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Authors: Bordes, Frédéric, Langand, Juliette, Feliu, Carlos, and Morand, Serge

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Helminth Communities of an Introduced Hare (*Lepus granatensis*) and a Native Hare (*Lepus europaeus*) in Southern France

Frédéric Bordes,[1] Juliette Langand,[1,4] Carlos Feliu,[2] and Serge Morand[3] [1]UMR 5244, CNRS-EPHE-UPVD Biologie et Ecologie Tropicale et Mediterranéenne, CBETM Université, 52 Avenue Paul Alduy, 66860 Perpignan Cedex, France; [2]Laboratories de Parasitologia, Facultat de Farmacia, Avenida Diagonal, s/n 08028 Barcelona, Spain; [3]Institut des Sciences de l'Evolution, Centre National de la Recherche Scientifique, Département Génome et Environnement, CC065, Université Montpellier 2, 34095 Montpellier Cedex 05, France; [4]Corresponding author (email: langand@univ-perp.fr)

ABSTRACT: We investigated the parasite communities of introduced Iberian hares (*Lepus granatensis*) and native European hares (*Lepus europaeus*) in southern France, where Iberian hares were introduced locally 20 yr ago as a game animal. Parasite communities of sympatric populations of the two hare species and of allopatric populations of European hares were compared. Iberian hares in France harbored a depauperate community of parasites relative to the population in its native habitat in Spain. European hares in areas of sympatry also were infected by *Nematodiroides zembrae*, which normally infects Iberian hares on their native range.

Key words: European hare, Iberian hare, introduced populations, *Lepus europaeus*, *Lepus granatensis*, macroparasites, *Nematodiroides zembrae*.

Iberian hares (*Lepus granatensis*) are endemic to the Iberian Peninsula and the island of Mallorca and live in a strict parapatry with the European hare (*Lepus europaeus*). *Lepus granatensis* is present throughout the peninsula except in the center and eastern areas of northern Spain. This northern limit of the natural range of the Iberian hare in the Iberian Peninsula is distant (200–300 km) from southern France, where only *L. europaeus* is naturally present (Palacios, 1983, 1998; Palomo and Gisbert 2002). Iberian hares have been introduced as game animals during the last 20 yr in the Department of Pyrénées Orientales (southern France), and they are now found in sympatry with European hares in some localities. Iberian hare populations have reached high densities, and in some areas of sympatry, they outnumber European hares (Departmental Federation of Hunters, unpubl.). In this study, we recorded and compared the helminth communities of *L. granatensis* and *L. europaeus* in sympatric and allopatric areas.

The study was conducted in the Department of Pyrénées Orientales in southern France. The study area was subdivided into two sectors including several localities. The first sector (longitude 2°30′–3°03′E, latitude 42°32′–42°54′N), the Roussillon lowland, consisted of vineyards where both species were present (sympatric area). The second sector (longitude 1°55′–2°20′E, latitude 42°24′–42°40′N), including the Conflent and Cerdagne, was a middle mountain sector in which only European hares were present at the time of the study (allopatric area). Hares were obtained during the hunting season, between September and December 2003, and species identification was based on morphologic differences: length, weight, color, and fur pattern according to Palacios (1989). The demographic structure (age and gender distribution) was recorded. Differences between species were tested using Fisher's exact tests.

To detect internal macroparasites, the abdominal cavity was first examined for cysts. The alimentary tract and the liver then were removed and frozen for future examination at the laboratory. Eighty hares were examined, 58 in the sympatric area (47 *L. granatensis* and 11 *L. europaeus*) and 22 in the allopatric area (all *L. europaeus*). The alimentary tract was divided into three regions (stomach, small intestine, and large intestine) before inspection. Viscera were examined under stereoscopic microscope, and helminths

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TABLE 1. Prevalence (P) and mean intensity (MI, with range of infection) of parasite species identified from *Lepus europaeus* and *L. granatensis* in allopatric and sympatric areas.

	Sympatric area				Allopatric area	
	Lepus granatensis (*n*= 47)		*Lepus europaeus* (*n*= 11)		*Lepus europaeus* (*n*=22)	
Parasite species	P (%)	MI	P (%)	MI	P (%)	MI
Passalurus ambiguus	0	0	0	0	30	4 (1–14)
Mosgovoyia ctenoides	0	0	0	0	14	1,5 (1–2)
Trichostrongylus retortaeformis	0	0	0	0	9	2
Graphidium strigosum	0	0	2	5	5	150 (100–200)
Leporidotaenia cf. wimerosa	0	0	0	0	5	25
Nematodiroides zembrae	72	128 (27–286)	74	161 (2–1,200)	0	0

were counted and preserved in 70% alcohol. Identification of parasites was made according to previous descriptions (Erhardova, 1957; Bernard, 1965; Tenora and Murai, 1978; Durette-Desset, 1979; Hugot et al., 1983; Genov et al., 1990). Terminology for describing parasite infestation (prevalence, mean intensities, and abundances) follows Bush et al. (1997). Differences in abundance were tested using the Mann-Whitney *U*-test.

