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ON THE HELMINTHFAUNA OF WILD MAMMALS (RODENTIA, INSECTIVORA AND LAGOMORPHA) IN AZORES ARCHIPELAGO (PORTUGAL)

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AZORES ARCHIPELAGO
MURIDAE
ERINACEIDAE
LEPORIDAE
HELMINTHFAUNA

SUMMARY. – The faunistic and ecological study on the helminthfaunas of mammals in Azorean islands is considered. 103 Rodents (*Rattus rattus* L., 1758 and *Mus musculus* L., 1758), 9 Insectivores (*Erinaceus europaeus* L., 1758) and 19 Lagomorphes (*Oryctolagus cuniculus* L., 1758) were analysed. The hosts have been captured in several biotopes of three islands (Sao Miguel, Terceira and Flores). 27 helminth species were detected (3 Digenea Trematoda, 5 Cestoda, 18 Nematoda and 1 Acantocephala). All hosts species showed high prevalences and no significant differences were found between different islands. The helminthfaunas show typical features of a young island parasitofaunas.

ARCHIPEL DES AÇORES
MURIDAE
ERINACEIDAE
LEPORIDAE
HELMINTHOFAUNE

RÉSUMÉ. – Helminthes parasites des Mammifères sauvages (Rongeurs, Insectivores et Lagomorphes) de l'Archipel des Açores (Portugal). Le présent travail concerne l'étude faunistique et écologique de l'helminthofaune de Mammifères sauvages de l'Archipel des Açores. 103 Rongeurs (*Rattus rattus* L., 1758 et *Mus musculus* L., 1758), 9 Insectivores (*Erinaceus europaeus* L., 1758) et 19 Lagomorphes (*Oryctolagus cuniculus* L., 1758) ont été analysés. Les hôtes ont été capturés dans différents biotopes de trois îles (Sao Miguel, Terceira et Flores). 27 espèces d'Helminthes (3 Trématodes, 5 Cestodes, 18 Nématodes et 1 Acantocéphale) ont été récoltées. Toutes les prévalences d'infestation sont élevées et les différences entre les îles ne sont pas significatives. Les helminthofaunes montrent les caractéristiques habituelles des parasitofaunes des hôtes dans les îles colonisées récemment.

INTRODUCTION

The helminthfauna of small mammals from some isolated ecosystems in several Mediterranean islands has been studied in depth by different authors. Moreover, there are numerous studies in which relevant conclusions about the insular syndrome have been stated (e.g. Mas-Coma and Feliu, 1984; Mas-Coma *et al.*, 1987). However, the Azores Archipelago, very interesting islands from a faunistical and ecological point of view, have almost been overlooked.

In the Azores, nine isolated islands in the middle of the North Atlantic Ocean, half way between Europe and America, land mammal (not bat) colonization was restricted to that carried out by men (Gorman, 1975). Considering such species and the volcanic origin of the islands, the Azores are considered to be "oceanic islands" (Mas-Coma *et al.*, 1987).

All mammals except the bat *Nictalus leisleri* (Kuhl) were introduced at different colonization times after the first half of the 15th century. Large distance to mainland, youth of the islands, and

Table I. – Host collection in Azorean Archipelago. N = number of hosts analysed, E = number of biotopes prospected.

	Sao Miguel		Terceira		Flores		GENERAL	
	N	E	N	E	N	E	N	E
R. rattus	11	4	35	13	5	3	51	20
M. musculus	11	3	19	9	22	9	52	21
E. europaeus	4	2	5	4	-	-	9	6
O. cuniculus	-	-	16	7	3	3	19	10
TOTAL	26	8	75	23	30	15	131	46

destructive volcanic activity are the more plausible explanations for the scarcity of the Azorean vertebrate fauna. The introduced species exhibit marked European influences : the black rat (*Rattus rattus* L., 1758), the house mouse (*Mus musculus* L., 1758) and the wild rabbit (*Oryctolagus cuniculus* L., 1758) were introduced by the first colonizers (Martins, 1993). Other wild mammal species were introduced at uncertain times (*Mustela* spp.) or more recently (*Erinaceus europaeus* L., 1758).

