

A HELMINTHOLOGICAL SURVEY OF SMALL MAMMALS (INSECTIVORES AND RODENTS) IN THE SERRA CALDERONA MOUNTAINS (VALENCIAN COMMUNITY, SPAIN)

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ABSTRACT: A total of 38 helminth species (4 trematodes, 10 cestodes and 24 nematodes) were detected in 315 small mammals (the insectivores *Aterix algeris* and *Crocidura russula*, and the rodents *Eliomys quercinus*, *Apodemus sylvaticus*, *Mus spretus* and *Rattus rattus*) captured over a 4-year period in the Serra Calderona mountains (Valencian Community, Spain). An account is provided of the qualitative composition, prevalences and bioecological characteristics of each parasite community. The Rhode index is applied to determine the parasite specificity of the shared helminth populations. The limited resources of the ecosystem investigated and the population characteristics of the hosts studied condition the qualitative and quantitative compositions of the helminthfauna.

KEY WORDS: Helminths, insectivores, rodents, Serra Calderona, Valencian community, Spain, prevalence, bioecology, specificity.

INTRODUCTION

As part of a series of studies on the helminthfauna parasitizing mammals in continental and insular Spain, an annual follow-up is being carried out of the helminth parasites of insectivores and rodents in a peninsular Mediterranean ecosystem. Since the year 1994, the helminthfauna of these small mammals (which constitute fundamental links in the food chain) has been surveyed on an annual basis (GALAN-PUCHADES *et al.*, 1996; GALAN-PUCHADES & FUENTES, 1996; CEREZUELA, FUENTES & GALAN-PUCHADES, 1997a, b; FUENTES, CEREZUELA & GALAN-PUCHADES, 1997).

The present paper reports the qualitative and quantitative helminthological results (prevalences) obtained after four years of study. Data are provided on the helminth parasites of the insectivores *Aterix algeris* (Lereboul-

let, 1842) (Erinaceidae) and *Crocidura russula* Hermann, 1780 (Soricidae), and of the rodents *Eliomys quercinus* (Linnaeus, 1766) (Gliridae), *Apodemus sylvaticus* (Linnaeus, 1758), *Mus spretus* Lataste, 1883 and *Rattus rattus* (Linnaeus, 1758) (Muridae).

MATERIAL AND METHODS

Characterization of the Serra Calderona: The Serra Calderona forms part of the easternmost region of the Spanish Iberian System in its descent to the Mediterranean. It occupies part of the provinces of Valencia and Castellón, with a total surface of approximately 52000 Ha (Fig. 1). This mountain range follows the general NW-SE orientation of the system, with a mean altitude of under 500 m.

The geological materials that surface in this territory correspond to three major lithostratigraphic units: a) Paleozoic, only present at points; b) Mesozoic, with good representations from the Triassic

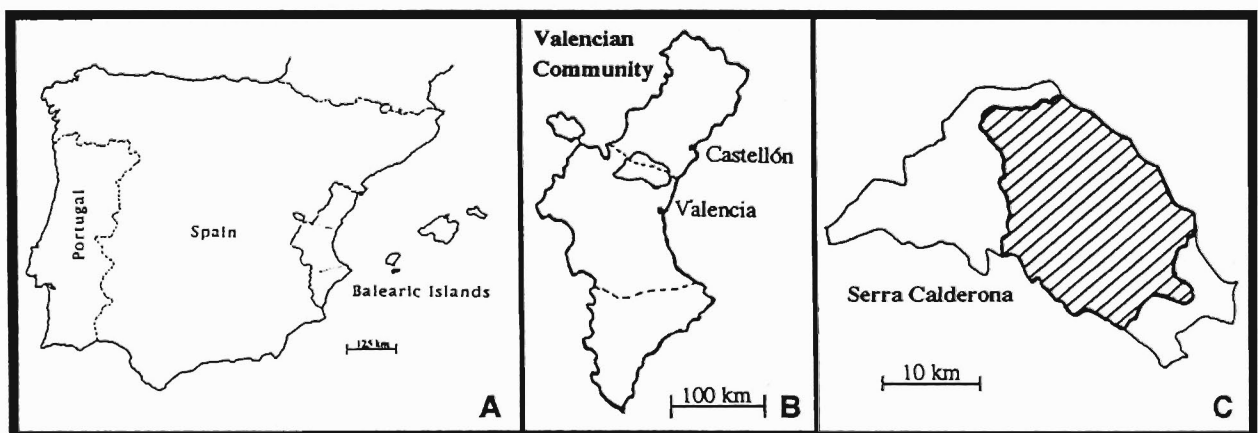


Fig. 1.— Geographical location of the Serra Calderona (Valencian Community, Spain).

(sand, clay, loam and dolomite), particularly in the easternmost zones, and Jurassic (limestone and dolomite) in the Western areas; c) Cenozoic, likewise almost exclusively limited to the septentrional zones.

The climate is typically Mediterranean, with irregular rainfall and intense summer droughts. The eastern and meridional regions correspond to the Thermomediterranean bioclimatic setting, and the ombroclimate is dry. In contrast, the westernmost and septentrional regions are included in the Mesomediterranean bioclimate, with slightly greater rainfall but without fully qualifying as a sub-humid ombroclimate. Hydrologically, there are no regular water courses but numerous springs that may dry out in the summer months, and ravines with typical flash-flood features.

