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Ectoparasites of the endangered Iberian lynx *Lynx pardinus* and sympatric wild and domestic carnivores in Spain

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Abstract. Ectoparasites can cause important skin disorders in animals and can also transmit pathogens. The Iberian lynx *Lynx pardinus* has been stated to be the most endangered felid in the world and such vector-borne pathogens may threaten its survival. We surveyed 98 wild carnivores (26 Iberian lynxes, 34 red foxes *Vulpes vulpes*, 24 Egyptian mongooses *Herpestes ichneumon*, 11 common genets *Genetta genetta*, two Eurasian badgers *Meles meles*, one polecat *Mustela putorius*) and 75 domestic but free-ranging carnivores (46 cats *Felis catus*, 29 dogs *Canis familiaris*) from June 2004 to June 2006 in the two areas where the last lynx metapopulations survive: Sierra Morena and Doñana (Andalusia, southern Spain). A total of 65% of lynxes were parasitized (50% by ticks, 19% by fleas, 4% by lice, 31% by hippoboscid flies), as were 75% of foxes (58%, 60%, 0%, 19%), 71% of mongooses (50%, 4%, 46%, 0%), 54% of genets (18%, 36%, 0%, 0%), 30% of cats (22%, 14%, 0%, 2%), and 7% of dogs (surveyed only for ticks). Both badgers presented ticks, fleas and lice. Five species of ixodid ticks (*Rhipicephalus pusillus* Gil Collado, *Rhipicephalus turanicus* Pomerantzev and Matikashvili, *Ixodes ricinus* (Linnaeus), *Ixodes hexagonus* Leach and *Ixodes ventalloi* Gil Collado; and *Hyalomma* sp.), four species of fleas (*Ctenocephalides canis* Curtis, *Pulex irritans* Linnaeus, *Spilopsyllus cuniculi* (Dale), *Xenopsylla cunicularis* Smit), three species of chewing lice (*Felicola* (*Felicola*) *inequalis* (Piaget), *Trichodectes* (*Trichodectes*) *melis* (Fabricius), and *Felicola* (*Lorisicola*) *isidoroi* Pérez and Palma), and one species of hippoboscid fly (*Hippobosca longipennis* (Fabricius)) were found. We did not detect any cases of mange. *Hippobosca longipennis* is a new record for Spanish wildlife, and all the flea species are new records for the Iberian lynx. Fleas were more frequent on lynxes and foxes in winter than in spring. *Rhipicephalus* spp. were more frequent on cats in spring than in any other season. These and other epidemiological findings are discussed with respect to the conservation of the Iberian lynx.

Key words. Arthropod-borne diseases, Carnivora, ectoparasites, fleas, hippoboscid fly, Iberian lynx, lice, ticks, Andalusia, Spain.

Introduction

The Iberian lynx *Lynx pardinus* has been recognized as perhaps the most endangered felid in the world (Baillie *et al.*, 2004), with no more than 160 individuals inhabiting two separate areas, both in Andalusia, southern Spain (Guzmán *et al.*, 2004). Endangered populations are markedly sensitive to diseases as a result of a variety of extrinsic and genetic factors

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(Munson *et al.*, 2005). Frequently, the last factor that leads to species extinction is an epizootic, which is often introduced by other more abundant, sympatric species that act as reservoirs of the pathogen (e.g. Williams *et al.*, 1988; Cleaveland *et al.*, 2000). The Iberian lynx coexists with other abundant carnivores, both domestic and wild, with which the lynx can share diverse pathogens. Free-ranging domestic cats *Felis catus* and red foxes *Vulpes vulpes* are abundant in the lynx distribution areas. Guard, hunting, shepherd and feral dogs *Canis familiaris* are also present and sometimes abundant around houses in hunting estates or villages. The Egyptian mongoose *Herpestes ichneumon* may reach densities of up to 1.2 individuals/km^2 in the Doñana National Park (Palomares, 2002). In addition, although at low densities, common genets *Genetta genetta*, Eurasian badgers *Meles meles* and other wild carnivores are present in lynx areas (Palomo & Gisbert, 2002).

Ectoparasites can cause severe skin disorders in animals. For example, sarcoptic mange epizootics can be critical to the conservation of endangered species (Pence & Ueckermann, 2002). The reintroduced population of European lynx *Lynx lynx* in Switzerland suffered from a mange outbreak in 1999 (Ryser-Degiorgis *et al.*, 2002). Mange is enzootic in red fox populations in Spain (Gortazar *et al.*, 1998). Ectoparasites are also relevant as vectors of pathogens. The cat flea, *Ctenocephalides felis* (Bouché) acts as a vector of *Rickettsia felis* in Spain (Márquez *et al.*, 2002). Moreover *Cytauxzoon* sp. was recently reported parasitizing the Iberian lynx (Luaces *et al.*, 2005; Millán *et al.*, 2007). This is a common haemoparasite of the bobcat *Lynx rufus* in the U.S.A., where is known to be transmitted via the ixodid tick *Demacentor variabilis* (Say) (Bondy *et al.*, 2005). Very little is known about the epidemiology of this parasite in Spain or about its impact on lynx populations (Millán *et al.*, 2007). In fact, there is a lack of information about the ectoparasites of the Iberian lynx and other wild carnivore species in southern Spain. The aim of the present work was to describe the ectoparasite fauna of the Iberian lynx and sympatric wild and domestic carnivores.

