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Gastrointestinal parasites of the Iberian lynx and other wild carnivores from central Spain

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Abstract. Between 1991 and 1995 fresh fecal samples from Iberian lynx (*Lynx pardinus*), wildcats (*Felis silvestris*), red foxes (*Vulpes vulpes*), and other carnivore species were collected in two areas of central Spain for isolation of parasite eggs and larvae. Twenty-three gastrointestinal coccidia, cestoda and nematoda species were identified. Common (≥20% prevalence) species were *Isospora felis*, *I. rivolta*, *Ancylostoma* spp., *Toxascaris leonina*, *Toxocara cati*, *Aelurostrongylus* spp., and *Physaloptera* spp. for the wildcat, *I. felis*, *Taenia* spp., *Ancylostoma* spp., *T. leonina*, and *Toxocara canis* for the Iberian lynx, and *I. canis*, *I. vulpis*, and *Physaloptera* spp. for the red fox. In contrast to the pattern found in most similar studies, the distribution of parasitic forms among individual hosts was not overdispersed. Differences in prevalence between host populations were only detected for *Physaloptera* spp. in the wildcat. Sexual differences in occurrence, prevalence and intensity were not found in any host. The number of parasite species per individual was significantly higher in adult than in subadult hosts, and negatively correlated with a rough index of host body condition. The consistence of parasite species across samples of the same individual host taken at different times was low. In this paper we provide the first data on intestinal parasites for the rare Iberian lynx.

Key words: wild carnivores, coccidia, cestoda, nematoda, population indices

Introduction

Most gastrointestinal faunas of carnivores have been described from the examination of adult parasites in host necropsies. In carnivore species that are hunted, exploited as furbearers, or targets to predator control programs, comprehensive studies on the composition of parasite communities stem from the ability to collect a large number of carcasses (Pence and Meinzer 1979, Smith et al. 1986, Waid and Pence 1988, Seville and Addison 1995). On the other hand, in rare or protected species dead animals are not easily available, and often the occurrence of parasites has to be described from a few carcasses (Seesee et al. 1981, Miquel et al. 1992, Yasuda et al. 1994). That is the case in western European countries, where most carnivore species are protected (e.g. 87% of 16 species in Spain; Blanco and González 1992). There, as a result, parasitologic studies have been mainly focused on the non-protected red fox *Vulpes vulpes* L. (Miquel et al. 1994), while information about parasites of other carnivore hosts in the wild is scarce. Coprological surveys may be a useful alternative when carcasses are difficult to obtain, and carnivore fresh feces can be collected in the field in conjuction with ecological studies (Müller-Graf 1995). Our aims were (1) to describe the intestinal parasites of red foxes and some protected carnivore species in south central Spain, by analyzing eggs and larval stages found in fresh feces; (2) to compare parasite occurrence, prevalence, and intensity between two separate areas, as well as between host age classes and sexes; and (3) to relate infection, in terms of number of parasite species and the abundance of their forms in fecal samples, with host body condition. Among the host species considered we report for the first time on the Iberian lynx, *Lynx pardinus* Temminck, a rare species recently classified as the most vulnerable felid in the world (Nowell and Jackson 1996).

Materials and methods

Between 1991 and 1995 an ecological study of Iberian lynx and wildcat *Felis silvestris* Schreber was undertaken in two study areas of south central Spain, Montes de

Toledo (3°40'W 39°20'N) and Sierra Morena (3°50'W 38°10'N). Carnivore fecal samples were obtained by daily surveying of traps and cages in which animals were caught. Some additional samples were collected during anaesthesia and tagging. Both felids and other carnivore species were trapped, totalling 225 captures. Catches included lynx (20), wildcat (114), red fox (60), common genet *Genetta genetta* L. (15), stone marten *Martes foina* Erxleben (8) and Egyptian mongoose *Herpestes ichneumon* L. (8). In spite of such a high trapping success, only a relatively small proportion of individuals (28%) produced feces that could be collected during the animal manipulation time interval (Table I). Animals always spent less than one day in traps or cages.