Corologically, the vegetation corresponds to the western Mediterranean subregion (COSTA, 1982, 1986; COSTA *et al.* 1985; CRESPO VILLABA, 1989; GARCIA-FAYOS, 1991). The climax vegetation is represented by four associations, fundamentally *Rubio longifoliae-Quercetum rotundifoliae* Costa *et al.*, 1982 (littoral holmoak) and *Asplenio onopteridis-Quercetum suberis* Costa *et al.*, 1985 / *Rubio-Quercetum rotundifoliae-Quercetosum suberis* García-Fayos, unpublished (continental corkoak), and point representations of *Bupleuro rigidi-Quercetum rotundifoliae* Br.-Bl. et O. de Bolòs, 1957 and *Hedero helici-Quercetum rotundifoliae* Costa *et al.*, 1985 (continental holmoak) and *Violo willkommii-Quercetum fagineae* Br.-Bl. et O. de Bolòs, 1950 (gall-oaks). As a consequence of the continuous degradation due both to anthropization (crops, charcoal production, grazing and urbanization) and numerous fires, the potential vegetation has been largely restricted by the different substitution stages, principally littoral kermesoak (*Quercus cocciferae-Pistacietum lentisci* Br.-Bl. *et al.*, 1935) and continental kermesoak (*Rhamno lycioidis-Quercetum cocciferae* Br.-Bl. et O. de Bolòs, 1957), along with different bushes and pastures. In addition, it may be pointed out that due to its peculiar location, the Serra Calderona is a transition zone between corological sectors, the flora being one of its main values due to the appearance of a number of endemisms.

Faunistically, emphasis may be placed on the presence of important populations of species, in terms of both numbers and variety. Among the invertebrates, a number of both Iberian and Valencian endemisms have been reported (DOCAVO *et al.*, 1987). As to the vertebrates, the herpetofauna and avian species are well represented, based on the geographic location and state of degradation that characterize the region. In this sense, a number of birds of prey are to be found (MURGÚ, 1997), including eagles (*Hieraeetus fasciatus*, *Circus gallicus*), and the large owl, *Bubo bubo*. Large and medium-sized mammals include boars (*Sus scrofa*), badger (*Meles meles*), fox (*Vulpes vulpes*), weasel (*Mustela nivalis*), mountain cat (*Felis silvestris*), and genet (*Genetta genetta*). Also present are the hare (*Lepus capensis*) and rabbit (*Oryctolagus cuniculus*). As to small mammals, the presence of three insectivores has been reported, the Algerian hedgehog (*Atelerix algirus*), the common shrew (*Crocidura russula*) and the dwarf shrew (*Suncus etruscus*), and 5 rodents, the squirrel (*Sciurus vulgaris*), the Garden dormouse (*Eliomys quercinus*), the Long-tailed field mouse (*Apodemus sylvaticus*), the wild mouse (*Mus spretus*) and the black rat (*Rattus rattus*).

Study sites and host captures: The study was initiated in February 1994. The present paper reports the results obtained corresponding to the material captured up to February 1997. Throughout the study area (Fig. 1C) three trapping stations were established for annual-seasonal follow-up. These areas comprise a total surface of about 5 Ha. The trap method used to capture hosts is based on the square plot (quadrante) technique, using the live-trapping and capture-mark-release methods. On a seasonal basis (four times annually at intervals of no longer than three months), 110 traps are placed at night in each of the three population study zones. The

traps are left in place for 48 hours and are checked in the morning. The captured animals are species identified and weighed; sexual activity is determined and the animals are then marked and released at the place of capture to record data on host population sizes. The parasitological study is in turn based on those animals that die during capture. In the event that no such deaths occur, no more than 10% of the captured specimens are sacrificed. With the aim of securing more helminthological data, this seasonal method is combined with the performance of numerous specific prospections in the course of the year using the line-up method. The animals obtained in these random prospections are destined exclusively for parasitological study.

Parasitological procedures: For the extraction of helminths and after collecting the data on each host individual (species identification, determination of sexual status, weighing and morphometry), routine procedures were used as to dissection and the study of all organs. In searching for specific parasite species in the cases of *E. quercinus*, *A. algirus* and *R. rattus*, a specific study was conducted of the nasal and frontal sinuses, these being habitual parasitization microhabitats in these hosts for the digenetic *Dollfusinus frontalis* Biocca et Ferretti, 1958. Likewise, the diaphragm of all host specimens was investigated for the possible presence of trichina larvae.

The helminths detected were studied using usual helminthological techniques. Trematodes were fixed in Bouin's solution, then stained for 24 hours with Grenacher's boracic carmine. Cestodes were fixed in 70% hot ethanol, followed by alcoholic chlorhydric carmine staining for 24 hours. Posteriorly, these plathyhelminths were differentiated with acidified alcohol, dehydrated in an alcohol series, cleared with xylene and mounted in Canada balsam between slide and coverslip. Nematodes were in turn fixed in 70% ethanol and posteriorly studied by direct examination between slide and coverslip with clearing fluid (e.g., lactophenol).

All helminths were specifically identified based on their morphology and morphometry, and employing the most relevant literature on each of the species involved. A number of specimens could not be specifically classified, due to limited development within the host (as in some anoplocephalid cestodes), the detection of larval stages or immature nematode adults, or because of the absence of some organ decisive for systematic classification (e.g., loss of the scolex in hymenolepidid cestodes).

Helminth study: In each host population records were made of the corresponding parasite prevalences. The term «prevalence» follows the definition of MARGOLIS *et al.* (1982). In this context, a distinction is made between «component» species (prevalence $\geq 10\%$) and «rare» species (prevalence $< 10\%$) (BUSH, AHO & KENNEDY, 1990). In parasite specificity studies of helminth species shared by more than one host, the index based on parasite prevalences (Sp) proposed by RHODE (1980) was applied.

RESULTS

HOSTS

In the studied area two insectivore and four rodent species were captured: *A. algirus* (520-655 g), *C. russula* (5,3-12 g), *E. quercinus* (23-76 g), *A. sylvaticus* (7-38 g), *M. spretus* (6,8-21 g) and *R. rattus* (70-185 g).

Postmortem helminthological studies were carried out in a total of 315 hosts. Table 1 shows the corresponding distribution by species and sex.

Host species	No.
<i>Atelerix algirus</i>	3 (2 ♂♂, 1 indet.)
<i>Crocidura russula</i>	31 (16 ♂♂, 15 ♀♀)
<i>Eliomys quercinus</i>	6 (2 ♂♂, 4 ♀♀)
<i>Apodemus sylvaticus</i>	192 (107 ♂♂, 85 ♀♀)
<i>Mus spretus</i>	68 (44 ♂♂, 24 ♀♀)
<i>Rattus rattus</i>	15 (6 ♂♂, 9 ♀♀)
Total	315

Table 1.— Small mammals (insectivores and rodents) studied in the Serra Calderona (Valencian Community, Spain).