Materials and methods

Study areas

The Iberian lynx persists in two regions of Andalusia: Sierra Morena, in the north, and Doñana, in the southwest (Guzmán *et al.*, 2004). The Sierra Morena region (38°13′ N, 4°10′ W) includes 1125 km^2 in two contiguous protected Natural Parks and several private hunting estates at 500−1300 m a.s.l. The soils are mainly of granite or slate and the climate is Mediterranean subhumid with marked seasons: winters are mild and wet, and summers are hot and dry. The plant communities are dominated by Mediterranean shrubland and the best preserved areas include tall, old-growth bush species (*Quercus coccifera*, *Pistacia lentiscus*, *Arbutus unedo*), a diversity of shorter scrub species, and trees (mostly *Quercus* spp.). In areas used for cattle raising, shrub vegetation has been almost completely eliminated and grasslands with scattered trees are dominant. The Doñana area (37°0′ N, 6°30′ W) includes 870 km^2 of land, mostly within the Doñana National and Natural Parks. It is a natural area bounded on the west by the Atlantic Ocean, on the east by the Guadalquivir River, and on the north by cropland. The area is flat, mostly near sea level, with predominantly sandy soils of marine origin. The climate is Mediterranean subhumid with marked seasons. Three ecosystem types are present: fixed dunes; mobile dunes, and marshes. Vegetation in the fixed dunes is a mixture of autochthonous Mediterranean shrubs (*Halimium halimifolium* and *Ulex* spp. or *Erica* spp.), pines (*Pinus pinea*) with variable understory vegetation, and *Eucalyptus camaldulensis* plantations in some areas.

Sampling

Animals examined for ectoparasites were collected by live trapping or had been hunter- or road-killed. Examinations of Iberian lynxes, domestic cats and dogs were conducted throughout the year. Other species were examined from January through June in the years 2004–06. Live trapping was conducted with box-traps baited with a variety of available meat, canned fish or commercial cat food. Animals in traps were anaesthetized with a combination of ketamine (Imalgène®; Merial, Lyon, France) plus medetomidine (Domtor®; Salud Animal-Pfizer, Madrid, Spain) prior to examination. Dogs were not anaesthetized and thus fleas and lice were not counted. Because the wild hosts were also surveyed for other diseases, the time available for examination was limited and lice were not counted. In order that the study include those domestic carnivores that were likely to be in contact with wild hosts, all the surveyed cats were feral or owned but free-ranging; and the dogs were guard, hunting or shepherd animals. The trapping and sampling protocol was conducted according to the current regulations of the Junta de Andalucía and Spanish laws on animal welfare in scientific research (Real Decreto 1201/2005).

Each animal was inspected visually as well as by palpation and ectoparasites were carefully removed and placed in 70% alcohol. They were identified by means of specific keys for ticks (Gil-Collado *et al.*, 1979; Márquez *et al.*, 1992; Manilla, 1998; Estrada-Peña *et al.*, 2004a), fleas (Beaucournu & Launay, 1990), lice (Martín-Mateo, 1977; Lyal, 1985; Soler *et al.*, 1989; Pérez *et al.*, 1990; Pérez & Palma, 2001), and flies (Grunin, 1989). Because of the invasiveness of the procedure, deep skin scraping to detect epidermal or follicle mites was performed only if visual examinations detected signs of mange. In such cases, samples were examined microscopically in 10% KOH (potassium hydroxide) solution. Culture in Sabouraud-chloramphenicol agar medium (BioMérieux, Marcy l'Etoile, France) for dermatophytes was also carried out as differential diagnosis.

ANOVA and Mann–Whitney *U*-tests were used to analyse differences in parasite abundance among sexes, ages, origins, status of animal (dead or alive), and seasons (winter: I−III; spring: IV−VI; summer: VII−IX; autumn: X−XII). Prevalences were tested using Fisher's exact test. Parasitological terminology follows Bush *et al.* (1997).

Results

Eight Iberian lynxes, 23 cats and 21 dogs from Sierra Morena were examined. Eighteen Iberian lynxes, 34 red foxes, 24 mongooses, 11 genets, two badgers, one polecat *Mustela putorius*, 46 cats and 29 dogs from Doñana were examined. The surveyed animals belonged to all age and sex classes with the exception of the mongooses (all adults) and the two badgers (juveniles).

Ectoparasites collected included 479 ticks (431 [90%] adults, 29 [6%] nymphs, 19 [4%] larvae), 221 fleas and 32 hippoboscid flies. In addition, chewing lice were noted but not counted (see above).