Fifty-eight fecal samples were collected and preserved in 10% formalin within 8 h after deposition, and four additional samples within 24 h. In order to isolate eggs, oocysts and larvae, samples of about 10 g were broken down, diluted, filtered, and then allowed to sediment in water after several suspensions following the simple gravidity sedimentation technique described in Ash and Orihel (1991, p. 30). For each sample, the volume of sediment was measured. All the sediment was placed on slides and observed under the microscope, and parasites were identified by size and morphology following Pellerdy (1965), Flynn (1973), Georgi and Georgi (1992), and Mehlhorn et al. (1992).

Carnivores were measured, weighed and tagged with colored collars or ear tags, thus enabling recognition when recaptured. As several indices that relate weight and body measurements can be used as indicators of nutritional status (Kirkpatrick 1980, Hasbrouck et al. 1992), we roughly estimated body condition from the ratio between weight (kg) and body length (mm). Sex was recorded, age was estimated from size, weight, and tooth wear, and individuals were classified as adults (two years or older) or subadults. Contingency table analyses were used to compare parasite prevalence between sex, age, and area categories. The significance level was set at 0.05. As for each host species the comparisons of each parasite species' prevalence were made on the same set of individuals, the significance level was adjusted by using the Bonferroni inequality (Manly 1992). Definitions of prevalence and intensity follow Margolis et al. (1982). However, mean intensity was calculated not only for each parasite species (according to the definition given in that paper) but also for taxa higher than species. Intensity was estimated as the number of parasitic forms per ml of sediment. Common parasite species were defined as those whose prevalence was at least 20% (Waid and Pence 1988). As raw estimates of intensity did not significantly depart from a normal distribution (Kolmogorov-Smirnov goodness of fit) for any parasite species or group of parasites, analysis of covariance was used to examine the effect of host species, sex, and age on the number of parasite species per individual and on mean intensity, using the body condition index as a covariate. We followed Zar (1984) for all statistical analyses.

Results

At least 23 parasite taxa were found in the fecal samples. Eight protozoan species were identified as true carnivore parasites (Table I). Common coccidia were *Isospora rivolta* Wenyon in wildcat, *I. felis* Wenyon in wildcat and lynx, and *I. canis* Nemeresi and *I. vulpis* Galli-Valerio in red fox (Table I). In addition to the species shown in the Table I, *Eimeria magna* Pérard occurred in six fox samples, *E. stiedae* Kisscalt et Hartmann was found once in both wildcat and genet samples, and three times in fox samples, *E. neoleporis* Carvalho was detected in one genet sample, and *E. musculi* Yakimoff et Gousseff occurred twice in both wildcat and fox samples. All these four *Eimeria* species were considered spurious parasites as they develop and reproduce in lagomorphs (the first three) or rodents (the last one; Pellerdy 1965), which are preyed upon by fox (Blanco 1988), genet (Palomares and Delibes 1991) and wildcat (Aymerich 1982) in Spain. At least five cestode species were found, but they did not reach high prevalences in wildcat and fox. However, *Taenia* (probably all of them *Taenia pisiformis* Bloch; see Discussion) was a common worm in Iberian lynx (Table I). Spurious cestodes occurred once in a lynx sample (*Cittotaenia* sp., Anoplocephalidae; an intestinal parasite of the European rabbit, *Oryctolagus cuniculus* L.; Quiroz 1984), and once in a stone marten sample [*Hymenolepis* sp., Hymenolepididae; a parasite genus of rodents and wild birds (Quiroz 1984), which are common in the diet of stone martens; Clevenger, 1994]. Nematodes were the most widespread parasites in all host species, especially in the wildcat, which harbored five species having over 20% prevalence (Table I). *Physaloptera* (probably *P. praeputialis* Linstow in most cases) infected more than 60% of individual wildcats, and 20% of foxes. Common nematodes in the Iberian lynx were *Ancylostoma* spp., *Toxascaris leonina* Linstow, and *Toxocara canis* Werner (Table I). *Heterakis* sp., an ascarid of birds (Noble et al. 1989), was found once in a wildcat sample.