PARASITES

Combined helminth community composition

The 38 helminth species found in the 315 host specimens, together with information on biological cycles, microhabitat (parasite site), host species and parasitisation prevalence are detailed in Table 2.

The different species have been identified according to the following descriptions and findings:

— Trematoda: *Brachylaima* spp. aff. *simoni* Feliu, Mas-Coma, Montoliu et Gállego, 1986; FELIU *et al.* (1986);

Helminth species	Life-cycle	Parasitisation site	Host species	n (%)
TREMATODA				
<i>Brachylaima</i> sp. aff. <i>simoni</i>	ILC	intestine	<i>C.r.</i>	2 (0,63)
<i>Brachylaima</i> spp.	ILC	intestine	<i>E.q.</i> , <i>A.s.</i> , <i>M.s.</i> , <i>R.r.</i>	13 (4,13)
<i>Dollfusinus frontalis</i>	ILC	nas. sin.	<i>E.q.</i>	1 (0,32)
Digenea gen. sp.		intestine	<i>C.r.</i>	2 (0,63)
CESTODA				
<i>Taenia parva</i> larvae	ILC	abd. cav.	<i>A.s.</i>	27 (8,57)
<i>T. martis</i> larvae	ILC	abd. cav.	<i>A.s.</i>	1 (0,32)
<i>Mesocostoides</i> sp. larvae	ILC	abd. cav.	<i>A.s.</i> , <i>M.s.</i> , <i>R.r.</i>	9 (2,86)
<i>Pseudocatenotaenia matovi</i>	ILC	intestine	<i>A.s.</i>	20 (6,35)
<i>Skrjabinotaenia lobata</i>	ILC	intestine	<i>A.s.</i>	12 (3,81)
Catenotaeniinae gen. sp.	ILC	intestine	<i>A.s.</i>	13 (4,13)
<i>Hymenolepis straminea</i>	ILC	intestine	<i>A.s.</i>	2 (0,63)
<i>H. pistillum</i>	ILC	intestine	<i>C.r.</i>	10 (3,17)
<i>H. tiara</i>	ILC	intestine	<i>C.r.</i>	15 (4,76)
<i>H. bilarius</i>	ILC	intestine	<i>C.r.</i>	10 (3,17)
<i>Hymenolepis</i> sp. indet.	ILC	intestine	<i>C.r.</i>	5 (1,59)
<i>Pseudhymenolepis redonica</i>	ILC	intestine	<i>C.r.</i>	14 (4,44)
NEMATODA				
<i>Trichuris muris</i>	DLC	intestine	<i>A.s.</i> , <i>R.r.</i>	37 (11,75)
<i>Eucoleus gastricus</i>	DLC?	st. wall	<i>R.r.</i>	1 (0,32)
<i>E. bacillatus</i>	DLC?	st. wall	<i>A.s.</i> , <i>M.s.</i>	56 (17,78)
<i>Liniscus incrassatus</i>	DLC?	ur. bladder	<i>C.r.</i>	10 (3,17)
<i>Aonchotheca annulosa</i>	ILC?	intestine	<i>A.s.</i> , <i>R.r.</i>	77 (24,44)
<i>A. myoxi-nitellae</i>	ILC?	intestine	<i>E.q.</i>	3 (0,95)
<i>A. europaea</i>	ILC?	st./int.	<i>C.r.</i>	26 (8,25)
Capillariinae gen. sp.		oesophag.	<i>C.r.</i>	1 (0,32)
<i>Parastrongyloides winchesi</i>	DLC	intestine	<i>C.r.</i>	2 (0,63)
<i>Crenosoma striatum</i>	ILC	lung	<i>A.a.</i>	2 (0,63)
<i>Paracrenosoma combesi</i>	ILC	lung	<i>C.r.</i>	3 (0,95)
<i>Heligmosomoides polygyrus</i>	DLC	intestine	<i>A.s.</i> , <i>M.s.</i> , <i>R.r.</i>	55 (17,46)
<i>Longistriata</i> sp.	DLC	intestine	<i>C.r.</i>	1 (0,32)
<i>Molineus patens</i>	DLC	intestine	<i>E.q.</i>	3 (0,95)
<i>Syphacia obvelata</i>	DLC	intestine	<i>M.s.</i>	26 (8,25)
<i>S. stroma</i>	DLC	intestine	<i>A.s.</i>	58 (18,41)
<i>S. muris</i>	DLC	intestine	<i>R.r.</i>	6 (1,90)
<i>S. frederici</i>	DLC	intestine	<i>A.s.</i>	64 (20,32)
<i>Aspiculuris tetraptera</i>	DLC	intestine	<i>A.s.</i> , <i>M.s.</i> , <i>R.r.</i>	11 (3,49)
<i>Gongylonema mucronatum</i>	ILC	oesophag	<i>A.a.</i>	1 (0,32)
<i>Mastophorus muris</i>	ILC	stomach	<i>A.s.</i> , <i>M.s.</i> , <i>R.r.</i>	30 (9,52)
<i>Pseudophysaloptera</i> sp.	ILC	stomach	<i>C.r.</i>	1 (0,32)
<i>Pterygodermatites</i> (<i>P.</i>) <i>plagiostoma</i>	ILC	intestine	<i>A.a.</i>	1 (0,32)
Acuariinae gen. sp.	ILC	tor. cav./st./int.	<i>C.r.</i>	9 (2,86)
Nematoda gen. sp. larvae		intestine	<i>A.s.</i>	1 (0,32)

Table 2.— Composition of the global helminth community of the small mammals in the Serra Calderona. ILC = indirect life cycle; DLC = direct life cycle; nas. sin. = nasal sinuses; abd. cav. = abdominal cavity; st. = stomach; int. = intestine; thor. = thoracic. The host abbreviations correspond to their generic and specific initials. n = number of parasitized hosts; % = global parasitisation prevalence.