Rhipicephalus (Rhipicephalus) pusillus Gil Collado and *Rhipicephalus turanicus* Pomerantzev & Matikashvili were the most prevalent and abundant tick species, parasitizing most of the hosts. *Ixodes ricinus* (Linnaeus), *Ixodes hexagonus* Leach, *Ixodes ventalloi* Gil Collado, and *Hyalomma* sp. were also found. Among fleas, the core species were the dog flea, *Ctenocephalides canis* Curtis, on the cat; the human flea, *Pulex irritans* Linnaeus, on the fox; and both together with the rabbit flea, *Spilopsyllus cuniculi* (Dale), on the lynx. *Xenopsylla cunicularis* Smit was also found on one mongoose. All the lice found on mongooses were *Felicola* (*Felicola*) *inequalis* (Piaget); those found on one lynx belonged to the recently described species *Felicola* (*Lorisicola*) *isidoroi* Pérez and Palma, and those found on one badger were *Trichodectes* (*Trichodectes*) *melis* (Fabricius). All the hippoboscid flies found on foxes, lynxes, and one cat were *Hippobosca longipennis* (Fabricius). The polecat was not parasitized. The observed prevalences and abundances per host are detailed in Tables 1 and 2. The eight lynxes surveyed in Sierra Morena were parasitized by 12 ticks (11 *R. pusillus* and one *R. turani*cus) in one case, fleas in another case, flies in two cases, and no parasites in the other cases.

Female mongooses were significantly more frequently parasitized by ticks ($\chi^2 = 4.5$, $P < 0.05$) and lice ($\chi^2 = 4.1$, $P < 0.05$) than males. No other sex- or age-related differences were found. No statistical differences were found relative to the status or origin of the animals.

Among wild carnivores, fleas were more abundant in winter than in spring (ANOVA, $F_{1,101} = 6.1$, $P < 0.05$). If only lynxes and foxes (which harboured most of the fleas) were taken into account, fleas were more frequent ($\chi^2 = 5.4$, $P < 0.05$) and also more abundant (Mann–Whitney *U*-test, z = 2.6, $P < 0.01$) in that season. Ticks of the genus *Rhipicephalus* were noted only on cats surveyed between late March and July, and were more frequent and more abundant in spring than in winter ($\chi^2 = 8.1$, $P < 0.01$; z = – 2.8, $P < 0.01$), or autumn ($\chi^2 = 18.1$, $P < 0.001$; z = – 3.2, $P = 0.001$), and also more frequent than in summer ($\chi^2 = 5.6$, $P < 0.05$). They were also more frequent in summer than in winter ($\chi^2 = 4.1$, $P < 0.05$) (Fig. 1). Among foxes, *R. pusillus* was also more abundant in spring than in winter, although differences were not significant (z = – 1.91, $P = 0.055$).

No cases of sarcoptic mange were confirmed, although two suspicious cases were found. In the first case, large areas of alopecia were observed on the neck and both cheeks of a mongoose, but analyses for mites and dermatophytes were negative. The mongoose was captured for radio-tagging and thus was soon released; therefore the cause of alopecia remained unclear. In the second case, areas of up to 1.5 cm of alopecia and encrustations were observed at the base of the ears and on the cheeks of a semiferal cat. We were not able to detect mites in the skin sample. However, dermatophytes were isolated and *Microsporidium canis* was identified. This is the most common species isolated from cats suffering from dermatophytosis in Spain (Cabañes *et al.*, 1997).

Discussion

Although wild carnivores from northern Spain have been the subject of numerous surveys for ectoparasites (e.g. Encinas,

Table 1. Overall observed prevalence and abundance of ectoparasites on carnivores in southern Spain (2004–06).

	n	EP		Ticks		Fleas		Lice		Hippoboscid flies	
Iberian lynx	26	0.65	P	0.50	(0.30–0.69)	0.19	(0.08–0.38)	0.04	(0.00–0.18)	0.31	(0.15–0.50)
Lynx pardinus			A	6.84	± 12.42	0.53	± 1.63	NC		0.88	± 1.88
Red fox	34	0.75	P	0.58	(0.41–0.74)	0.60	(0.42–0.76)	0		0.19	(0.09–0.37)
Vulpes vulpes			A	4.30	± 11.94	5.8	± 9.12			0.26	± 0.57
Egyptian mongoose	24	0.71	P	0.50	(0.31–0.68)	0.04	(0.00–0.20)	0.46	(0.27–0.66)	0	
Herpestes ichneumon			A	1.63	± 3.03	0.04	± 0.20	NC			
European genet	11	0.54	P	0.18	(0.03–0.50)	0.36	(0.13–0.66)	0		0	
Genetta genetta			A	0.20	± 0.42	0.55	± 0.82				
Eurasian badger	2	1.00	P	1.00	(0.22–1.00)	1.00	(0.22–1.00)	0.50	(0.02–0.97)	0	
Meles meles			A	2.50	± 2.12	5.00	± 0.00	NC			
Cat	46	0.30	P	0.22	(0.12–0.36)	0.14	(0.06–0.28)	0		0.02	(0.01–0.09)
Felis catus			A	2.21	± 10.23	0.34	± 1.03			0.02	± 0.14
Dog	29	–	P	0.07	(0.01–0.22)						
Canis familiaris			A	0.58	± 2.97						

EP, total ectoparasite prevalence; P, prevalence for each ectoparasite taxa (95% confidence interval); A, abundance (± standard deviation); NC, not counted.

Table 2. Prevalence and abundance of tick and flea species from carnivores in southern Spain (2004–06).

