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Helminth communities of the autochthonous mustelids *Mustela lutreola* and *M. putorius* and the introduced *Mustela vison* in south-western France

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Abstract

This study presents the first comprehensive helminthological data on three sympatric riparian mustelids (the European mink *Mustela lutreola*, the polecat *M. putorius* and the American mink *M. vison*) in south-western France. One hundred and twenty-four specimens (45 *M. lutreola*, 37 *M. putorius* and 42 *M. vison*) from eight French departments were analysed. Globally, 15 helminth species were detected: *Troglotrema acutum*, *Pseudamphistomum truncatum*, *Euryhelmis squamula*, *Euparyphium melis* and *Ascocotyle* sp. (Trematoda), *Taenia tenuicollis* (Cestoda), *Eucoleus aerophilus*, *Pearsonema plica*, *Aonchotheca putorii*, *Strongyloides mustelorum*, *Molineus patens*, *Crenosoma melesi*, *Filaroides martis* and *Skrjabingylus nasicola* (Nematoda) and larval stages of *Centrorhynchus* species (Acanthocephala). The autochthonous European mink harboured the highest species richness (13 species) followed by the polecat with 11 species. The introduced American mink presented the most depauperate helminth community (nine species). The prevalence and worm burden of most of the helminths found in *M. putorius* and *M. lutreola* were also higher than those of *M. vison*. Some characteristics of their helminth communities were compared to relatively nearby populations (Spain) and other very distant populations (Belarus). This comparison emphasized *M. patens* as the most frequent parasite in all of the analysed mustelid populations. It was possible to conclude that the invasive *M. vison* contributes to the maintenance of the life cycle of the pathogenic *T. acutum* and *S. nasicola* helminths, with possible implications for the conservation of the endangered European mink.

Introduction

In the past, the European mink, *Mustela lutreola* (L., 1761), was widely distributed in Europe. Nowadays, some populations have declined or disappeared from several countries, and currently it is one of the most endangered small carnivores in the world (Schreiber *et al.*, 1989; Maran & Henttonen, 1995). French and Spanish populations are currently continuous, but there is no connection to other important populations in Eastern Europe (Palazón & Ruíz-Olmo, 1997; Michaux *et al.*, 2005). Presently, the European mink is still declining in all countries (Maran *et al.*, 1998a; Tumanov, 1999; Gotea & Kranz, 1999; Sidorovich, 2000a; Palazón *et al.*, 2002). In France, it lost nearly half of its range between 1980 and 2000

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(Maizeret *et al.*, 2002) being presently restricted to seven departments of south-western France (Charente, Charente-Maritime, Dordogne, Gironde, Landes, Lot-et-Garonne and Pyrénées-Atlantiques) where population density seems to be low (unpublished data). The polecat, *Mustela putorius* (L., 1758), once present throughout most of continental Europe, is now restricted to the south of Europe and some parts of northern Europe (Roger *et al.*, 1988). A recent study has shown that *M. putorius* is present in most of the French departments but there are no available data on its population densities (Ruette *et al.*, 2004). Also, in south-western France *M. putorius* is less tightly linked to wetlands than *M. lutreola* (Fournier *et al.*, 2007). The American mink, *Mustela vison* Schreber, 1777 is a species of Nearctic distribution. However, due to the economical importance of their fur, minks were brought to breeding farms in Europe about a century ago. Wild populations of *M. vison* soon became invasive all over Europe. In France, the first observations of free individuals of *M. vison* occurred in 1960 but the colonization in nature was observed 10 years later (Léger & Ruette, 2005). In Spain, free individuals were first reported in 1978 (Ruíz-Olmo *et al.*, 1997) and currently both countries present some high-density populations. Presently, *M. vison* is widely spread, with distribution areas partially overlapping those of *M. lutreola* (Barrault *et al.*, 2003; Mission Vison d'Europe, 2003), which can be locally displaced by the more aggressive introduced mink (Ruíz-Olmo *et al.*, 1997; Palazón *et al.*, 2002).