For most parasite species, mean intensity in all host species was below 10 forms/ml, although some nematodes reached values between 10 and 20 forms/ml in wildcats and lynx (Table I). No evidence of overdispersion (i.e. aggregated distribution of parasitic forms among individual hosts) was found. In all 17 parasite-host combinations in which variance could be calculated the ratio between variance and mean intensity was <1.

The distribution of parasite occurrences between host populations, sex and age is shown in Table II. Nine (45%) of the parasite taxa listed in this table occurred only in one of the study areas, suggesting a quite different pattern of parasite composition between areas. However, most parasite species absent in one of the areas were present in very

Table I. Number of infected individuals, prevalence (%), and mean intensity (number of parasitic forms per ml of sediment) of gastrointestinal parasites in Iberian carnivore hosts

Samples	*Felis silvestris* 19				*Lynx pardinus* 10				*Vulpes vulpes* 23				*Martes foina* 4	*Genetta genetta* 5	*Herpestes ichneumon* 1
Individuals	16				9				20				4	5	1
	infect.	prev.	intensity mean	intensity SE	infect.	prev.	intensity mean	intensity SE	infect.	prev.	intensity mean	intensity SE	infected	infected	infected
Coccidia	**12**	**75.00**	**7.92**	**1.31**	**3**	**33.33**	**6.00**	**2.08**	**13**	**65.00**	**8.08**	**1.20**			
Eimeria felina	3	18.75	2.00	0.58	0				0					1	
Eimeria vulpis	0				0				0						1
Isospora canis	0				0				9	45.00	8.00	0.47			
Isospora felis	5	31.25	6.20	0.58	2	22.22	8.00	1.00	0					1	
Isospora rivolta	7	43.75	7.86	0.74	1	11.11	2.00	0.00	3	15.00	7.67	1.20	1	3	
Isospora vulpis	0				0				4	20.00	2.50	0.65			
Toxoplasma gondii	2	12.50	1.50	0.50	0				0						
Balantidium coli	0				0				0				1		
Cestoda	**3**	**18.75**	**7.67**	**0.33**	**3**	**33.33**	**10.33**	**2.60**	**2**	**10.00**	**2.00**	**0.00**			
Mesocestoides lineatus	1	6.25	1.00	0.00	0				0						
Taenia pisiformis	0				1	11.11	8.00	0.00	0						
Taenia taeniaeformis	1	6.25	6.00	0.00	0				0						
Taenia spp.	2	12.50	8.00	0.00	3	33.33	7.67	1.20	2	10.00	2.00	0.00			
Dipylidium caninum	0				0				0						
Diplopylidium sp.	0				0				0						1
Nematoda	**16**	**100**	**15.75**	**2.31**	**3**	**33.33**	**47.00**	**8.74**	**14**	**70.00**	**5.93**	**0.84**		1	
Ancylostoma spp.	4	25.00	8.00	0.82	2	22.22	9.00	1.00	1	5.00	4.00	0.00			
Uncinaria sp.	1	6.25	2.00	0.00	0				0						
Toxascaris leonina	6	37.50	12.33	0.84	3	33.33	16.00	2.31	3	15.00	6.67	0.67		1	
Toxocara canis	0				2	22.22	21.50	0.50	1	5.00	3.00	0.00			
Toxocara cati	5	31.25	17.60	1.21	1	11.11	18.00	0.00	1	5.00	4.00	0.00	1		
Aelurostrongylus spp.	4	25.00	6.75	0.46	0				2	10.00	7.00	1.00			
Physaloptera praeputialis	1	6.25	4.00	0.00	0				0						
Physaloptera spp.	9	56.25	2.56	0.44	0				4	20.00	2.25	0.63		1	
Strongyloides stercoralis	0				1	11.11	8.00	0.00	0				1		
Capillaria aerophila	2	12.50	6.00	0.00	1	11.11	6.00	0.00	2	10.00	2.00	0.00			
Trichuris vulpis	0				0				3	15.00	8.33	0.88			
Trichuris sp.	0				0				0					1	
Total	**16**	**100**	**23.13**	**2.92**	**6**	**66.67**	**31.67**	**12.24**	**19**	**95.00**	**10.11**	**1.55**	**2**	**5**	**1**