		R. p.	*R. t.*	*R.* sp.	*I. r.*	*I. h.*	*I. v.*	*I.* sp.	*H.* sp.	*Ct. c.*	*P. i.*	*S. c.*	*X. c.*
Iberian lynx	P	0.25	0.12	0.03	0.06	0	0.12	0	0	0.04	0.08	0.08	0
Lynx pardinus	A	4.0	1.27	1.31	0.17		1.28	0.09		0.07	0.11	0.34	
Red fox	P	0.21	0.42	0.03	0.09	0	0.06	0	0	0	0.58	0	0
Vulpes vulpes	A	0.57	3.42	0.06	0.09		0.12				5.8		
Egyptian mongoose	P	0.09	0.18	0.04	0	0.09	0.04	0.27	0.04	0	0	0	0.04
Herpestes ichneumon	A	0.17	0.32	0.04		0.09	0.04	0.81	0.09				0.04
Common genet	P	0.10	0	0	0	0	0	0.10	0	0.09	0	0.18	0
Genetta genetta	A	0.10						0.10		0.18		0.27	
Eurasian badger	P	0.50	0	0	0.50	0	0	0	0	0	1.00	0	0
Meles meles	A	0.50			1.00						5.00		
Domestic cat	P	0.11	0.12	0.02	0	0	0	0.02	0	0.14	0	0.02	0
Felis catus	A	1.93	0.39	0.02				0.02		0.35		0.02	
Dog	P	0	0.07	0.04	0	0	0	0	0	–	–	–	–
Canis familiaris	A		0.14	0.45									

P, prevalence; A, abundance; *R. p.*, *Rhipicephalus pusillus*; *R. t.*, *Rhipicephalus turanicus*; *R.* sp., *Rhipicephalus* sp.; *I. r.*, *Ixodes ricinus*; *I. h.*, *Ixodes hexagonus*; *I. v.*, *Ixodes ventalloi*; *I.* sp., *Ixodes* sp.; *H.* sp., *Hyalomma* sp.; *Ct. c.*, *Ctenocephalides canis*; *P. i.*, *Pulex irritans*; *S. c.*, *Spilopsyllus cuniculi*; *X. c.*, *Xenopsylla cunicularis*.

1986; Estrada-Peña *et al.*, 1992; Domínguez, 2004), there is little information on the distribution of ectoparasites in the southern part of the country, and often only the original descriptions are available (e.g. Soler *et al.*, 1989; Pérez *et al.*, 1990; Pérez & Palma, 2001). Thus, this work represents the first large-scale survey for ectoparasites in wild carnivores in southern Spain, including the extremely endangered Iberian lynx. In addition, data on ectoparasites of sympatric domestic carnivores are presented.

Ticks

All the tick species found have been previously reported from carnivores in the Iberian Peninsula (Cordero *et al.*, 1994). However, this is the first record, for *R. turanicus* and *Hyalomma* sp. on mongooses; which is probably a result of the scarcity of studies dealing with diseases of this herpestid in Spain.

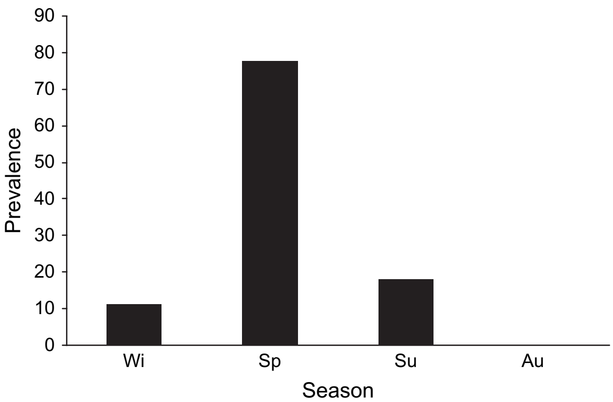

Fig. 1. Frequency of *Rhipicephalus* spp. ticks per season in free-ranging domestic cats (*Felis catus*) in southern Spain. Wi, winter; Sp, spring; Su, summer; Au, autumn.

The two most frequent tick species found were *R. turanicus* and *R. pusillus*. These results are in contrast with those of Domínguez (2004) in northern Spain, where species of the genera *Ixodes*, *Haemaphysalis* and *Dermacentor* were the most frequently found on carnivores (no lynxes or mongooses are currently present in northern Spain). In that study, *R. pusillus* was found on only one wolf (*Canis lupus*). These differences may be the result of marked differences in temperature and humidity between northern and southern Spain. As observed by Estrada-Peña *et al.* (2004b), *R. turanicus* displays a great affinity for Mediterranean habitats. In Spain, *R. turanicus* is widely distributed, predominantly colonizing territories of low altitude. These *R. sanguineus* group ticks showed a marked ability to adapt to different types of vegetation, resulting in their presence over a wide range of abiotic conditions. Estrada-Peña *et al.* (2004b) collected species of this group mainly in open areas at low altitude with high temperatures. They showed a tendency to invade sub-Mediterranean oak habitats (composed mainly of *Quercus ilex*), as well as patches of *Pinus* spp. and even thick shrub, always below 800 m a.s.l. To summarize, the common biotopes of *R. turanicus* are characterized by a dry period of 2–6 months. These characteristics are similar to those found in the present study. By contrast, *Rhipicephalus pusillus* and *I. ventalloi* are tick species whose life cycle depends mainly on wild rabbits, *Oryctolagus cuniculus* (Márquez, 1989, 1990; Márquez *et al.*, 1992). However, these two species have also been found to parasitize several carnivore species in the Iberian Peninsula (Cordero *et al.*, 1994). The main prey of the Iberian lynx is rabbit, as it is of most carnivores in the Iberian Peninsula, so it is unsurprising to find rabbit ticks on their predators.