In south-western France, all three mustelids are sympatric but several authors have shown that differences in their diets or habitat use are sufficiently large to prevent intense competition, which may only occur during periods of poor feeding conditions (Sidorovich, 1992; Lodé, 1993; Maran *et al.*, 1998b; Fournier *et al.*, 2007). Nevertheless, *M. vison* represents a major source of Aleutian mink disease parvovirus and is a more opportunistic and competitive predator than *M. lutreola* (Sidorovich, 2000b; Fournier-Chambrillon *et al.*, 2004). Furthermore, the cross-transmission of pathogenic helminths between neighbouring populations of both European and American minks may occur, as previously assessed in Spain (Torres *et al.*, 2003, 2006). However, global helminthological knowledge on *M. lutreola*, *M. putorius* and *M. vison* in south-western Europe is scarce, compared to Eastern countries where a great deal of information has been compiled in the past decade (Sidorovich & Bychkova, 1993; Sidorovich & Anisimova, 1997; Shimalov & Shimalov, 2001; Anisimova, 2002). In this context, the present study aims to provide the first comprehensive helminthological data on these three riparian mustelids in France. Considering the importance of the continuity of both French and Spanish populations of the endangered *M. lutreola*, this information will complement the available data on these carnivores in Spain (Torres *et al.*, 1996, 2003, 2006). In addition, the survey will also allow the comparison of the helminth communities of both native (*M. lutreola* and *M. putorius*) and introduced (*M. vison*) mustelids in areas of France, while analysing the possible cross-transmission of some pathogenic helminths, which may produce a negative effect on the French population of *M. lutreola*.

Materials and methods

Carcasses of 45 *M. lutreola*, 37 *M. putorius* and 42 *M. vison* were collected by the European Mink Network between 1992 and 2005 in six river basins of south-western France (fig. 1). This large network of trained trappers has been organized for the standardized study of the European mink's distribution (Maizeret *et al.*, 2002) and for the control of the feral population of the American mink (Barrault *et al.*, 2003). Members of the network were also asked to collect all dead mustelids found fortuitously in the wild.

The river basins that provided the majority of specimens were: Adour et Midouze (8 *M. lutreola*, 15 *M. putorius* and 34 *M. vison*) and Garonne (10 *M. lutreola*, 12 *M. putorius* and 6 *M. vison*). Most of the *M. lutreola* specimens came from the remaining river basins prospected: Eyre (3 *M. lutreola*, 1 *M. putorius* and 1 *M. vison*), Contis (9 *M. lutreola* and 2 *M. putorius*), Dordogne (7 *M. lutreola*, 3 *M. putorius* and 1 *M. vison*) and Charente (8 *M. lutreola* and 4 *M. putorius*). Each animal was necropsied by trained veterinarians within 48 h when possible, or carcasses were stored frozen until necropsy. All skulls and viscera were frozen until parasitological analysis. Skulls were scanned for cranial helminths, especially in the nasolacrimal sinuses. All viscera were systematically checked under stereoscopic microscope and all helminths found were removed and preserved with fixative agents. Helminths were processed according to classical helminthological methods, identified, and counted. Ecological terminology follows Bush *et al.* (1997). Prevalences and intensities were compared using a chi-square analysis of contingency tables and the Mann–Whitney *U*-test, respectively.