Table II. Occurrence of gastrointestinal parasites in carnivore host species according to study area, sex, and age. Comparison of prevalence between categories for each parasite taxon was made by two-tailed Fisher exact test on 2×2 contingency tables. Significance is shown at the right side of the comparison: *$p<0.05$, **$p<0.01$, ***$p<0.001$

Individuals	*Felis silvestris* 16					*Lynx pardinus*[a] 9					*Vulpes vulpes* 20							
	area		sex			age		sex			age		area		sex		age	
	Montes	S. Morena	female	male		adult	subadult	female	male		adult	subadult	Montes	S. Morena	female	male	adult	subadult
Sample size	11	5	10	6		11	5	3	6		4	5	16	4	6	14	13	7
Coccidia	7	5	6	6		8	4	3	0	*	2	1	11	2	5	8	8	5
Eimeria felina	1	2	2	1		3	0	0	0		0	0	0	0	0	0	0	0
Isospora canis	0	0	0	0		0	0	0	0		0	0	7	2	4	5	7	2
Isospora felis	3	2	3	2		3	2	2	0		2	0	0	0	0	0	0	0
Isospora rivolta	3	4	2	5	*	6	1	1	0		0	1	3	0	1	2	2	1
Isospora vulpis	0	0	0	0		0	0	0	0		0	0	4	0	1	3	2	2
Toxoplasma gondii	2	0	1	1		1	1	0	0		0	0	0	0	0	0	0	0
Cestoda	3	0	3	0		2	1	0	3		1	2	1	1	0	2	1	1
Mesocestoides lineatus	1	0	1	0		1	0	0	0		0	0	0	0	0	0	0	0
Taenia pisiformis	0	0	0	0		0	0	0	1		1	0	0	0	0	0	0	0
Taenia taeniaeformis	1	0	1	0		1	0	0	0		0	0	0	0	0	0	0	0
Taenia spp.	2	0	2	0		1	1	0	3		1	2	1	1	0	2	1	1
Nematoda	10	5	10	6		11	5	1	2		2	1	12	2	5	9	10	4
Ancylostoma spp.	1	3	1	3		2	2	0	2		1	1	1	0	0	1	1	0
Uncinaria sp.	0	1	0	1		1	0	0	0		0	0	0	0	0	0	0	0
Toxascaris leonina	2	4	* 4	2		6	0	1	2		2	1	3	0	1	2	3	0
Toxocara canis	0	0	0	0		0	0	0	2		1	1	1	0	1	0	1	0
Toxocara cati	3	2	2	3		4	1	1	0		1	0	0	1	0	1	1	0
Aelurostrongylus spp.	3	1	2	2		3	1	0	0		0	0	1	1	1	1	1	1
Physaloptera spp.	10	0	*** 7	3		6	4	0	0		0	0	3	1	0	4	2	2
Strongyloides stercoralis	0	0	0	0		0	0	0	1		1	0	0	0	0	0	0	0
Capillaria aerophila	2	0	2	0		1	1	0	1		0	1	2	0	1	1	1	1
Trichuris vulpis	0	0	0	0		0	0	0	0		0	0	3	0	1	2	2	1
Corrected α[b]			0.0028			0.0029					0.0038							

[a]All lynx specimens were caught in S. Morena; [b]Bonferroni correction: $0.05/k$, where k is the number of comparisons.

low frequencies in the other area, and absence might be simply a result of small sample size.

After Bonferroni correction, no significant differences were found in prevalence between sexes and age classes (Table II) in any of the three host species considered. Only the prevalence of *Physaloptera* species in the wildcat in Montes de Toledo (91%) was significantly higher (Fisher two-tailed exact test, $p = 0.001$) than in Sierra Morena (absent; Table II).