Significant differences in age (adults and juveniles) and gender distribution between samples from sympatric European and Iberian hare populations or between sympatric and allopatric European hare populations were not detected ($P>0.05$). Only two species of nematodes were recorded in the Iberian hare samples in the sympatric area: *Nematodiroides zembrae* in the small intestine, and *Graphidium strigosum*, which was found in the stomach of a single animal (Table 1). *Nematodiroides zembrae* is known to be endemic to the Iberian Peninsula and Zembra Island (near the coast of Tunisia), where it is a common parasite of both European rabbits (*Oryctolagus cuniculus*; Blasco 1996) and Iberian hares (Moreno Montanez et al., 1979; Martinez-Gomez et al., 1987; Molina i Figueras, 1998).

The parasite species community of European hares in the sympatric area was very poor, and only one parasite species (*N. zembrae*) was detected (Table 1). The prevalence and intensity of *N. zembrae* in the sympatric area, however, were high in both hare species (Table 1), but differences between species were not detected (Mann-Whitney *U*-test; $P>0.9$).

The helminth fauna of the European hares in the allopatric area was richer despite a smaller sample size from the mountain localities. Three nematodes (*Passalurus ambiguus*, *Graphidium strigosum*, and *Trichostrongylus retortaeformis*) and two cestodes (*Mosgovoyia ctenoides* and *Leporidotaenia cf. wimerosa*) were recorded (Table 1). *Nematodiroides zembrae* was not observed in this allopatric area. The species composition of the parasite community of European hares in the allopatric area was similar to that of parasite communities investigated in other countries, but it differed by the presence of the cestode *Leporidotaenia cf. wimerosa*. The cestode *L. cf wimerosa* has only recorded in mountain hares (*Lepus timidus*) and rabbits (Genov et al., 1990), and this is the first report for the European hare.

The parasite community of European hares in the sympatric area in the Department of Pyrénées Orientales was poor and limited to a single nematode species, *N. zembrae.* The paucity of the parasite community could be related to the small sample size, the low densities of European hares in this area, or to ecological differences between the sympatric area (lowland agriculture area) and the allopatric area (subalpine). Concerning the third

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TABLE 2. Surveys of parasite species richness of *Lepus granatensis* in Iberian Peninsula (native area) and Pyrenees Orientales (present study).

References	Moreno Montanez et al. (1979)	Martinez-Gomez et al. (1987)	Molina i Figueras (1998)	Present study (2003)
Sites	Provincia de Cordoba[a]	Provincia de Cordoba[a]	Provincia de Navarra[a]	Pyrenees Orientales (France)
No.	42	45	19	47
Species richness of helminths[b]	7	8	5	2
Cestodes[c]	2	2	1	0
Nematodes	5	6	3	2
Trematodes	0	0	1	0
Prevalence (%) of *Nematodiroides zembrae*	5	10	28	71

[a] Iberian Peninsula.

[b] Digestive tract, including peritoneal cavity.

[c] Larval and adult forms.

assumption, it is known that parasite transmission rates can be affected by moisture availability (Hulbert and Boag, 2001; Wilson et al., 2001). Previously, *N. zembrae* had only been recorded in the Iberian Peninsula and Zembra Island, where it occurs only in rabbits and in Iberian hares (Moreno Montanez et al., 1979; Martinez-Gomez et al., 1987; Blasco et al., 1996; Molina i Figueras, 1998). Many studies have been conducted on the helminth fauna of *L. europaeus* in other countries outside of the Iberian Peninsula, and there have been no reports of *N. zembrae* from this species (Sharpilo, 1975; Kutzer and Frey, 1976; Sugar et al., 1978; Forstner and Ilg, 1982; Soveri and Valtonen, 1983; Boag, 1987; Canestri-Trotti et al., 1988; Allgoewer, 1992; Poglayen et al., 1994; Molina i Figueras, 1998; Shimalov and Shimalov, 2001). This nematode species also has not been recorded from European hares in northern Spain, where Iberian hares are absent (Molina i Figueras, 1998). Our study is the first record of this nematode for *L. europaeus* and France. These data, and the absence of *N. zembrae* in the allopatric samples in our study, strongly support the hypothesis that *N. zembrae* was introduced with Iberian hares in the Roussillon and now parasitizes European hares in this area.

The parasite community of the introduced Iberian hares was species-poor and did not include parasite species previously reported from Iberian hares sampled from its native range (Iberian Peninsula). In comparison with previous published parasitologic surveys on *L. granatensis*, the parasite community in the introduced area is reduced to two nematodes, both of which are characterized by a direct life cycle (Table 2). Parasite species with complex life cycles (which involve invertebrate intermediate hosts) were absent in our study area; these include two cestode species (*Mosgovoyia pectinata* and *Cysticercus pisiformi*) and one trematode species (*Dicrocoelium dentriticum*) that occur in Iberian hares in Spain (Table 2). The observed loss of parasite diversity can be explained by a founder effect. In addition, for those parasites with complex life cycles, the potential lack of suitable intermediate hosts in the introduction area also may have limited the potential for parasite introduction (Dobson and May, 1988; Goüy de Bellocq et al., 2002; Torchin et al., 2003). In Iberian hares, a founder effect seems likely because releases of this game animal are usually limited in number.

In contrast to the overall reduction in parasite diversity, a high prevalence and

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intensity (72% and 74%) of *N. zembrae* was observed in areas where Iberian hares have been introduced compared to native areas. Our restricted collection period may have affected both intensity and prevalence estimates as parasite burdens are seasonally variable (Boag et al., 2001); however, the high densities of Iberian hares, and resulting high transmission rates, may explain the high prevalence of *N. zembrae*.

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