This study describes the helminthological data of four small mammal species (*R. rattus, M. musculus, O. cuniculus* and *E. europaeus*) from three islands (Sao Miguel, Terceira and Flores). The material comes from several mammalian surveys to the Archipelago, between May and June of 1994. Little is known about the parasite fauna of these mammals in the Azorean islands and only occasional reports have been described up to date. The present study provides information on faunistic and ecological features of their helminthfaunas in Eastern (Sao Miguel), Central (Terceira) and Western (Flores) Azorean islands.

MATERIAL AND METHODS

One hundred and three rodents (*Rattus rattus* – 51, *Mus musculus* – 52), nine insectivores (*Erinaceus europaeus*) and nineteen lagomorphes (*Oryctolagus cuniculus*) from 46 biotopes were examined. No animals were captured in three of them (Sao Miguel – 1; Terceira – 2). Two or three species were captured in 14 biotopes : *Rattus rattus* + *Mus musculus* (Sao Miguel – 1, Terceira – 5, Flores – 3), *R. rattus* + *Erinaceus europaeus* (Sao Miguel – 1), *R. rattus* + *O. cuniculus* (Terceira – 1), *M. musculus* + *O. cuniculus* (Terceira, 1) and *R. rattus* + *M. musculus* + *O. cuniculus* (Terceira – 2) (Table I).

General helminthologic techniques were used to process samples for microscopic observation. From an ecological point of view, terminology used in the study is defined according to Margolis *et al.* (1982) and Esch *et al.* (1990). Statistical analysis and association aspects follow Sokal and Rohlf (1986) and Combes (1983, 1987) descriptions.

RESULTS

Twenty-seven helminth species were identified : *Brachylaima* sp., *Skrjabinocoelus* sp., *Zonorchis* sp. (Digenea); *Taenia taeniaeformis* (Batsch, 1786) larvae, *Cladotaenia globifera* (Batsch, 1786) larvae, *Neoctenotaenia ctenoides* (Railliet, 1890), *Hymenolepis straminea* (Goeze, 1782), *H. diminuta* (Rudolphi, 1819) (Cestoda); *Trichuris muris* (Schrank, 1788), *Aonchotheca erinacei* (Rudolphi, 1819), *A. annulosa* (Dujardin, 1843), *Calodium hepaticum* (Bancroft, 1893), *Eucoleus gastricus* (Baylis, 1926), *Graphidium strigosum* (Dujardin, 1845), *Trichostrongylus retortaeformis* (Zeder, 1800), *Nippostrongylus brasiliensis* (Travassos, 1914), *Crenosoma striatum* (Zeder, 1800), *Passalurus ambiguus* (Rudolphi, 1819), *Syphacia obvelata* (Rudolphi, 1802), *S. muris* (Yamaguti, 1935), *Heterakis spumosa* (Schneider, 1866), *Porrocaecum* sp. larvae, *Gongylonema neoplasticum* (Fibiger et Ditlevsen, 1914), *Spirura* sp. larvae, *Mastophorus muris* (Gmelin, 1790), *Nematodirus* sp. (Nematoda); *Prosthorhynchus* sp. (Acanthocephala).

Tables II, III, IV A and IV B show the helminthfauna (qualitative and quantitative composition) of the four host species in the studied islands. Infestation intensity of *C. hepaticum* was not determined due to the difficulty of helminth extraction from parasitized livers.

All host species showed high prevalences and no significant differences (χ^2, $p < 0.001$) were found between different islands.

As for rodents, the helminthfauna of *M. musculus* was slightly more numerous than that of the black rat. Eight parasite species were found in both Murids (Tables II and III). The black rat seemed to be the more common host when a parasite species were found in both hosts in the same island. Excluding the non-nominated species, the Oxyuridae *S. muris* (in *Rattus*) and *S. obvelata* (in *Mus*) were the only characteristic species of the respective helminthic communities. The species *T. taeniaeformis* (*l*), *C. globifera* (*l*), *H. straminea* and *G. neoplasticum* were detected in only one of the three islands. The highest mean

Table II. – Quantitative composition of *Mus musculus* helminth community in Azores islands. P = prevalence, MI = mean intensity, STD = standard deviation, Min = minimum, Max = maximum.