- Brachylaima* spp.: MAS-COMA, MONTOLIU & VALERO (1984); *Doliffusinus frontalis* Biocca et Ferretti, 1958; BIOCCA & FERRETTI (1958), MAS-COMA & MONTOLIU (1987).
- Cestoda: *Taenia parva* Baer, 1926 larvae: HUNKELER (1974); *Taenia martis* (Zeder, 1803): WAHL (1967), MURAI & TENORA (1973); *Mesocestoides* sp. larvae: VAUCHER (1971), HUNKELER (1974); *Pseudocatenotaenia matovi* (Genov, 1971): TENORA *et al.* (1980), QUENTIN (1994); *Skrjabinotaenia lobata* (Baer, 1925): TENORA *et al.* (1980), QUENTIN (1994); *Hymenolepis straminea* (Goeze, 1782): BAER & TENORA (1970); *H. pistillum* (Dujardin, 1845): VAUCHER (1971); *Hymenolepis tiara* (Dujardin, 1845): VAUCHER (1971); *Hymenolepis biliaris* (Villot, 1877): VAUCHER (1971), MAS-COMA & JOURDANE (1977); *Pseudhymenolepis redonica*: JOYEUX & BAER (1936), VAUCHER (1971).
- Nematoda: *Trichuris muris* (Schränk, 1788): ROMAN (1951), BERNARD (1963); *Eucoleus gastricus* (Baylis, 1926): ROMAN (1951), BERNARD (1963), TENORA & ZAVADIL (1967), MORAVEC (1982); *E. bacillatus* Eberth, 1863: ROMAN (1951), BERNARD (1963), TENORA & ZAVADIL (1967), MORAVEC (1982); *Liniscus incrassatus* (Diesing, 1851): JOYEUX & BAER (1937), BERNARD (1961a, b), MORAVEC (1982); *Aonchotheca annulosa* (Dujardin, 1843): ROMAN (1951), BERNARD (1963), TENORA & ZAVADIL (1967), MORAVEC (1982); *Aonchotheca myoxi-nitellae* (Diesing, 1881): LE-VAN HOA (1960), TENORA & ZAVADIL (1967), MORAVEC (1982); *A. europaea* Mas-Coma et Galán-Puchades, 1985; MAS-COMA & GALAN-PUCHADES (1985); *Parastrongyloides winchesi* Morgan, 1928: MORGAN (1928); *Crenosoma striatum* (Zeder, 1800): BARUS & BLAZEK (1971), BARUS & PROKOPIC (1972); *Paracrenosoma combesi* Mas-Coma, 1977: MAS-COMA (1977); *Heligmosomoides polygyrus* (Dujardin, 1845): ROMAN (1951), DURETTE-DESSERT (1968), TENORA (1967); *Molineus patens* (Dujardin, 1845): SKRJABIN, SCHIKHOBALOVA & SHULTS (1954), SCHMIDT (1965); *Syphacia obvelata* (Rudolphi, 1802), *S. stroma* (Linstow, 1884), *S. muris* (Yamaguti, 1935), *S. frederici* Roman, 1945 and *Aspicularis tetraptera* (Nistch, 1821): ROMAN (1951), BERNARD (1963), QUENTIN (1971), TENORA & MESZAROS (1975); *Gongylonema mucronatum* Seurat, 1916: SEURAT (1916), QUENTIN & SEGUIGNES (1979); *Mastophorus muris* (Gmelin, 1790): BERNARD (1963), QUENTIN (1970), WERTHEIM (1962); *Pterygodermatites (Pterygodermatites) plagiostoma* Wedl, 1961: QUENTIN (1969); Acuariinae gen. sp. larvae: CHABAUD (1975).

The best represented helminths were nematodes, which contributed 24 species. In almost all of these cases the small mammals constituted the definitive hosts.

Cestodes were the second most common parasites, with 10 species. Small mammals were the definitive hosts of 7 of these species, carnivores and birds of prey being the definitive hosts of the three cestode larval stages detected in rodents.

Trematodes contributed only four species. This is the minimum number, for as several representatives of the genus *Brachylaima* were present (morphologically non-differentiable adults at species level) in four different host species, more than one digenean species could have been involved. Despite their scant gonad development, the young trematodes classified as Digenea gen. sp. were morphologically verified as not belonging to the genus *Brachylaima*; their systematic classification could not be further specified.

Despite the existence of species with non-established biological cycles, helminths with indirect cycles were found to predominate.

The intestine was the most colonized microhabitat, involving 26 different species, while the most exceptional was represented by the nasal sinuses of the Garden dormouse.

Of the 38 species detected, 6 were component species of the global helminth community (all nematodes) (Table 2).

Host helminth communities

Tables 3-8 show the results obtained for each of the hosts studied. The bioecological characteristics of the helminth communities of each host are in turn detailed in Table 9.

***Atelerix algirus*:** In the three specimens of the Algerian hedgehog studied, three nematode species were detected (Table 3). Of these, attention is drawn to the presence of *P. (P.) plagiostoma*, as this is the first report to date of this helminth in *A. algirus* on the Iberian Peninsula. The parasite has recently been reported in this same host on the Balearic island of Ibiza (MAS-COMA *et al.*, 2000). No monoxenous cycles were detected in the three hedgehogs studied (Table 9).

***Crocidura russula*:** The helminth community found in the 31 specimens of common shrew corresponded to 14 species: 2 trematodes, 4 cestodes and 8 nematodes (Table 4). Due to the scarcity of specimens found within the infected shrews, two of these 8 nematodes remain undetermined at species level. Thus, we only detected one female nematode belonging to the genus *Longistriata*. This specimen remains undetermined because the confi-

Helminth species	n (%)
NEMATODA	2 (66,67)
<i>C. striatum</i>	2 (66,67)
<i>G. mucronatum</i>	1 (33,33)
<i>P. (P.) plagiostoma</i>	1 (33,33)
Total	2 (66,67)

Table 3.— Qualitative and quantitative compositions of the helminthfauna detected in the three specimens of *Atelerix algirus* studied. n = number of parasitized hosts; % = global parasitization prevalence.

guration of the caudal bursa of the males is necessary to arrive at species level. Likewise, one shrew was infected by three specimens classified within the genus *Pseudophysaloptera* according to the characteristics of the cephalic extremity and the caudal bursa of the male. The morphological and biogeographical characteristics of our material approach those of *P. soricina* and *P. kottani*. However, the impossibility of carrying out a detailed study of the caudal bursa of the only male specimen found (as a result of poor fixation conditions) prevented its classification at species level.