Results

The helminthological study of all 124 mustelids revealed a total of 15 helminth species. Table 1 shows the qualitative and quantitative data of all three helminth communities. The highest global prevalence was evidenced in *M. putorius* (94.6%) and the lowest in *M. vison* (80.9%). The European mink harboured the richest community (13 species), which contrasts with the most depauperate community (nine species) found in the introduced American mink. Only six helminths were shared by all three mustelids, including two pathogenic cranial species (the fluke *Troglotrema acutum* and the nematode *Skrjabingylus nasicola*). Contrarily, helminths such as *Euparyphium melis*, *Ascocotyle* sp. and *Pearsonema plica* were only scarcely evidenced in both European and American minks. There were no significant differences among *Aonchotheca putorii* prevalences in all three mustelids. The prevalence of *Euryhelmis squamula* in *M. putorius* was significantly higher than in *M. lutreola* ($\chi^2 = 17.12$, $P < 0.001$) and *M. vison* ($\chi^2 = 8.95$, $P = 0.003$). The mean intensity of this fluke in *M. putorius* was also significantly higher than that of *M. vison* ($U = 44.5$, $P = 0.15$). Similarly, the prevalence and mean intensity of *S. nasicola* in *M. putorius* were significantly higher than in *M. vison* ($\chi^2 = 10.29$, $P = 0.002$; $U = 12.5$, $P < 0.001$) and *M. lutreola* ($\chi^2 = 4.71$, $P = 0.037$; $U = 67.0$, $P < 0.001$). In addition, the mean intensity of *S. nasicola* in *M. lutreola* was also