Mus musculus	Sao Miguel			Terceira			Flores			GENERAL		
	P	MI±STD	Min-Max	P	MI±STD	Min-Max	P	MI±STD	Min-Max	P	MI±STD	Min-Max
TREMATODA	9.09			5.26			4.54			5.76		
Brachylaima sp.				5.26	2.0±0.0	2	4.54	1.0±0.0	1	3.80	1.5±0.36	1-5
Skrjabinocoelus sp.	9.09	12±0.0	12							1.92	12.0±0.0	12
CESTODA	9.09			26.31			4.54			13.46		
T. taeniaeformis (l.)				10.52	1.5±0.67	1-2				3.84	1.5±0.67	1-2
C. globifera (l.)				5.26						1.92		
H. diminuta	9.09	1.0±0.0	1	5.26	1.0±0.0	1	4.54	1.0±0.0	1	5.76	1.0±0.0	1
H. straminea				5.26	1.0±0.0	1				1.92	1.0±0.0	1
NEMATODA	90.90			63.15			90.90			80.76		
T. muris	18.18	3.0±1.41	2-4							3.84	3.0±1.41	2-4
C. hepaticum	36.30			21.05			45.45			34.61		
A. annulosa				10.52	8.5±5.03	1-16	31.81	5.8±5.88	1-25	17.30	7.2±4.85	1-25
E. gastricus	9.09	2.0±0.0	2	5.26	4.0±0.0	4	4.54	35.0±0.0	35	5.76	13.7±5.77	2-35
N. brasiliensis				10.52	4.0±1.93	2-6	4.54	1.0±0.0	1	5.76	2.1±1.03	1-6
H. spumosa	45.45	5.4±3.9	1-10	5.26	1.0±0.0	1	31.81	3.0±2.12	1-8	25.00	3.1±2.58	1-10
M. muris	18.18	2.0±1.01	1-3	15.78	5.0±2.71	3-8	22.72	2.0±1.09	1-4	19.23	3.0±1.68	1-8
S. obvelata	36.36	220.7±189.32	1-500	21.05	76.2±71.90	1-230	13.63	8.7±3.36	7-10	21.15	110.3±104.05	1-500
Nematoda sp.	9.09	2.0±0.0	2							1.92	2.0±0.0	2
ACANTOCEPHALA							9.09			3.84		
Prosthorhynchus sp.							9.09	6.5±2.82	1-12	3.84	6.5±2.82	1-12
GENERAL	90.90			68.42			90.90			82.69		

Table III. – Quantitative composition of *Rattus rattus* helminth community in Azores islands. P = prevalence, MI = mean intensity, STD = standard deviation, Min = minimum, Max = maximum.

Rattus rattus	Sao Miguel			Terceira			Flores			GENERAL		
	P	MI±STD	Min-Max	P	MI±STD	Min-Max	P	MI±STD	Min-Max	P	MI±STD	Min-Max
TREMATODA	9.09			22.85						17.64		
Brachylaima sp.	9.09	1±0.0	1	20.00	4.4±2.50	1-11				15.68	4.0±2.10	1-11
Zonorchis sp.				2.85	1.0±0.0	1				1.96	1.0±0.0	1
CESTODA	18.18			11.42			40.00			15.68		
H. diminuta	18.18	1.0±0.0	1	11.42	1.0±0.0	1	40.00	1.5±0.89	1-2	15.68	1.5±0.42	1-2
NEMATODA	100			97.14			100			98.03		
T. muris				5.71	2.5±0.70	1-4				3.92	2.5±0.70	1-4
C. hepaticum	81.80			45.71	-	-	80.00	-	-	56.86	-	-
A. annulosa	72.72	20.9±17.16	4-55	60.00	15.8±18.51	1-90	100	6.0±2.91	2-10	66.66	15.5±17.28	1-90
E. gastricus				28.57	15.4±9.86	1-41				19.60	15.4±9.86	1-41
N. brasiliensis	100	22.9±17.46	2-45	80.00	56.8±91.41	1-464	80.00	83.5±53.67	26-160	84.30	50.6±78.05	1-464
H. spumosa	81.81	20.5±7.78	2-137	74.28	20.1±21.84	1-86	80.00	20.0±5.81	3-59	76.47	20.2±18.76	1-137
Spiruridae				2.85	1.0±0.0	1				1.96	1.0±0.0	1
M. muris	45.45	8.2±6.18	1-17	28.57	3.5±2.03	1-8	80.00	7.5±4.63	3-11	37.25	5.6±1084.72	1-17
S. muris	54.54	1384.0±2299.33	11-7713	25.71	114.3±76.64	1-8	60.00	78.0±69.93	4-160	35.29	531.5±0.28	1-7713
G. neoplasticum				5.71	1.5±0.34	1-2				3.92	1.5±0.34	1-2
GENERAL	100			97.14			100			98.00		