Lynx harboured up to 52 ticks per animal. Heavy infestations with ticks can result in anaemia and death (Sonenshine *et al.*, 2002). In addition to direct impacts on the host, the ixodid ticks found during this survey are vectors for various disease agents. For example, *Rhipicephalsus* spp. of the *R. sanguineus* group (Walker *et al.*, 2000) have been implicated as vectors for agents in Europe such as spotted fever group rickettsiae, *Coxiella burnetti* (Bacellar *et al.*, 1995), and diverse piroplasmids (Walker *et al.*, 2000). *Ixodes ricinus* is known to transmit *Borrelia burdogferi sensu lato* in Spain (Márquez *et al.*, 2005). *Dermacentor* spp. were not present in the current study although, as stated earlier, *Dermacentor variabilis* is a known vector of *C. felis* in the U.S.A. Efforts must be made to determine the tick species acting as the vector(s) of the *Cytauxzoon* species parasitizing the lynx in the Iberian Peninsula.

Fleas

To the best of our knowledge, this is the first report of *C. canis*, *S. cuniculi* and *P. irritans* from the Iberian lynx. *Spilopsyllus cuniculi* is the European wild rabbit flea (Beaucournu & Launay, 1990; Durden & Traub, 2002). Lynx probably became infested after preying upon rabbits, as observed in the case of ticks. The same is applicable for genets. In the case of the mongoose infested by *X. cunicularis* (also a rabbit flea), it is likely they become infested when using rabbit burrows. It is surprising that the cat flea *Ct. felis* was not collected during the present survey. This species is generally regarded as the predominant flea among dogs and cats (Beck *et al.*, 2006; citations therein). In the current study, however, *Ct. canis* was the most prevalent flea species from cats and was also present on two lynx and one genet. This species can be found infesting felids, although always at lower prevalence than *Ct. felis* (Beck *et al.*, 2006). Surprisingly, however, the current study did not find *Ct. canis* on foxes, whereas Domínguez (2004) reported a prevalence of 27% on foxes from northern Spain. In the present study, *P. irritans* was present on all the flea-parasitized foxes. Other studies have reported similar prevalences for this species on the red fox in Spain (Domínguez, 2004) and Hungary (Sréter *et al.*, 2003).

Fleas are of concern for several reasons: their feeding activity causes discomfort; their saliva is allergenic in some species; bites can lead to secondary infections; and they can transmit diverse pathogens including tapeworms (e.g. *Ctenocephalides* spp. and *P. irritans* are intermediate hosts for the double pored tapeworm, *Dypilidium caninum*) and several bacteria, rickettsia and viruses (see Durden & Traub, 2002).

Flies

Hippobosca longipennis was common on both lynx and fox during the present survey. This hippoboscid was originally a parasite of wild carnivores in East Africa. It has since become widely distributed in association with domestic dogs from southern Europe and the Mediterranean region, and it appears to be best adapted to warm climates (Lloyd, 2002), such as in the regions included in the present study. According to Lloyd (2002), *H. longipennis* is found mainly on dogs in the Palaeartic region, although no flies were observed on dogs in the current study. Lloyd (2002) reported this fly from foxes, mongooses, civets, hyenas (unspecified species) and cats.

Few data are available concerning this fly in Spain. Cordero *et al.* (1994) recorded *H. capensis* Olfers (a junior synonym of *H. longipennis*) as a parasite of dogs in Salamanca (central Spain) and Portugal. Although Lariviere & Calzada (2001) observed that 'flies (*Hippobosca*)' were common parasites of genets in southern Spain, they did not provide specific diagnoses. Thus, as far we know, this is the first record of *H. longipennis* from wild carnivores in the Iberian Peninsula.

Hippoboscid flies can vector a variety of pathogens (see Lloyd, 2002) including *Dipetalonema dracunculoides*, which is present in the Iberian Peninsula and is reported to develop in *H. longipennis* (Cordero *et al.*, 1994). Although it was recoded at low intensities (a maximum of eight flies on one lynx), it was found on almost a third of the surveyed lynxes. Therefore, we believe that this parasite deserves further attention.

Lice

Lice were only found on one lynx, one badger, and half the mongooses. Each host species was parasitized by a single louse species. In fact, almost all lice are very host-specific (Durden, 2001). Close association between hosts (such as that occurring during the care of young or copulation) provides the greatest opportunity for louse transfer. However, the population density of lynxes is low and they are solitary animals. Thus, the possibility of intraspecific transmission is low. This may explain the low prevalence of lice from this host. As Pérez & Palma (2001) claimed, this parasite is probably close to extinction, together with its host.

Contacts and thus parasite transmission are particularly common in gregarious animals (Durden, 2001) which could explain the high louse prevalence on mongooses. In the current study the prevalence is lower than that reported for *F. cynictis* (Bedford) on yellow mongooses *Cynictis penicillata* in South Africa (Horak *et al.*, 1999). Badgers are also social animals. The parasitized badger was a young individual which carried hundreds of lice.

