis milensis* and in *Podarcis erhardii*. Apart from *P. mutabile*, only the heteroxenous nematodes *S. hoffmanni* in *Podarcis erhardii* and Spirurida gen. sp. (*larvae*) in *Podarcis milensis* show high prevalences but not high abundances.

The following helminth species have been found as larval forms: *Brachylaima* sp. (*metacercariae*), *Mesocestoides* sp. (*larvae*), *Diplopylidium acanthotetra* (*larvae*), *Acuaria* sp. (*larvae*), Spirurida gen. sp. (*larvae*). Except for *Brachylaima* sp. which is an accidental species (ROCA & HORNERO, 1991), all occurs in the body cavity. Their prevalences are not high (except for Spirurida gen. sp. in *Podarcis milensis*) but they are an important part of the parasite fauna of almost all hosts.

		Prevalenc		Int. infest.		Abundance	
Helminth species	Site	n/Sampl.	%	Range	x	N	x
P. mutabile	gall-bladder	129/564	22.9	1-56	8.1	1040	1.8
Brachylaima sp.	intestine	1/564	0.2	-	-	1	-
O. gallica	intestine	25/564	4.4	1-264	30.4	759	1.3
N. tarentolae	intestine	19/564	3.4	1-10	2.6	50	0.1
D. acanthotetra	body cavity	16/56	2.8	1-35	10.1	161	0.3
Mesocestoides sp.	body cavity	9/564	1.6	1-56	12.4	112	0.2
S. medinae	cloaca	67/564	11.9	1-20	4.8	323	0.6
S. cabrerae	cloaca	193/564	34.2	1-222	20.9	4037	7.2
P. bulbosus	cloaca	104/56	18.4	1-134	17.6	182	3.2
P. micipsae	cloaca	123/564	21.8	1-15	4.6	536	1
S. ophiusensis	intestine	7/564	1.2	1-37	9.7	68	0.1
Acuaria sp.	body cavity	5/564	0.9	1-8	3.8	19	0.03
Spirurida gen. sp.	body cavity	6/564	1.1	1-6	2.8	17	0.03
Centrorhynchus sp.	body cavity	4/564	0.7	1-4	2.5	10	0.01

Table 1.- Infestation parameters of the helminths parasitizing *P. pityusensis*

		Prevalence		Int. infest		Abundance	
Helminth species	Site	n/Sampl.	%	Range	x	N	x
P. mutabile	gall-bladder	80/541	14.8	1-26	6.2	498	0.9
Brachylaima sp.	intestine	3/541	0.6	1-2	1.3	4	0.008
O. gallica	intestine	3/541	0.6	1-5	2.3	7	0.01
N. tarentolae	intestine	1/541	0.2	-	-	2	0.003
S. medinae	cloaca	101/541	18.7	1-17	4.2	429	0.8
S. cabrerae	cloaca	203/541	37.5	1-187	12.6	2565	4.7
P. bulbosus	cloaca	25/541	4.6	1-22	8.6	215	0.4
P. micipsae	cloaca	80/541	14.8	1-40	4.8	380	0.7
S. hoffmanni	intestine	4/541	0.7	1-5	2.0	8	0.01
Abbreviata sp.	intestine	1/541	0.2	-	-	1	-
Acuaria sp.	body cavity	10/541	1.8	1-20	4.2	42	0.08
Spirurida gen. sp.	body cavity	9/541	1.7	1-6	3.0	27	0.05
Centrorhynchus sp.	body cavity	5/541	0.9	1-5	2.0	10	0.02

Table 2.- Infestation parameters of the helminths parasitizing *P. lilfordi*.

		Prevalence		Int. infest.		Abundance	
Helminth species	Site	n/Sampl.	%	Range	x	N	x
Mesocestoides sp.	body cavity	1/17	5.9	-	-	102	-
S. medinae	cloaca	5/17	29.4	1-3	2.2	11	0.6
S. saxicolae	cloaca	4/17	23.5	1-6	3.8	15	0.9

Table 3.- Infestation parameters of the helminths parasitizing *P. tiliguerta*.