With the exception of a single shrew, all specimens were found to be parasitized (prevalence $p = 96,77\%$), this reflecting the marked colonizing capacity of the helminths detected, as regards cestodes ($p = 87,10\%$) and particularly nematodes ($p = 90,32\%$). Of these 12 species constituting the helminth community, 8 corresponded to component helminths (i.e., 66,67%); the dominant species was found to be the nematode *A. europaea* ($p = 83,87\%$). From the bioecological point of view, the helminth community of *C. russula* reflects the dominance of both indirect cycle species and of hosts carrying heteroxenous helminths (Table 9).

***Eliomys quercinus*:** Four helminth species were detected in the 6 specimens of *E. quercinus* studied: 2 trematodes and 2 nematodes (Table 5). The detection of *D. frontalis* at the time represented the first report of this particular digenean in a continental shrew (GALAN-PUCHADES *et al.*, 1994). The parasitized hosts exhibited both direct and indirect cycle helminths (Table 9).

Helminth species	n (%)
TREMATODA	4 (12,90)
<i>B. sp. aff. simoni</i>	2 (6,45)
Digenea gen. sp.	2 (6,45)
CESTODA	27 (87,10)
<i>H. pistillum</i>	10 (32,26)
<i>H. tiara</i>	15 (48,39)
<i>H. biliarius</i>	10 (32,26)
<i>P. redonica</i>	14 (45,16)
<i>Hymenolepis</i> sp. indet.	5 (16,13)
NEMATODA	28 (90,32)
<i>L. incassatus</i>	10 (32,26)
<i>A. europaea</i>	26 (83,87)
Capillariinae gen. sp.	1 (3,23)
<i>P. winchesi</i>	2 (6,45)
<i>P. combesi</i>	3 (9,68)
<i>Longistriata</i> sp.	1 (3,23)
<i>Pseudophysaloptera</i> sp.	1 (3,23)
Acuariinae gen. sp.	9 (29,03)
Total	30 (96,77)

Table 4.— Qualitative and quantitative compositions of the helminthfauna detected in the 31 specimens of *Crocidura russula* studied. n = number of parasitized hosts; % = global parasitization prevalence.

Helminth species	n (%)
TREMATODA	4 (66,67)
<i>Brachylaima</i> spp.	3 (50)
<i>D. frontalis</i>	1 (16,67)
NEMATODA	4 (66,67)
<i>A. myoxi-nitellae</i>	3 (50)
<i>M. patens</i>	3 (50)
Total	4 (66,67)

Table 5.— Qualitative and quantitative compositions of the helminthfauna detected in the 6 specimens of *Eliomys quercinus* studied. n = number of parasitized hosts; % = global parasitization prevalence.

***Apodemus sylvaticus*:** The most varied helminth community in terms of the number of species was detected in the Long-tailed field mouse. Moreover, this was the most frequently captured host species. With the exception of the representatives of the genus *Brachylaima*, the 14 remaining species corresponded to cestodes and nematodes (6 and 8 species, respectively) (Table 6). The detection of the larval stage of *T. martis* represented the first report of this taeniid in a murid species on the Iberian Peninsula. Likewise, the capture in the Serra Calderona of three specimens of *A. sylvaticus* parasitized by *Tetrathyridium* larvae of the genus *Mesocostoides* constitutes the first such report in the field mouse in both continental and insular Spain.

The population of *A. sylvaticus* exhibited a high global parasitization prevalence (86,98%), with a dominant presence of nematodes in the host material studied ($p = 82,29\%$). Sixty percent of the helminth parasites were component species of the helminth community, *A. annulosa* being the dominant species ($p = 35,42\%$). Although the helminth community of *A. sylvaticus* presents a slight predominance of helminths with indirect cycles, those with direct cycles exhibited a greater colonizing capacity and were found in 78,13% of the hosts studied, versus 58,33% of the hosts with heteroxenous helminths (Table 9).

***Mus spretus*:** Five of the 7 species constituting the helminth community of the specimens of *M. spretus* investigated were nematodes (Table 7). The platyhelminths detected included representatives of the genus *Brachylaima* and a larval stage of the genus *Mesocostoides*, this being the first such report for the wild mouse on the Iberian Peninsula. No adult stage cestodes were detected. *S. obvelata* and *E. bacillatus* were the only two community component species found, the rest being rare within the helminth community. Of all the hosts studied, *M. spretus* exhibited the lowest global parasitization prevalence, for out of 68 specimens analyzed, 27 contained no helminths. The indirect cycle helminths exhibited a low colonizing capacity in the wild mice studied ($p = 14,71\%$) in comparison to the direct cycle parasites ($p = 51,47\%$) (Table 9).

Helminth species	n (%)
TREMATODA	3 (1,56)
<i>Brachylaima</i> spp.	3 (1,56)
CESTODA	57 (29,69)
<i>T. parva</i> larvae	27 (14,06)
<i>T. martis</i> larvae	1 (0,52)
<i>Mesocostoides</i> sp. larvae	3 (1,56)
<i>P. matovi</i>	20 (10,42)
<i>S. lobata</i>	12 (6,25)
Catenotaeniinae gen. sp.	13 (6,77)
<i>H. straminea</i>	2 (1,04)
NEMATODA	158 (82,29)
<i>T. muris</i>	36 (18,75)
<i>E. bacillatus</i>	48 (25)
<i>A. annulosa</i>	68 (35,42)
<i>H. polygyrus</i>	48 (25)
<i>S. stroma</i>	58 (30,21)
<i>S. frederici</i>	64 (33,33)
<i>A. tetraptera</i>	8 (4,17)
<i>M. muris</i>	22 (11,46)
Nematoda gen. sp. larvae	1 (0,52)
Total	167 (86,98)

Table 6.— Qualitative and quantitative compositions of the helminthfauna detected in the 15 specimens of *Mus spretus* studied. n = number of parasitized hosts; % = global parasitisation prevalence.