Lice populations can sometimes reach extremely high numbers on individual hosts, particularly young, old or sick animals. Large numbers of sucking lice can cause anaemia, dermatitis, allergic responses or hair loss. A few pathogens are known to be transmitted by lice (see Durden, 2002). Nothing is known about pathogen transmission by the species collected during this survey.

Sex- and season-related differences

Female mongooses were found to be more severely parasitized by lice and ticks than males. Turner (1971) observed that lice are typical from gregarious species. Adult male Egyptian mongooses are solitary, whereas females usually live in groups together with juveniles (Palomares, 2002), which may explain the differences seen in the current study.

Ticks (principally *Rhipicephalus* spp.) were markedly more frequent and abundant on cats in spring than in the other seasons. Similarly, Ruiz-Fons *et al.* (2006) found a peak of *R. bursa* (Canestrini and Fanzago) on red deer (*Cervus elaphus hispanicus*) in Spain during the months of May, June and July. Different tick species have different seasonal activities (Sonenshine *et al.*,

2002) and presumably higher rainfall with mild temperatures during spring in the study area benefits *Rhipicephalus* spp. Conversely, fleas were more frequent in winter than in spring. Unfortunately, we were not able to survey wild carnivores in other seasons, with the exception of a few lynxes. Environmental factors (humidity, temperature and soil moisture content) are often important in determining the abundance of fleas in different habitats or regions (Durden & Traub, 2002). All the foxes and almost all the lynxes were surveyed in Doñana. Winters in this area are mild and wet, which probably favours flea survival. Alternatively, the condition of individual animals may be worse during winter, affecting their capability to avoid flea infestation. As far we know, there are no previous studies on the seasonality of flea infestation of wild carnivores. Seasonal differences in the prevalence of fleas have been reported on domestic cats by Akucewich *et al.* (2002), who observed higher prevalences on feral cats from Florida in June and July compared with August and September. These authors believed that differences in humidity between these periods were the key factor. Koutinas *et al.* (1995) also collected the majority of fleas on cats and dogs in Greece during the high-humidity season (September–December). However, no relationship between season and flea infestation rates of cats and dogs in Germany was reported by Beck *et al.* (2006), although it is difficult to compare these results with those of the current study because cats and dogs usually receive care from humans.

Conclusions

Mammalian carnivores from the study area had a diverse ectoparasite fauna. The Iberian lynx, despite its small population size, was parasitized by up to 10 different ectoparasite species belonging to four different orders. Lynx probably became infested from their prey in many cases. In addition, the lynx shares ectoparasites (and probably pathogens) with all the other carnivore species with which it coexists. Interestingly, but sadly, the most host-specific lynx ectoparasite (the louse *F. isidoroi*) was the least frequently found. This mirrors the extremely endangered status of the Iberian lynx.

Neither sarcoptic nor any other type of mange was detected during this survey. However, the prevalence may represent an underestimate as a result of undetectable subclinical mange. In fact, there are sporadic observations in both study areas of hairless foxes. This encourages the necessity of sanitary vigilance for all of these sympatric animals in order to detect health risks. This may help in avoiding disease outbreaks, and thus in the conservation of the unique Iberian lynx.

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References

Akucewich, L.H., Philman, K., Clark, A., Gillespie, J., Kunkle, G., Nicklin, C.F. & Greiner, E.C. (2002) Prevalence of ectoparasites in a population of feral cats from north central Florida during the summer. *Veterinary Parasitology*, **109**, 129–139.

Bacellar, F., Regnery, R.L., Nuncio, M.S. & Filipe, A.R. (1995) Genotypic evaluation of rickettsial isolates recovered from various species of ticks in Portugal. *Epidemiology and Infection*, **114**, 169–178.

Baillie, J.E.M., Hilton-Taylor, G. & Stuart, S.N. (2004) *2004 IUCN Red List of Threatened Species. A Global Species Assessment*, pp. 191. IUCN Publications Services Unit, Cambridge.

Beaucournu, J.C. & Launay, H. (1990) *Les Puces de France et du Bassin Méditerranéen Occidental*, pp. 548. Faune de France 76, Féderation Française des Sociétés de Sciences Naturelles, Paris.

Beck, W., Boch, K., Mackensen, H., Wiegand, B. & Pfister, K. (2006) Qualitative and quantitative observations on the flea population dynamics of dogs and cats in several areas of Germany. *Veterinary Parasitology*, **137**, 130–136.

Bondy, P.J. Jr, Cohn, L.A., Tyler, J.W. & Marsh, A.E. (2005) Polymerase chain reaction detection of *Cytauxzoon felis* from field-collected ticks and sequence analysis of the small subunit and internal transcribed spacer 1 region of the ribosomal RNA gene. *Journal of Parasitology*, **91**, 458–461.

Bush, A.O., Lafferty, K.D., Lotz, J.M., Shostak, A.W. (1997) Parasitology meets ecology on its own terms: Margolis *et al*. revisited. *Journal of Parasitology*, **83**, 575–583.

Cabañes, F.J., Abarca, M.L. & Bragulat, M.R. (1997) Dermatophytes isolated from domestic animals in Barcelona, Spain. *Mycopathologia*, **137**, 107–113.