Up to seven different parasite species were found in the same individual host. The number of parasite species per individual decreased slightly but significantly ($r = -0.08$, $p = 0.025$) as body condition increased (Table III). A similar weak ($r = -0.19$, $p = 0.006$) but significant relationship between body condition and the number of parasite species per individual was found in the coccidia subsample (Table III). On average, individual wildcats were infected by a larger number of total parasites ($\bar{x} = 3.31$ species, SE = 0.44) and nematodes ($\bar{x} = 2.00$ species, SE = 0.27) than were foxes ($\bar{x} = 1.75$, SE = 0.25 and $\bar{x} = 0.85$, SE = 0.15, respectively, Table III; Tukey contrasts between means, $q = 4.94$ and 5.09, respectively, $df = 31$, $p<0.01$). The trend was the same for coccidia and cestoda, but differences were not significant (Table III). The mean number of parasite species per individual in the Iberian lynx was 1.78 (SE = 0.68), close to the value found in the fox. Both sexes in all host species were infected by a similar number of parasite species, and consequently sexual differences were not significant (Table III). The mean number of coccidia species per individual was 0.93 (SE = 0.15) in adult hosts compared to 0.59 (SE = 0.12) in subadults, and correspondent figures for the total number of parasite species per individual were 2.57 (SE = 0.34) and 1.88 (SE = 0.35), respectively. These age differences were significant (Table III).

Mean intensity of the 10 parasite species in which the number of infected individuals was enough to perform ANCOVA did not significantly differ between host

Table III. Summary of main effects (ANCOVA) of body condition, host species, sex, and age class on the mean number of parasite species per individual; df_1: numerator degrees of freedom; df_2: denominator degrees of freedom

Effect	Body condition				Host			Sex			Age		
	df_2	F	df_1	p	F	df_1	p	F	df_1	p	F	df_1	p
Coccidia	31	8.55	1	0.006	0.58	2	ns	0.50	1	ns	6.98	1	0.013
Cestoda	31	1.82	1	ns	0.27	2	ns	0.89	1	ns	0.43	1	ns
Nematoda	31	1.10	1	ns	4.51	2	0.019	2.75	1	ns	1.29	1	ns
All parasites	31	5.58	1	0.025	3.94	2	0.030	3.25	1	ns	4.42	1	0.044

Table IV. Summary of main effects (ANCOVA) of body condition, area, host species, sex, and age class on the mean intensity of parasite groups. Sample size is not enough to perform this analysis in the Cestoda subsample; df_1: numerator degrees of freedom; df_2: denominator degrees of freedom

Effect	Body condition				Host			Sex			Age			Area		
	df_2	F	df_1	p	F	df_1	p	F	df_1	p	F	df_1	p	F	df_1	p
Coccidia	19	0.92	1	ns	0.09	2	ns	1.11	1	ns	6.98	1	0.016	0.23	1	ns
Nematoda	25	0.00	1	ns	14.07	2	0.000	1.69	1	ns	0.06	1	ns	1.75	1	ns
All parasites	32	0.51	1	ns	5.04	2	0.013	3.71	1	ns	3.16	1	ns	0.23	1	ns

Table V. Number and percentage of coincident species in different fecal samples of the same individual host

Individual	Number of parasite species			
	days between samples	sample 1	sample 2	matching species	percentage
F. silvestris	379	3	5	1	14.29
F. silvestris	353	1	3	0	0.00
F. silvestris	0	1	3	1	33.33
F. silvestris	25	5	2	0	0.00
L. pardinus	4	3	2	0	0.00
L. pardinus	0	1	4	0	0.00
L. pardinus	0	1	3	1	33.33
L. pardinus	0	4	3	2	40.00
V. vulpes	1	3	1	0	0.00
V. vulpes	34	3	1	0	0.00
V. vulpes	2	1	2	0	0.00

species, between host sex and age categories, nor between study areas. There was not a significant relationship between intensity and the body condition index either. However, some of these factors affected mean intensity at a higher taxonomic level (Table IV). On average, intensity of coccidia was significantly higher in adult hosts than in young ones (Tables I and IV). Mean intensity of nematodes was significantly higher in lynx than in both wildcats (Tukey test, $q = 6.26$, $df = 25$, $p<0.01$) and foxes ($q = 9.25$, $df = 25$, $p<0.01$), and higher in wildcats than in foxes as well ($q = 5.18$, $df = 25$, $p<0.01$). Overall mean intensity, considering all parasite forms, was significantly higher in wildcats than in foxes ($q = 4.45$, $df = 32$, $p<0.05$).