		Prevalence		Int. infest.		Abundance	
Helminth species	Site	n/Sampl.	%	Range	x	N	x
P. mutabile	gall-bladder	11/73	15.1	1-35	13.2	145	1.9
O. gallica	intestine	6/73	8.2	1-8	4.0	24	0.3
N. tarentolae	intestine	1/73	1.4	-	-	1	-
D. acanthotetra	body cavity	1/73	1.4	-	-	5	0.07
S. medinae	cloaca	25/73	34.2	1-44	5.6	141	1.9
S. cabrerae	cloaca	14/73	19.2	2-57	13.1	184	2.5
P. bulbosus	cloaca	9/73	12.3	4-33	13.3	120	1.6
P. micipsae	cloaca	5/73	6.8	1-10	5.4	27	0.4
Acuaria sp.	body cavity	1/73	1.4	-	-	1	-
Spirurida gen. sp.	body cavity	2/73	2.7	2-4	3.0	6	0.08

Table 4.- Infestation parameters of the helminths parasitizing *P. muralis*.

		Prevalence		Int. infest.		Abundance	
Helminth species	Site	n/Sampl.	%	Range	x	N	x
P. mutabile	gall-bladder	25/77	32.5	1-23	7.4	185	2.4
O. gallica	intestine	1/77	1.3	-	-	1	-
S. medinae	cloaca	16/77	20.8	1-18	4.5	72	0.9
S. cabrerae	cloaca	26/77	33.8	1-34	8.6	223	2.9
Acuaria sp.	body cavity	2/77	2.6	1-4	2.5	5	0.06
Spirurida gen. sp.	body cavity	4/77	5.2	3-41	12.5	50	0.6

Table 5.- Infestation parameters of the helminths parasitizing *P. sicula*.

		Prevalence		Int. infest.		Abundance	
Helminth species	Site	n/Sampl.	%	Range	x	N	x
P. mutabile	gall-bladder	2/21	9.5	3-12	7.5	15	0.7
S. medinae	cloaca	5/21	23.8	1-27	6.6	33	1.6
S. paratectipenis	cloaca	8/21	38.1	3-35	15.3	122	5.8
Parapharyngodon sp.	cloaca	1/21	4.8	-	-	1	0.05
A. abbreviata	cloaca	2/21	9.5	1-4	2.5	5	0.2
Spirurida gen. sp.	body cavity	3/21	14.3	1-2	1.3	4	0.2
Centrorhynchus sp.	body cavity	1/21	4.8	-	-	1	0.05

Table 6.- Infestation parameters of the helminths parasitizing *P. milensis*.

		Prevalence		Int. infest.		Abundance	
Helminth species	Site	n/Sampl.	%	Range	x	N	x
P. mutabile	gall-bladder	4/26	15.4	1-34	17.8	71	2.7
S. medinae	cloaca	8/26	30.8	1-12	5.9	47	1.8
S. paratectipenis	cloaca	12/26	46.2	2-103	32.9	395	15.2
S. hoffmanni	cloaca	6/26	23.1	1-5	2.2	13	0.6

Table 7.- Infestation parameters of the helminths parasitizing *P. erhardii*.

Host	Sample size	Number of species/host	Number of helminths/host	Brillouin's Index	P
P. pityusensis	564	x = 1.35±1.02 range: 0-5	x = 16.44±31.22 range: 0-420	x = 0.242±0.292 range: 0-1.211	0.60
P. lilfordi	541	x = 0.97±0.78 range: 0-4	x = 7.74±14.43 range: 0-187	x = 0.094±0.198 range: 0-0.906	0.79
P. tiliguerta	17	x = 0.59±0.71 range: 0-2	x = 7.53±24.96 range: 0-104	x = 0.034±0.121 range: 0-0.499	0.88
P. muralis	73	x = 1.03±0.93 range: 0-3	x = 8.96±14.24 range: 0-61	x = 0.147±0.249 range: 0-0.935	0.69
P. sicula	77	x = 0.96±0.94 range: 0-3	x = 6.96±10.39 range: 0-54	x = 0.141±0.248 range: 0-0.830	0.74
P. milensis	21	x = 1.05±0.92 range: 0-3	x = 8.62±12.13 range: 0-35	x = 0.097±0.216 range: 0-0.767	0.76
P. erhardii	26	x = 1.12±0.95 range: 0-3	x = 20.23±34.57 range: 0-135	x = 0.108±0.201 range: 0-0.574	0.73

Table 8: Overall diversity parameters of the helminth infracommunities from the searched hosts. (P): Proportion of sample with 0 or 1 helminth species.

DISCUSSION

In spite of the differences in the parasite species number among hosts, we can see quite homogeneous helminth fauna in Mediterranean lizards, several species parasiting almost all hosts, as *P. mutabile, O. gallica, S. medinae*, and *S. cabrerae*. This fact migth be in accordance with the hipothesis of ALCOVER (1988) regarding the common origin of these lizards.