Cleaveland, S., Appel, M.G., Chalmers, W.S., Chillingworth, C., Kaare, M. & Dye, C. (2000) Serological and demographic evidence for domestic dogs as a source of canine distemper virus infection for Serengeti wildlife. *Veterinary Microbiology*, **72**, 217–227.

Cordero, M., Castañón, L. & Reguera, A. (1994) *Índice-Catálogo de Zooparásitos Ibéricos*, pp. 650. Secretariado de Publicaciones, Universidad de León, León.

Domínguez, G. (2004) North Spain (Burgos) wild mammals ectoparasites. *Parasite*, **11**, 267–272.

Durden, L.A. (2001) Lice (Phthiraptera). *Parasitic Diseases of Wild Mammals*, 2nd edn (ed. by W. M. Samuel, M. J. Pybus & A. A. Kocan), pp. 3–17. Iowa State University Press, Ames, IO.

Durden, L.A. (2002) Lice (Phthiraptera). *Medical and Veterinary Entomology* (ed. by G. Mullen & L. Durden), pp. 45–65. Academic Press, San Diego.

Durden, L.A. & Traub, R. (2002) Fleas (Siphonaptera). *Medical and Veterinary Entomology* (ed. by G. Mullen & L. Durden), pp. 103–128. Academic Press, San Diego.

Encinas, A. (1986) Ticks of the province of Slamanca (Central/NW Spain). *Annales de Parasitologie Humaine et Comparée*, **61**, 95–107.

Estrada-Peña, A., Bouattour, A., Camicas, J.L. & Walter, A.R. (2004a) *Ticks of Domestic Animals in the Mediterranean Region. A Guide to Identification of Species*, pp. 131. Zaragoza University Press, Zaragoza.

Estrada-Peña, A., Osácar, J.J., Gortazar, C., Calvete, C. & Lucientes, J. (1992) An account of the ticks of the northeast of Spain (Acarina, Ixodidae). *Annales de Parasitologie Humaine et Comparée*, **67**, 42–49.

Estrada-Peña, A., Quíez, J. & Sanchez-Acedo, C. (2004b) Species composition, distribution, and ecological preferences of the ticks of grazing sheep in north-central Spain. *Medical and Veterinary Entomology*, **18**, 123–133.

Gil-Collado, J., Guillén-Lera, J.L. & Zapatero-Ramos, L.M. (1979) Claves para la identificación de los Ixodoidea españoles (adultos). *Revista Ibérica de Parasitología*, **39**, 107–118.

Gortazar, C., Villafuerte, R., Blanco, J.C. & Fernández de Luco, D. (1998) Enzootic sarcoptic mange in red foxes in Spain. *Zeitschrift für Jagdwissenschaft*, **44**, 251–256.

Grunin, K.Y. (1989) *Family Hippoboscidae. Keys to the Insects of the European Part of the USSR*, Vol. V. *Diptera and Siphonaptera* (ed. by G. Bei-Bienko), pp. 979–986. E.J. Brill, Leiden.

Guzmán, J.N., García, F.J., Garrote, G., Pérez de Ayala, R. & Iglesias, C. (2004) *El Lince Ibérico (Lynx Pardinus) en España y Portugal. Censo-Diagnóstico de Sus Poblaciones*, pp. 174. Dirección General para la Biodiversidad, Ministerio de Medio Ambiente, Madrid.

Horak, I.G., Chaparro, F., Beaucournu, J.C. & Louw, J.P. (1999) Parasites of domestic and wild animals in South Africa. XXXVI. Arthropod parasites of yellow mongooses, *Cynictis penicillata* (G. Cuvier, 1829). *Onderstepoort Journal of Veterinary Research*, **66**, 33–38.

Koutinas, A.F., Papazahariadou, M.G., Rallis, T.S., Tzivara, N.H. & Himonas, C.A. (1995) Flea species from dogs and cats in northern Greece: environmental and clinical implications. *Veterinary Parasitology*, **58**, 109–115.

Lariviere, S. & Calzada, J. (2001) Genetta genetta. *Mammalian Species*, **680**, 1–6.

Lloyd, J.E. (2002) Louse flies, keds, and related flies (Hippoboscoideaa). *Medical and Veterinary Entomology* (ed. by G. Mullen & L. Durden), pp. 349–363. Academic Press, San Diego.

Luaces, I., Aguirre, E., García-Montijano, M. *et al*. (2005) First report of an intraerythrocytic small piroplasm in wild Iberian lynx (*Lynx pardinus*). *Journal of Wildlife Diseases*, **41**, 810–815.

Lyal, C.H.C. (1985) A cladistic analysis and classification of trichodectid mammal lice. *Bulletin of the British Museum (Natural History) Entomology*, **51**, 187–346.

Manilla, G. (1998) *Fauna d'Italia*. *Acari: Ixodida*, pp. 280. Edizioni Calderini, Bologna.

Márquez, F.J. (1989) Population dynamics of *Rhipicephalus pusillus* Gil Collado, 1938 (Acarina, Ixodidae) in 1986–87 in south-eastern Spain: modelling of the biological cycle. *Annales de Parasitologie Humaine et Comparée*, **64**, 374–390.

Márquez, F.J. (1990) Dinámica de la población de *Ixodes ventalloi* Gil Collado, 1936 (Acarina, Ixodidae) durante 1986–87 en el sureste de España. *Revista Ibérica de Parasitología*, **50**, 101–114.