Individual recognition of hosts allowed comparison of parasite occurrence between feces produced by the same individual at different times. The consistence of parasite species found in different fecal samples was surprinsingly low in all the three host species where any comparison could be made. Matching parasite species never reached more than 40% of total parasite species, and the most common result was no matching at all between fecal samples (replicates) of the same individual, sometimes even when feces were produced the same day (Table V).

Changes in body condition over time were calculated in animals which were recaptured after >20 days. In three of them, changes in the condition index were not significant. On the other hand, a heavily parasitized female wildcat (with 7 gastrointestinal parasite species and a high parasitic burden of *P. praeputialis*) lost 41% of its body weight in 25 days, and it was found dead six days after the recapture, but the ultimate cause of death remains unknown. Evident external pathological responses which may be partly attributed to gastrointestinal parasitic infection were only detected in this female wildcat and in a fox which showed strong diarrhea and mucus secretion probably associated to coccidiosis by *I. vulpis*.

Discussion

Most helminth species found in foxes and wildcats in this study were previously reported in the Iberian Peninsula as parasites of felid or canid hosts (Cordero del Campillo et al. 1994). However, *Aelurostrongylus* spp. is reported for the first time in Spain, both in foxes and wildcats. This genus has been rarely found in cats (Wilson-Hanson and Prescott 1982, Shaw et al. 1983), as adults live in the lungs (Mehlhorn et al. 1992), and larvae, which quit the host via the digestive system, may be easily undetected in the usual macroscopical intestinal examinations. We have not found previous reports of this parasite in other fox populations either. Terrestrial molluscs (snails and slugs) are intermediate hosts of *Aelurostrongylus* spp. (Quiroz 1984), but wildcats do not eat them (Aymerich 1982), and are likely infected through ingestion of rodents (*Apodemus sylvaticus* L. and *Microtus duodecimcostatus* Sélys-Longchamps) which may be paratenic hosts.

In agreement with the results obtained in other populations (Ianchev and Genov 1978, Mituch et al. 1988), the number of helminth species in the wildcat was relatively high, compared to the simplified faunas found in domestic or feral cats, especially those living in urban environments (e.g. Nichol et al. 1981, Engbaek et al. 1984). This may be related to the higher number of potential intermediate and paratenic hosts eaten by wildcats, which include several rodents, lagomorphs, birds, reptiles and insects in central Spain (Aymerich 1982). We have observed that the mean number of parasite species per individual (mainly nematodes) in foxes is lower than in wildcats, despite both host species are infected by a similar number of parasites (and of nematodes, in particular) at the population level. The mean number of parasite species per individual host may be influenced by the overall parasite composition of the host species (i.e. the number of possible parasites) and this, in turn, is mainly determined by host specificity. But the extent of individual infections may be also partly explained by ecological and behavioral factors. Infection may be easier when the host population density is high, and in our study areas wildcat populations are reinforced, compared to those of foxes, by feral and domestic cats which are common and may share parasites with wildcats. In addition, wildcats frequently ingest grass (Corbett 1979). This behavior may increase the chances of individual wildcats to be infected by several monoxenic nematode species. Differences between host species in nematode mean intensity are more difficult to explain because differences between nematode species in egg production. Thus, estimates based on eggs and larvae tell us little about the actual number of adult parasites living within an individual host and, therefore, about infection chances.