Table IV. – A) Quantitative composition of *Erinaceus europaeus* helminth community in Azores islands. B) Quantitative composition of *Oryctolagus cuniculus* helminth community in Azores islands. P = prevalence, MI = mean intensity, STD = standard deviation, Min = minimum, Max = maximum.

A

Erinaceus europaeus	Sao Miguel			Terceira			GENERAL		
	P	MI±STD	Min-Max	P	MI±STD	Min-Max	P	MI±STD	Min-Max
CESTODA				20.00			11.11		
C. globifera (l.)				20.00	15.0±0.0	15	11.11	15.0±0.0	15
NEMATODA	100			100			100		
A. erinacei	75.00	96.7±68.98	40-160	100	364.8±352.56	117-972	88.88	264.2±295.81	40-972
Porrocaecum sp. *(l.)*				20.00	6.0±0.0	6	11.11	6.0±0.0	6
C. striatum	100	45.7±25.21	14-67	80.00	145.7±172.74	17-419	88.88	95.7±128.65	17-419
Spirura sp. *(l.)*				20.00	3.0±0.0	3	11.11	3.0±0.0	3
GENERAL	100			100			100		

B

Oryctolagus cuniculus	Terceira			Flores			GENERAL		
	P	MI±STD	Min-Max	P	MI±STD	Min-Max	P	MI±STD	Min-Max
CESTODA	12.50						10.52		
N. ctenoides	12.50	1.5±0.54	1-2				10.52	1.5±0.54	1-2
NEMATODA	100			100			100		
T. retortaeformis	93.75	97.3±125.93	4-450	100	18.3±17.61	2-37	94.73	84.1±118.30	2-450
G. strigosum	75.00	28.7±43.43	1-159	100	111.0±168.30	4-305	78.94	45.1±76.44	1-350
Nematodirus sp.	6.25	2.0±0.0	1				5.26	2.0±0.0	1
P. ambiguus	75.00	161.2±203.85	1-625				63.15	161.2±191.54	1-625
GENERAL	100			100			100		

parasitation intensities were those of the Oxyurids. Platyhelminthes showed the lowest abundances (Tables II and III).

E. europaeus showed a 100% infestation prevalence in the two studied islands (Table IV A). The helminthfauna of hedgehog showed a higher number of species in Terceira than it did in Sao Miguel. This host was parasitized in Terceira by a Spirurid species and two larval stages, *C. globifera* and *Porrocaecum* sp., of adult parasites of predator birds. The highest mean intensities were those of *A. erinacei* (264.2) and *Crenosoma striatum* (95.7), typical parasites of Erinaceids.

Five parasite species were found in *O. cuniculus* (Table IV B). In Flores, and probably due to the low number of studied hosts, only two helminth species were detected. The helminths, except *N. ctenoides* and *Nematodirus* sp., showed high infestation intensities, the highest being that of *P. ambiguus* (161.2).

Associations of pairs of helminth species were not significant (χ^2, $p < 0.001$) in any of the studied host species. However, the number of associations of pairs of species was extremely high.