The presence of *S. paratectipenis* in the Eastern lizards (*Podarcis milensis* and *Podarcis erhardii*) enlarges the list of the parasitized hosts and also its distribution area, which was limited to the Western part of the Mediterranean Basin (GARCÍA-CALVENTE, 1948; ROCA *et al.*, 1985), corroborating its palearctic origin and its limit to the circummediterranean area (ROCA, 1993).

The low diversity shown by the helminth infracommunities of all hosts (Table 8) suggests that they are depauperate communities. This agrees with the typical pattern of helminth infection of many reptiles (ROCA & HORNERO, 1994), poverty being related with several features of hosts such as ectothermy, simplicity of the alimentary canal, low vagility, simple diet, and generalist feeding (KENNEDY *et al.*, 1986; ROCA & HORNERO, 1994). So, helminth infracommunities of these lizards are isolationist (HOLMES & PRICE, 1986; STOCK & HOLMES, 1988; ROCA & HORNERO, 1994).

The finding of larval forms of cestodes, nematodes, and acanthocephalans in Mediterranean lizards, involves that they are intermediate or paratenic hosts of these helminths. *D. acanthotetra* (*larvae*) has been found in many places of the Mediterranean Basin (JOYEUX & BAER, 1936; LÓPEZ-NEYRA, 1947). The experiences made by PARROT & JOYEUX (1920) and the observations of LÓPEZ-NEYRA & MUÑOZ-MEDINA (1919) and ROCA & HORNERO (1991) point out cats and genets as possible definitive hosts for this cestode because they sometimes are predators of lizards. For *Mesocestoides* sp. (*larvae*), ROCA & HORNERO (1991) suggest that some bird of prey could be the definitive host, although the small carnivorous may also be definitive hosts of some species of this genus. Probably the acanthocephalan *Centrorhynchus* sp. (*larvae*) has also as definitive host a bird of prey (YAMAGUTI, 1963; HORNERO & ROCA, 1992). For the nematodes *Acuaria* sp. (*larvae*) and Spirurida gen. sp. (*larvae*), lizards could be second paratenic hosts, being the first intermediate host an invertebrate (POINAR, 1983) and the definitive host perhaps an herpetophagous bird (ROCA & HORNERO, 1991).

One of the effects of the insularity on the helminth fauna of small mammals has been noted by MAS-COMA & FELIU (1984) and MAS-COMA *et al.* (1987) as a higher prevalence of infection of the hosts with respect to hosts living in continental lands. In lizards this effect should not be generalized. The known data on lizards from the Iberian Peninsula are: p = 66.1% for *Podarcis hispanica*; p = 45.7% for *Podarcis muralis*; and p = 66.1% for *Podarcis bocagei* (HORNERO, 1991). Figure 2 shows the global prevalences of insular Mediterranean lizards. There is a group of four species, *Podarcis pityusensis, Podarcis lilfordi, Podarcis milensis*, and *Podarcis erhardii* whose prevalences (higher than 70%) are always superior to the prevalences of continental lizards. Two species, *Podarcis muralis*, and *Podarcis sicula* have higher prevalences than continental *Podarcis muralis* and *Podarcis bocagei* but lower than continental *Podarcis hispanica*. *Podarcis tiliguerta* has similar prevalences to continental lizards.

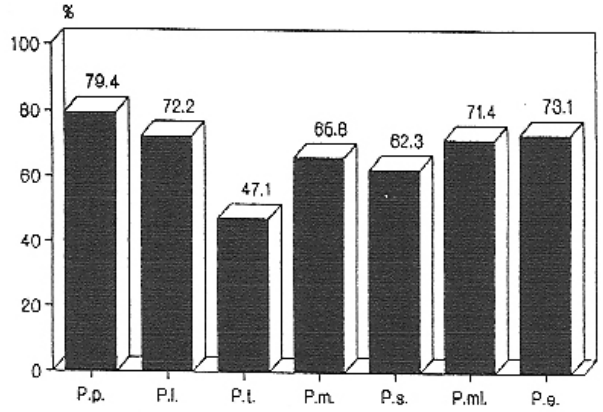

Figure 2: Histogram showing global infection prevalences of Mediterranean lizards. P.p.: *Podarcis pityusensis*; P.l.: *P. lilfordi*; P.t.: *P. tiliguerta*; P.m.: *P. muralis*; P.s.: *P. sicula*; P.mi.: *P. milensis*; P.e.: *P. erhardii*.

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