Helminth species	n (%)
TREMATODA	3 (4,41)
<i>Brachylaima</i> spp.	3 (4,41)
CESTODA	3 (4,41)
<i>Mesocostoides</i> sp. larvae	3 (4,41)
NEMATODA	38 (55,88)
<i>E. bacillatus</i>	8 (11,76)
<i>H. polygyrus</i>	6 (8,82)
<i>S. obvelata</i>	26 (38,23)
<i>A. tetraptera</i>	1 (1,47)
<i>M. muris</i>	4 (5,88)
Total	41 (60,29)

Table 7.— Qualitative and quantitative compositions of the helminthfauna detected in the 68 specimens of *Mus spretus* studied. n = number of parasitized hosts; % = global parasitisation prevalence.

***Rattus rattus*:** The 15 specimens of *R. rattus* studied presented 9 helminth species, including 7 nematodes (Table 8). The platyhelminths in *R. rattus* were fully comparable to those found in the wild mouse, with representatives of the genus *Brachylaima*, the larval stage of the genus *Mesocostoides* (which, as in the case of *M. spretus*, represents the first such report in the black rat on the Iberian Peninsula), and the absence of adult cestodes. The community component helminths included *A. annulosa* in first place, with the highest prevalence (p

Helminth species	n (%)
TREMATODA	4 (26,67)
<i>Brachylaima</i> spp.	4 (26,67)
CESTODA	3 (20)
<i>Mesocostoides</i> sp. larvae	3 (20)
NEMATODA	14 (93,33)
<i>T. muris</i>	1 (6,67)
<i>E. gastricus</i>	1 (6,67)
<i>A. annulosa</i>	9 (60)
<i>H. polygyrus</i>	1 (6,67)
<i>S. muris</i>	6 (40)
<i>A. tetraptera</i>	2 (13,33)
<i>M. muris</i>	4 (26,67)
Total	15 (100)

Table 8.— Qualitative and quantitative compositions of the helminthfauna detected in the 15 specimens of *Rattus rattus* studied. n = number of parasitized hosts; % = global parasitisation prevalence.

= 60%), and three other nematode species. The platyhelminths were likewise community component helminths in *R. rattus*. As to the rare species, emphasis is placed on the observation of *H. polygyrus*, this being the first such report in this host species on the Iberian Peninsula. All the specimens of *R. rattus* investigated were parasitized, and almost all exhibited indirect cycle helminths (p = 86,67%), with far fewer direct cycle parasites (p = 46,67%) (Table 9).

SPECIFICITY

Eight of the 38 species detected (specifically, a trematode, a larval stage cestode and 6 nematodes) presented parasite populations in more than one host population. In the case of the genus *Brachylaima*, it is not possible to confirm circulation of a single species among different hosts, since different species could be involved even if the adult stages are morphologically analogous. Likewise, in the case of the *Tetrathyridium* larvae, it cannot be confirmed that the specimens detected in the three murids pertain to the same species. For this reason Rhode's index was applied to the 6 adult nematodes that shared more than one murid (Table 10).

According to HOLMES (1979), the host populations may be divided into three categories: required, suitable and unsuitable hosts. Based on the criteria of this author, the parasite specificity models for the shared species in the Serra Calderona are graphically shown in Fig. 2. Thus, *A. sylvaticus* appears as a required host to *T. muris*, *E. bacillatus* and *H. polygyrus*, while the same applies to *R. rattus* in relation to *A. annulosa*, *A. tetraptera* and *M. muris*. *R. rattus* would in turn behave as a host intermediate between suitable and unsuitable for *H. polygyrus*, as a single mature specimen of this nematode was detected in one black rat. The same case would apply to *M. spretus* and *A. tetraptera*.

Host species	<i>A.a.</i>	<i>C.r.</i>	<i>E.q.</i>	<i>A.s.</i>	<i>M.s.</i>	<i>R.r.</i>
No. helminth species	3	14	4	15	7	9
No. ILC helminths	3	10	3	9	3	4
% ILC helminths	100	71,43	75	60	42,86	44,44
No. host with ILC helminths	3	30	4	112	10	13
% with ILC helminths	100	96,77	66,67	58,33	14,71	86,67
Poliheteroxenous	—	2	2	2	2	2
terrestrial cycle	—	2	2	2	2	2
only gastropods as i.h.	—	2	2	1	1	1
acting as i.h.	—	—	—	1	1	1
Diheteroxenous	3	8	1	7	1	2
terrestrial cycle	3	8	1	7	1	2
invertebrates not arthropods as i.h.	1	2	1	1	—	1
arthropods as invertebrate host	2	5	—	4	1	1
acting as i.h.	—	—	—	2	—	—
acting as p.h.	—	1	—	—	—	—
No. DLC helminths	—	4	1	6	4	5
% DLC helminths	—	28,57	25	40	57,14	55,56
No. host with DLC helminths	—	14	3	150	35	7
% with DLC helminths	—	45,16	50	78,13	51,47	46,67
ageohelminths	—	—	—	2	1	1
pseudogeohelminths	—	2	—	3	2	3
geohelminths	—	2	1	1	1	1

Table 9.— Bioecological characteristics of the helminthfaunas of the small mammals investigated. The host abbreviations correspond to their generic and specific initials. ILC = indirect life cycle; DLC = direct life cycle; i.h. = intermediate host; p.h. = paratenic host.

Helminth species	<i>T. m.</i>	<i>E. b.</i>	<i>A. a.</i>	<i>H. p.</i>	<i>A. i.</i>	<i>M. m.</i>
Host						
<i>A. sylvaticus</i>	18,75	25	35,42	25	4,17	11,46
<i>R. rattus</i>	6,67		60	6,67	13,33	26,67
<i>M. spretus</i>		11,76		8,82	1,47	5,88
Sp	0,87	0,84	0,81	0,78	0,84	0,78

Table 10.— Results of the Rhode index based on the parasite prevalences (Sp). The parasite abbreviations correspond to their generic and specific initials.