Table V shows the results of Forbes and Dice association indexes in helminthfaunas of *R. rattus* and *M. musculus*. In *E. europaeus* only a single association is present : *A. erinacei-C. striatum* in Sao Miguel ($D = 0.85 \pm 0.27$; $F = 1$) and in Terceira ($D = 0.88 \pm 0.21$; $F = 1$). In *O. cuniculus* the helminth associations are : *T. retortaeformis-P. ambiguus* ($D = 0.81 \pm 0.15$; $F = 0.9$), *G. strigosum-P. ambiguus* ($D = 0.76 \pm 0.16$; $F = 1.1$), *T. retortaeformis-G. strigosum* ($D = 0.88 \pm 0.12$; $F = 1$) in Terceira and *T. retortaeformis-G. strigosum* ($D = 1 \pm 0.0$; $F = 1$) in Flores.

Table V indicates also the number of monoxenous and heteroxenous species and their prevalences in each island and host species. In Azorean Archipelago, only in wild rabbit helminthfauna the number and prevalence of monoxenous species are clearly higher than heteroxenous ones.

DISCUSSION

The best small mammal colonizer species of insular ecosystems are, in sequence, *R. rattus*, *O. cuniculus*, *M. musculus*, *Rattus norvegicus* and *Rattus exulans* (Rowe, 1981; Armstrong, 1982; Wodzicki and Taylor, 1984). Populations of the first four species arised recently in the Azorean Archipelago by antropochoric ultramarine dispersion (Martins, 1993). Thus, endemic insular spe-

Table V. – Upper part, values of Dice ± Standard deviation (D ± STD) and Forbes (F) association indexes in *Rattus rattus* and *Mus musculus* helminthfaunas. Below, Number (n) and prevalence (P) of monoxenous (Mx) and heteroxenous (Htx) species in each island and host species. ? = probably monoxenous helminth but unknown life cycle.

	Rattus rattus						*Mus musculus*			
	Sao Miguel		Terceira		Flores		Sao Miguel		Flores	
	D±STD	F	D±STD	F	D±STD	F	D±STD	F	D±STD	F
A. annulosa-C. hepaticum	0.94±0.11	1.22	0.61±0.18	1.2	0.88±0.21	1.0	-	-	0.58±0.27	1.57
A. annulosa-N. brasiliensis	0.84±0.24	1.0	0.59±0.16	0.9	1.00±0.0	1.0	-	-	-	-
A. annulosa-H. spumosa	0.70±0.24	0.91	0.65±0.15	1.01	0.88±0.21	1.0	-	-	0.71±0.98	2.24
A. annulosa-M. muris	-	-	0.28±0.21	0.8	-	-	-	-	0.16±0.28	0.62
A. annulosa-E. gastricus	-	-	0.40±1.34	1.05	-	-	-	-	0.25±0.39	3.14
C. hepaticum-N. brasiliensis	0.90±0.13	1.0	0.51±0.18	0.89	0.88±0.21	1.0	-	-	-	-
C. hepaticum-H. spumosa	0.77±0.21	0.95	0.61±0.28	1.09	0.75±0.33	0.93	0.66±0.35	1.65	0.47±0.29	1.25
C. hepaticum-M. muris	-	-	0.38±0.23	1.09	-	-	-	-	0.46±0.31	1.32
H. spumosa-N. brasiliensis	0.90±0.13	1.0	0.75±0.12	0.99	0.89±0.22	1.0	-	-	-	-
H. spumosa-E. gastricus	-	-	0.50±0.20	1.21	-	-	-	-	0.28±0.4	3.66

	Rattus rattus				*Mus musculus*				*Erinaceus europaeus*				*Oryctolagus cuniculus*			
	Mx		Htx		Mx		Htx		Mx		Htx		Mx		Htx	
	n	P	n	P	n	P	n	P	n	P	n	P	n	P	n	P
Sao Miguel	4	100	4	90.9	4/5?	90.9	3	18.1	1?	75	1	100	-	-	-	-
Terceira	5/6?	97.1	7	82.8	5/6?	52.6	6	42.1	1?	100	4	100	4	100	1	12.5
Flores	4	100	3	100	5/6?	77.2	4	54.5	-	-	-	-	2	100	-	-

ciation or subspeciation has not occurred yet (Ulfstrand, 1961).

Several helminth species had been previously cited in Rodents and wild rabbits from Sao Miguel and Terceira (Afonso-Roque, 1989), but little is known about the helminthfauna in other Azorean islands.