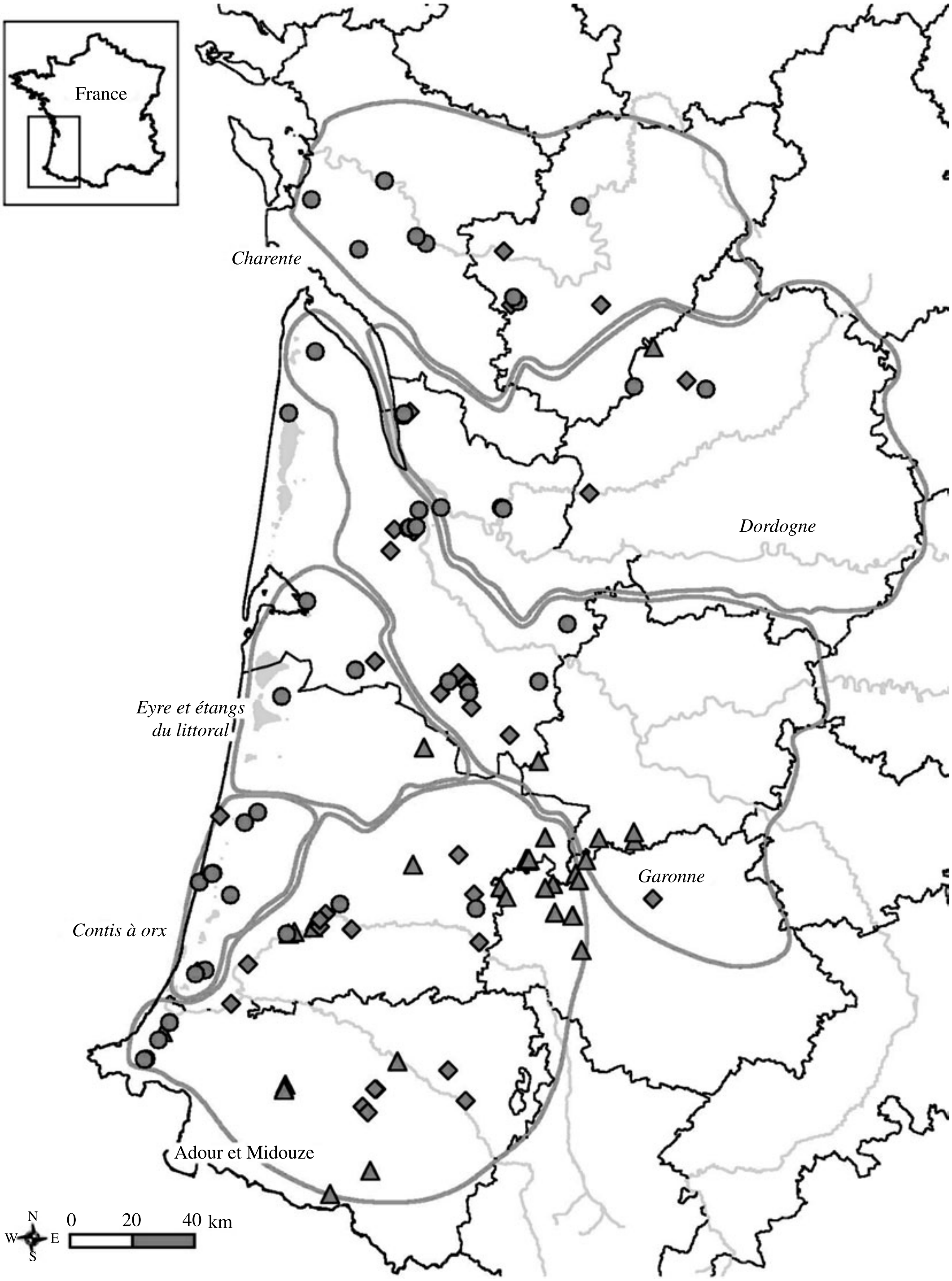

Fig. 1. Origin of the hosts examined from the six prospected river basins of south-western France. The thick lines delimit the prospected river basins. ● = *M. lutreola*, ◆ = *M. putorius*, ▲ = *M. vison*.

statistically higher than in *M. vison*. *Strongyloides mustelorum* was evidenced in *M. vison* with statistically lower prevalence than those found in *M. lutreola* ($\chi^2 = 15.21$, $P < 0.001$) and *M. putorius* ($\chi^2 = 8.57$, $P = 0.005$). On the other hand, *M. vison* harboured a higher prevalence of *T. acutum* compared to *M. lutreola* ($\chi^2 = 14.73$, $P < 0.001$) and *M. putorius* ($\chi^2 = 11.99$, $P < 0.001$). The prevalence of *Molineus patens* was statistically higher in *M. lutreola* than in *M. vison* ($\chi^2 = 11.81$, $P = 0.001$) and *M. putorius* ($\chi^2 = 4.22$, $P = 0.04$).

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Table 1. The prevalence (%) and mean intensity (MI) of helminth parasites of *M. lutreola*, *M. putorius* and *M. vison* in south-western France. *n* = number of hosts examined and worm ranges are in brackets.

	Mustela lutreola (*n* = 45)		*Mustela putorius* (*n* = 37)		*Mustela vison* (*n* = 42)	
	%	MI	%	MI	%	MI
Troglotrema acutum	2.27	1	3.57	1	33.33	12.90 (1–52)
Euryhelmis squamula	15.38	17.00 (3–41)	60.61	485.95 (1–4860)	26.32	22.10 (1–70)
Ascocotyle sp.	2.56	1			2.63	98
Euparyphium melis	2.56	2			2.63	1
Pseudamphistomum truncatum	22.86	30.50 (2–86)				
Taenia tenuicollis			12.12	1.25 (1–2)		
Aonchotheca putorii	15.00	3.00 (1–13)	21.21	6.42 (1–22)	18.42	9.43 (1–33)
Eucoleus aerophilus	32.50	89.38 (1–705)	9.09	17.67 (1–37)		
Pearsonema plica	13.33	6.00 (2–12)			2.70	4
Strongyloides mustelorum	35.90	26.36 (1–250)	24.24	3.37 (1–10)	2.63	1
Molineus patens	84.61	15.15 (1–220)	63.64	45.52 (1–317)	50.00	15.89 (1–65)
Skrjabingylus nasicola	54.54	7.12 (1–20)	78.57	35.45 (1–201)	41.67	1.47 (1–4)
Filaroides martis	18.42	40.14 (4–150)	29.41	2.60 (1–9)		
Crenosoma melesi			17.65	9.67 (2–20)		
Centrorhynchus sp. larvae	9.76	2.00 (1–5)	24.14	1.14 (1–2)		
Total	88.89		94.59		80.95	

Discussion

Despite the fact that samples of all three mustelids were quite homogeneous, the helminth fauna of *M. lutreola* was qualitatively richer (13 helminths) than that of *M. putorius* (11 helminths) and *M. vison* (9 helminths). However, they shared the most abundant species (*T. acutum*, *E. squamula*, *A. putorii*, *S. mustelorum*, *M. patens* and *S. nasicola*).