DISCUSSION

The results obtained to date in the Serra Calderona are of considerable interest in both strictly populational terms (unpublished data) and as regards the parasitological perspective. These first prospections show that although the study area generally appears to suffer important perturbations (droughts, fires, human activity, etc.), which have undoubtedly exerted an adverse effect upon the populations of small mammals, the parasitological observations reflect a relatively rich qualitative diversity suggesting that the Serra Calderona continues to preserve points or redoubts of great ecological value.

The present study corresponds to an annual follow-up survey (extending over several years) of 6 sympatric rodent and insectivore host populations in a Mediterranean vegetation ecosystem. With the exception of the Balearic Islands (MAS-COMA *et al.*, 1997a, b), most of the hel-

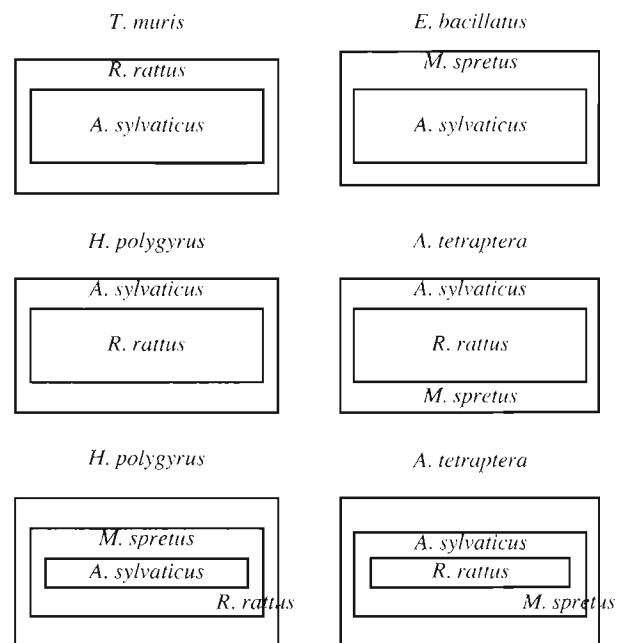


Fig. 2.— Host specificity pattern for shared helminth species in small mammals in the Serra Calderona. The inner, intermediate and outer rectangles respectively encompass required, suitable and unsuitable hosts.

minthological data presently available on small mammals in Mediterranean countries refer to isolatedly studied hosts (ESTEBAN *et al.*, 1987a, b; BEHNKE *et al.*, 1993; PORTOLES, GRANEL & ESTEBAN, 1997; FELIU *et*

al., 1997). FELIU, MAS-COMA & GALLEGO (1984) report qualitative data in 5 murids, though within the global context of Catalonia (Spain). Only TORRES & FELIU (1990), from a qualitative point of view, analyzed the helminthfauna of 8 small mammals (insectivores and rodents) captured in the Delta del Ebro (Spain).

In order to interpret the helminthological characteristics detected in each host species studied, two important aspects must be taken into account: a) the degradation of the ecosystem investigated and its limited resources; b) the composition of the sympatric host community in the Serra Calderona. This region has suffered droughts for a number of years, as a result of which the hydrological resources are very limited, a fact that greatly conditions the absence of helminths possessing aquatic cycles. Thus, digenean trematodes that typically reflect the helminthfauna of some of the hosts found in other geographical settings such as the Delta del Ebro or the Eastern Pyrenees have not been found in the Serra Calderona (e.g., representatives of the families Microphallidae in *C. russula*, and Plagiorchiidae and Collyriidae in *A. sylvaticus*).

Erinaceidae

***Atelerix algirus*:** The scant representativity of the three specimens of Algerian hedgehog studied do not allow the drawing of conclusions. Nevertheless, mention may be made of the detection of *G. mucronatum* in this host species. This nematode had already been reported in *A. algirus* in North Africa and on the Balearic islands of Mallorca and Formentera (ESTEBAN *et al.*, 1987b). Thus, its identification in the Serra Calderona supports the hypothesis originally proposed by MAS-COMA (1978) regarding the colonization routes of the Balearic Archipelago from North Africa, along the Betic-Rif-Magreb arch.

Soricidae

***Crocidura russula*:** The results obtained in *C. russula* are qualitatively comparable to those recently published by MAS-COMA *et al.* (1998, 2000) in the Balearic Islands and to the observations of PORTOLES, GRANEL & ESTEBAN (1996) for this same host species in the Albufera Natural Park of Valencia (Spain). From the quantitative point of view, the parasitism indices are generally higher in the Serra Calderona than in the Albufera Natural Park as regards both the global helminth statistics and trematodes, cestodes and nematodes individually. Likewise, while in the Albufera only 37.5% of the helminths found in the common shrew are component species of its helminth community, in the Serra Calderona these species account for 66.67% of the community detected. In turn, whereas in the Serra Calderona *A. europaea* proved to be the dominant species, with a prevalence of 83.87%, in the Albufera it was rare in *C. russula* ($p = 2.6\%$ according to PORTOLES, GRANEL & ESTEBAN, 1996). Similarly, *L. incrasatus*, a rare species in the Albufera Natural Park ($p = 1.0\%$ according to PORTOLES, GRANEL &

ESTEBAN, 1996), constitutes a component species in the Serra Calderona ($p = 32.26\%$). As the biological cycles of both nematodes have not been established, the results obtained are difficult to interpret, though they are undoubtedly related to the different ecological characteristics of the two ecosystems, which likely exert different influences upon the colonization routes of these and other helminths.

Gliridae

***Eliomys quercinus*:** As in the case of the Algerian hedgehog, the limited number of specimens studied ($n = 6$) do not allow the drawing of conclusions, apart from the observation of the nasal digenean *D. frontalis* in this species (GALAN-PUCHADES *et al.*, 1994).

Muridae

The results obtained in the three murid species detected reflect the typical characteristics of each host, as well as the relationships established between these and other host species (fundamentally carnivores and birds of prey) in the same ecosystem.