Numerous helminth species were found in both, rats and mice, from all the studied islands. Spatial restrictions in small islands seems to favour infestation of both rodents by helminths with eurixenous specificity. The structure of helminth communities in these hosts is determined by different conditions, namely : decrease in the variety of habitats susceptible to colonization, host ethology changes in insular conditions and variety of preys in host diets. Rare species found in Rodents come from other hosts species (*Skrjabinocoelus* is a parasite of birds in Azores). The decrease in number of larval stages of Cestodes could be explained by the reduction of the wild carnivore populations in the Azorean Archipelago.

E. europaeus and *O. cuniculus* seem to have a characteristic helminthfauna. However, *C. globifera* appeared in *E. europaeus* and in mice from Terceira. The adult stage of this Cestode is a typical parasite of birds of prey from continental areas and its larval stage was found in rodents and insectivores in the Azores islands. Their presence is explained by the existence of important continental migratory bird populations in Azores (Ulfstrand, 1961).

Qualitative composition of the helminthfauna of *E. erinaceus* showed a strong european influence. *A. erinacei* and *C. striatum* were not found in Northern Africa, and typical African worms of *Atelerix algirus* have not been described in Azorean hedgehogs up to date (Seurat, 1916, 1917; Meggit, 1920; Baylis, 1928; Ortlepp, 1922, 1937; Dollfus, 1951, 1953, 1954; Chabaud, 1954; Petrochenko, 1956; Nelson and Ward, 1966; Quentin and Seguignes, 1979). Nevertheless, many parasite species denounced in this host in Europe have never been found in Azores (Prokopic, 1957; Bauer and Stoye, 1983; Barutzki *et al.*, 1984). Such species are mainly helminths with indirect life cycle whose intermediate hosts are Gasteropoda (Digenea) or Arthropoda (Physalopteridae and Rictulariidae).

The helminthfauna of the wild rabbit is poor with respect to the parasitofauna of the same host in the continent (e.g. Tenora, 1967; Tenora and Murai, 1968; Sugar *et al.*, 1978). However, the more frequently found species in Iberian populations of *O. cuniculus* were also found in Azores (Cordero del Campillo *et al.*, 1984). The presence of an oriental virus plague in 1990 wiped out rabbit populations in most islands (Martins, 1993). Ecological consequences of such reduction of available definitive hosts to maintain parasite transmission determined changes in the qualitative composition of the parasitofauna of this host (see Mas-Coma *et al.*, 1987). A similar situation was reported to happen in rabbit populations of Coll island (Scotland) after the establishment of the myxomatosis virus (Boag, 1987). This fact could have reduced the number of rabbits below the threshold density required to maintain some of the less common helminth species. When comparing the helminthfauna of rabbits in Coll and Eigg islands Boag (op. cit) explained their similarity due to the presence of hares, which acted as alternative hosts and maintained the cycle of helminths (Mackintosh, 1955). No *Lepus* spp. can be found in the Azores islands. On the other hand, the helminthfauna described in *O. cuniculus* from Zembra island (Northern Africa) is similar to that of Coll and Eigg Scottish islands (Bernard, 1965).

Fasciola hepatica (Digenea) was introduced in Sao Miguel in 1957. Its intermediate host, *Lymnaea truncatula*, was also probably introduced during the first quarter of the century in this island and extended later to Terceira. Some small mammal species (mainly *Rattus* spp.) are important hosts in insular ecosystems (Mas-Coma *et al.*, 1988). Rabbits appear to be parasitized also by this Trematode in the European Continent (Bailenger *et al.*, 1965) and in Sao Miguel (Azores) (Afonso-Roque, 1989). In the present study, the trematode has not been found in Terceira or in Flores. However, presence of Fasciolosis in these islands can not be excluded.

Reports on small mammal helminth species in other insular ecosystems showed a relatively structural uniformity. Nevertheless, in relation to these helminthfaunas, information available about insular character (oceanic or continental), historical time, distance to continent, etc. is scarce (Mas-Coma *et al.*, 1987). The helminthfaunas studied does not show specific differentiation of parasite populations, but it shows typical features of a young island helminthfaunas.

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