All digeneans observed in the present study are transmitted by fish (*Ascocotyle* sp., *E. melis* and *P. truncatum*) or by amphibians (*T. acutum* and *E. squamula*). Therefore, particular data on digeneans in each mustelid surveyed may be related to their respective diet. In the study area, there are data on the feeding ecology of *M. lutreola* and *M. putorius* at the Eyre and Ciron rivers, the latter belonging to the Garonne river basin (Libois, 2001). Unfortunately, there are no data on the diet of the American mink. No digeneans transmitted by fish were detected in *M. putorius*, although both of the above-mentioned amphibian-transmitted flukes were detected with different prevalence and abundance values (table 1). These data may be explained by considering the polecat's diet in most countries, including south-western France (Weber, 1989; Sidorovich, 1992; Lodé, 1993; Sidorovich *et al.*, 1998; Hammershøj *et al.*, 2004): fish is rarely taken (<1% of occurrence) whereas amphibians are common (>60% of the occurrence of anurans). On the contrary, the European mink (the other autochthonous mustelid) is mainly parasitized by species transmitted by fish (*P. truncatum*, particularly) but also by those transmitted by amphibians (especially by *E. squamula*). This feature reflects the generalist diet of the European mink in the study area (*c.* 19% occurrence of fish and *c.* 30% of anurans in the diet). The fact that the introduced *M. vison* species is scarcely parasitized by species transmitted by fish but regularly infected by those transmitted by amphibians could be related to this mustelid's diet. In fact, the diet of *M. vison* seems to be highly variable, either presenting high (Sidorovich, 1992; Maran *et al.*, 1998b; Sidorovich *et al.*, 1998; Hammershøj *et al.*, 2004) or low amphibian occurrences (Chanin & Linn, 1980; Lodé, 1993).

Generally, riparian mustelids are scarcely infected by cestodes and acanthocephalans. In fact, in the present study only some *Taenia tenuicollis* adult specimens were found exclusively in four *M. putorius* and some larval stages of *Centrorhynchus* were evidenced in a few *M. lutreola* and *M. putorius* specimens.

Eight species of nematodes were identified in all analysed mustelids (seven in both autochthonous *M. lutreola* and *M. putorius* species and five in *M. vison*). In agreement with data from Spain (Torres *et al.*, 1996, 2003), *M. patens* is one of the best-adapted nematodes to French riparian mustelids, probably due to their long-lasting host–parasite associations. The present prevalence of *M. patens* in *M. lutreola* (84.6%) is much higher than that reported in this mustelid from Belarus and Spain (18.0% and 53.6%, respectively) (Sidorovich & Bychkova, 1993; Torres *et al.*, 2003). It is also higher in *M. vison* (50.0%) in comparison to that in Belarus (8.0%) and Spain (24.1%) (Shimalov & Shimalov, 2001; Torres *et al.*, 2003). Furthermore, the prevalence of *M. patens* in *M. putorius* is also higher (63.6%) in respect to that found in Spain (44.1%) (Torres *et al.*, 1996). French data concerning *S. mustelorum* in riparian mustelids are very similar to those obtained in Spain. In fact, the present prevalence in *M. lutreola*, *M. putorius* and *M. vison* (35.9%, 24.2% and 2.6%, respectively) are very close to those from Spain (respectively 46.4%, 23.5% and absence of parasitization; Torres *et al.*, 1996, 2003). Among Capillariinae, the most adapted species to riparian mustelids seems to be *A. putorii*, with a prevalence of around 15–20% in all three mustelids (table 1). These values are relatively similar to that reported in *M. lutreola* from Spain (18.7%; Torres *et al.*, 2003). Surprisingly, *E. aerophilus* and *P. plica* were frequently found not only in *M. lutreola* (table 1) but also in *M. putorius* (9.1% of *E. aerophilus*) and *M. vison* (2.7% of *P. plica*). These findings are in disagreement with the Spanish data, considering that *E. aerophilus* and *P. plica* have never been found in any riparian mustelid in Spain (Cordero del Campillo *et al.*, 1994; Torres *et al.*, 1996, 2003). In order to complete their life cycle, fully embryonated eggs of both Capillariinae need to hatch in earthworms, developing into the infective stage within a month, which must be incorporated by the definitive host (Anderson, 2000). Although several authors mentioned the presence of earthworm remains in the scats of several mustelids, including the polecat and the American mink (Bradbury, 1977; Chanin & Linn, 1980; Wroot, 1985; Weber, 1989; Lodé, 1990, 1991), this item is rarely specifically searched for in diet studies. In south-western France, earthworms were not found in scats of *M. lutreola* and they were detected once in *M. putorius* scats. However, the specific search for earthworms was performed on a small sample (20 scats) of each species (Libois, 2001), precluding a reliable inference about the frequency of ingestion of earthworms by these mustelids. Apart from the results concerning *S. nasicola*, which will be discussed later, two metastrongylid species (*Filaroides martis* and *Crenosoma melesi*) have been detected in these riparian mustelids in France (table 1). Both species seem to be well adapted to the polecat but they are absent from the introduced *M. vison* and only *F. martis* was found in *M. lutreola*. All metastrongylids have a similar life cycle, including a gastropod (snails or slugs) obligatory intermediate host (Anderson, 2000).