***Apodemus sylvaticus*:** The helminthfauna detected in *A. sylvaticus* agrees with the results of FELIU *et al.* (1997) for this host species on the Iberian Peninsula, and moreover includes the presence of larvae of *T. martis* and *Mesocostoides* sp. in the Serra Calderona. The absence of certain helminths in this area with respect to the parasites observed by FELIU *et al.* (1997) is explained by the limited resources in the Serra Calderona in comparison to global continental Spain.

The large number of captures of the field mouse reflects its high population in the studied area (unpublished data). This dominant feature of *A. sylvaticus* is reflected by its helminthfauna in two main aspects. Firstly, it is the murid host most likely to become infested by the eggs of cestodes eliminated by carnivores and birds of prey (the latter being the definitive hosts), as reflected by the larger number of cestode larval stages detected in *A. sylvaticus* (*T. parva*, *T. martis* and *Mesocostoides* sp.). Secondly, *A. sylvaticus* is the required host for three species shared with other murids, and in turn becomes infested by species characteristic of the wild mouse and black rat (i.e., *A. tetraptera*, *M. muris*). These considerations are all accounted for by the colonizing nature of *A. sylvaticus*, which thus possesses a cosmopolitan and interactive character in the ecosystem investigated.

***Mus spretus*:** The specimens of *M. spretus* analyzed show this murid population to be the least parasitized by helminths and with the poorest helminth community. This species appears to present helminths more characteristic of other hosts, with the exception of its main community component, *S. obvelata*, for which the wild mouse is the required host. The rest of the species detec-

ted, with the exception of *E. bacillatus* (the only other component helminth), are rare in the community of the wild mouse and are typical of *A. sylvaticus* (i.e., *H. polygyrus*) and the black rat (*A. tetraptera*, *M. muris*). The role of *M. spretus* in the Serra Calderona could thus be defined as that of a reservoir host for helminthiases specific of other murids.

The general absence of adult cestodes is typical of this host species. The helminthological data available on *M. spretus* in other close-lying geographical settings such as the Balearic Archipelago likewise fail to reveal the presence of adult cestodes in this particular murid species (MAS-COMA *et al.*, 2000). On the Iberian Peninsula, only two species have been reported: *Catenotaenia pusilla*, a cestode typical of the domestic mouse (*M. musculus* Linnaeus, 1766), and *Hymenolepis straminea*, typical of *A. sylvaticus* (FELIÚ *et al.*, 1997). In Portugal, three adult cestode species (all typical of *M. musculus*) have been found to parasitize *M. spretus*. The presence of these cestodes in *M. spretus* in the neighbouring country is due to the sympatry of the wild mouse population studied with the domestic mouse (BEHNKE *et al.*, 1993). In the Serra Calderona, both the absence of *M. musculus* in the area investigated and the low prevalence of *H. straminea* in *A. sylvaticus* led to the absence of the adult cestodes habitually reported in this host in other geographical settings.

BEHNKE *et al.* (1993) reported parasitisation prevalences for *M. spretus* in Portugal. They related the scant presence of *A. tetraptera* ($p = 3.4\%$) and *E. bacillatus* ($p = 8.6\%$) to the fact that *M. spretus* keeps its faeces away from the areas where it lives and moves, as a result of which parasite species that require a period of days or even months to embryonate to the infective stage (pseudogeoelminths) for transmission are rarely found in this host (BEHNKE *et al.*, 1993).

According to our results, this behaviour could explain the very minor presence of *A. tetraptera* in the mice analyzed. However, in our case, *E. bacillatus* was not a rare species but a community component in the wild mice studied. In this context, it should be taken into account that the cycle of this capillarine has not been fully established. BEHNKE *et al.* (1993) fed house mice with embryonated eggs of *E. bacillatus* but obtained no adults. This points to the existence of a diheteroxenous cycle rather than a monoxenous pseudogeoelminth; as a result, the ethology of this murid regarding its faeces would not influence the presence of *E. bacillatus*.

Finally, two possibilities may be proposed to explain the fact that almost 40% of the specimens captured were not parasitized. On one hand, the existence of not very large populations of this particular host, since in large populations ageohelminth monoxenous species (i.e., those in which the eggs shed already possess infesting capacity) tend to exhibit high prevalences. These possibly limited populations would account for the absence of *S. obveleta*, a species easily transmitted by contact among specimens of *M. spretus*. In this context, our re-

sults regarding the population dynamics of the hosts in the Serra Calderona confirm the existence of such low wild mouse populations (unpublished data).

Secondly, *M. spretus* has been more frequently captured in cultivated areas in the Serra Calderona. The possible use of pesticides in these biotopes may have adversely affected the invertebrate arthropod fauna, thereby limiting the transmission of heteroxenous helminths vectored by them.

***Rattus rattus*:** Despite the limited number of black rats studied, the helminthfauna detected suggests that the population of this particular murid in the Serra Calderona presents many of the typical elements of this host in close-lying geographical settings (*S. muris*, *A. tetraptera*, *M. muris*). *R. rattus* also exhibited helminth populations (*T. muris*, *H. polygyrus*) resulting from the sharing of ecological niches with *A. sylvaticus*, the dominant small mammal in the Serra Calderona. These two helminth species are absent in the helminthfauna of the black rat in the Delta del Ebro, due to the scant presence of *A. sylvaticus* in this ecosystem (TORRES & FILLIÚ, 1990). It is not clear which species is the required host of *A. annulosa* in the Serra Calderona, for although it is more prevalent in *R. rattus*, it is more abundant in *A. sylvaticus*.

The most notorious absences in this murid correspond to species typical of *R. norvegicus* (Berkhout, 1769) such as *Trichosomoides crassicauda* (Bellingham, 1840), *Heterakis spumosa* (Schneider, 1866), *Nippostrongylus brasiliensis* (Travassos, 1914), etc. The fact that no specimen of *R. norvegicus* was captured in the study area suggests that coexistence between the two related species is minimal, for only one helminth species typical of *R. norvegicus* (*E. gastricus*) was detected.

The absence of cestodes in the helminth community of *R. rattus* may have an explanation similar to that given for *M. spretus*; however, the limited number of host specimens examined may be the reason for the absence of *H. diminuta* (Rudolphi, 1819) or *H. fraternus* (Stiles, 1906), for example.

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