Márquez, F.J., Hidalgo, A., Contreras, F., Rodríguez, J.J. & Muniain, M.A. (2005) Ticks (Acarina: Ixodidae) as vectors and reservoirs of pathogen microorganisms in Spain. *Enfermedades Infecciosas y Microbiología Clínica*, **23**, 94–102.

Márquez, F.J., Morel, P.C., Guiguen, C. & Beaucournu, J.C. (1992) Clé dichotomique des *Ixodidae* d'Europe. I. Les larves du genre *Ixodes*. *Acarologia*, **33**, 325–330.

Márquez, F.J., Muniain, M.A., Pérez, J.M. & Pachón, J. (2002) Presence of *Rickettsia felis* in the cat flea from southwestern Europe. *Emerging Infectious Diseases*, **8**, 89–91.

Martín-Mateo, M.P. (1977) Estudio de Trichodectidae (Mallophaga: Insecta) en España. *Revista Ibérica de Parasitología*, **37**, 1–25.

Millán, J., Naranjo, V., Rodríguez, A., Pérez de la Lastra, J.M., Mangold, A.J. & de la Fuente, J. (2007) Prevalence of infection and 18S rRNA gene sequences of *Cytauxzoon* species in Iberian lynx (*Lynx pardinus*) in Spain. *Parasitology*, **134**, 995–1001.

Munson, L., Terio, K.A., Worley, M., Jago, M., Bagot-Smith, A. & Marker, L. (2005) Extrinsic factors significantly affect patterns of disease in free-ranging and captive cheetah (*Acinonyx jubatus*) populations. *Journal of Wildlife Diseases*, **41**, 542–548.

Palomares, F. (2002) Herpestes ichneumon *(Linnaeus, 1758). Atlas de los Mamíferos Terrestres de España* (ed. by L. J. Palomo & J. Gisbert), pp. 274–277. Dirección General de Conservación de la Naturaleza-SECEM-SECEMU, Madrid.

Palomo, L.J. & Gisbert, J. (2002) *Atlas de los Mamíferos Terrestres de España*, pp. 564. Dirección General de Conservación de la Naturaleza-SECEM-SECEMU, Madrid.

Pence, D.B. & Ueckermann, E. (2002) Sarcoptic mange in wildlife. *Revue Scientifique et Technique de l'Office International des Epizooties*, **21**, 385–398.

Pérez, J.M. & Palma, R.L. (2001) A new species of *Felicola* (Phthiraptera: Trichodectidae) from the endangered Iberian lynx: another reason to ensure its survival. *Biodiversity and Conservation*, **10**, 929–937.

Pérez, J.M., Soler, M.D., Benítez, R., Ruiz, I., Díaz, M., Palomares, F. & Delibes, M. (1990) Phthiraptera from some wild carnivores in Spain. *Systematic Parasitology*, **15**, 107–117.

Ruiz-Fons, F., Fernández-de-Mera, I.G., Acevedo, P., Hofle, U., Vicente, J., de la Fuente, J. & Gortazar, C. (2006) Ixodid ticks parasitizing Iberian red deer (*Cervus elaphus hispanicus*) and European wild boar (*Sus scrofa*) from Spain: geographical and temporal distribution. *Veterinary Parasitology*, **140**, 133–142.

Ryser-Degiorgis, M.P., Ryser, A., Bacciarini, L.N., Angst, C., Gottstein, B., Janovsky, M. & Breitenmoser, U. (2002) Notoedric and Sarcoptic mange in free-ranging lynx from Switzerland. *Journal of Wildlife Diseases*, **38**, 228–232.

Soler, D.M., Pérez, J.M., Benítez, R., Muñoz, S., Florido, A.M., Ruiz, I., Diaz, M. & Palomares, F. (1989) *Felicola (Felicola) inaequalis* Piaget, 1880 (Mallophaga: Trichodectidae) parásito de *Herpestes ichneumon* L. (Carnivora: Herpestidae) Doñana. *Acta Vertebrata*, **16**, 172–179.

Sonenshine, D.E., Lane, R.S. & Nicholson, W.L. (2002) Ticks (Ixodida). *Medical and Veterinary Entomology* (ed. by G. Mullen & L. Durden), pp. 518–558. Academic Press, San Diego.

Sréter, T., Szell, Z. & Varga, I. (2003) Ectoparasite infestations of red foxes (*Vulpes vulpes*) in Hungary. *Veterinary Parasitology*, **115**, 349–354.

Turner, E.C. (1971) Fleas and lice. *Parasitic Diseases of Wild Mammals* (ed. by J. W. Davis & R. C. Anderson), pp. 65–80. Iowa State University Press, Iowa City.

Walker, J.B., Keirans, J.E. & Horak, I.G. (2000) *The Genus* Rhipicephalus *(Acari, Ixodidae). A Guide to the Brown Ticks of the World*, pp. 655. Cambridge University Press, Cambridge.

Williams, E.S., Thorne, E.T., Appel, M.J. & Belitsky, D.W. (1988) Canine distemper in black-footed ferrets (*Mustela nigripes*) from Wyoming. *Journal of Wildlife Diseases*, **24**, 385–398.

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