The pathogenic helminths *T. acutum* and *S. nasicola* were found in the nasolacrimal sinuses of all three mustelids (table 1). Both helminths had previously been reported in free-living *M. lutreola*, *M. vison* and *M. putorius* specimens in Spain (Aymerich *et al.*, 1983; Torres *et al.*, 1996, 2006), but to our knowledge, they had never been found before in these mustelids in France. The distribution of *T. acutum* mainly encompasses central European countries, usually parasitizing the polecat and other carnivores considered as accidental hosts (Koubek *et al.*, 2004). Nevertheless, a relatively important focus involving *M. vison* specimens was recently pointed out by Torres *et al.* (2006) in Spain after studying the skulls of 46 American minks from a population located quite close to that of the present study area (30.4% in Álava). This value is very similar to that obtained in the present study (34.5% in Adour et Midouze) where sympatric *M. lutreola* and *M. putorius* specimens were not found to be affected. Therefore, in accordance with Torres *et al.* (2006), further attention should be devoted to evaluating the role of the introduced *M. vison* in the maintenance of the life cycle of *T. acutum* in south-western Europe by potentially favouring its transmission on to other mustelids, including *M. lutreola*, in which it can inflict serious cranial lesions. As in other European countries, the distribution of *T. acutum* in France seems to be discontinuous and its presence depends on the suitability of biocoenoses for the completion of its life cycle. Although no precise information is available about the life cycle of *T. acutum* in the prospected area, the present results imply that, at least in Adour et Midouze, *M. vison* must frequently feed on infested amphibians. The cosmopolitan nematode *S. nasicola* affects several representatives of the genus *Mustela*, having the capacity to produce severe damage. Its high prevalence in all of the analysed mustelids and mean intensity in both autochthonous species (table 1) contrasts with the currently available data from Spain (Torres *et al.*, 2006), where both European and American minks are very poorly affected by skrjabingylosis. The infective stage of *S. nasicola* is mainly developed in several snails and slugs (Anderson, 2000). Given that conditions are relatively similar in the French prospected areas where all three mustelids are sympatric, it is likely that *M. vison* consumes fewer snails and/or slugs than *M. lutreola* and *M. putorius*. However, gastropods may be taken more frequently in France than in Spain, considering the present results and all the available data in south-western Europe. It is possible to conclude that, at least in some French areas, the introduced American mink is a usual host of *S. nasicola* and mainly of *T. acutum*. Therefore, *M. vison* plays a considerable role in the maintenance of the life cycle of both pathogenic helminths by favouring its transmission on to other mustelids, including the autochthonous and severely endangered European mink.

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