Prevalence values for most helminths in wildcats are similar to those found in Europe (Ianchev and Genov 1978, Burt et al. 1980, Mituch et al. 1988). However, *Physaloptera* spp. occurred in 62% of individuals, whereas it was virtually absent in the European populations of wild, feral or domestic cats. Insects, especially Coleoptera and Orthoptera, are the intermediate hosts of *Physaloptera* spp. (Georgi and Georgi 1992). In continental Europe wildcats feed almost exclusively on rodents (Stahl and Léger 1992), and in Scotland European rabbits are the main prey (Corbett 1979). The diet of the wildcat in central Spain is more diverse, and insects (mainly beetles) are eaten throughout the year, being present in up to the 43% of wildcat feces in summer (Rodríguez et al. unpubl.). These differences in feeding habits may influence exposure to infection and may account for the high prevalence of *Physaloptera* spp. in Spanish wildcats. Taeniids reached small prevalences compared to the results of most other studies. Rabbits are the main intermediate host of *T. pisiformis* (Leiby and Dyer 1971). Rabbits occur in over 50% of the wildcat feces and, in spite of this, no taeniid could be identified as *T. pisiformis*. This species grows very slowly in the wildcat, and even long worms may be not

able to produce mature proglottids. In addition, the growth of *T. pisiformis* may be further suppressed if the animal is already infected by *T. taeniaeformis* Batsch (Burt et al. 1980). But even *T. taeniaeformis* resulted less common than expected in our wildcat samples, taking into account that several species of rodents (intermediate hosts; Loos-Frank and Zeyhle 1982) occurred in >60% of analyzed feces.

The prevalence of most parasites, especially helminths, found in the fox samples was low. Remarkable differences with other studies were found with regard to *Uncinaria* spp., which was not detected (this study) or infected <10% of foxes in central Spain (Martínez et al. 1978, Navarrete et al. 1990), whereas prevalence ranged between 26 and 74% in other European populations (Loos-Frank and Zeyhle 1982, Borgsteede 1984, Pétavy et al. 1985, Deblock et al. 1988, Miquel et al. 1994). Ingestion of larvae living on the ground seems to be the usual way of infection (Gibbs 1961), and the large amount of fruits (eaten on the ground when ripe), other vegetables, and insects present in the diet of foxes in central Spain (Blanco 1988) would suggest a higher infestation rate than that found. Low survival of free-living infective larvae (Loos-Frank and Zeyhle 1982) cannot be invoked either as an explanation for low prevalence of *Uncinaria* spp. in our study, as average temperatures in all seasons are within the suitable range for development and survival (5–35°C; Balasingam 1964). Thus, other factors seem to affect the overall low frequencies of this parasite in central Spain. On the other hand, *Physaloptera* spp. infected 20% of foxes in our study areas. This result agrees with the common finding of this spirurid genus in many American felid and canid hosts (e.g. Seesee et al. 1981, Smith et al. 1986, Waid and Pence 1988), while it has not been reported in other European fox or cat populations.

Although not all the *Taenia* eggs found in lynx samples could be identified to the species level, it is likely that all of them belong to *T. pisiformis*, as lynx feed almost exclusively upon rabbits (Delibes 1980), its intermediate host. Only seven helminth species were found in lynx samples. It has been suggested (Smith et al. 1986) that a low number of helminth species might be related to the dominance of a single prey species in the diet, and this may apply to Iberian lynx and rabbits. Lynx do not forage opportunistically on the ground, and grass or insects are usually absent in their feces (Delibes 1980). So, most infections with monoxenic coccidia and nematoda might take place through direct transmission between mother and kittens, or through rabbits as paratenic hosts.

The common genet in Europe only occupies the Iberian Peninsula and southeastern France. Helminth species in central Spain differ from scarce existing reports: in northwestern Spain only two species were found in 15 individuals, *Toxocara genettae* Warren and *Taenia parva* Baer (Álvarez et al. 1990), in west central Spain Navarrete et al. (1990) reported three cestodes in 14 specimens, *Dipylidium acanthotetra* Parona, *D. diseriale* (sic, perhaps *D. triserialis* Luhe), and *Taenia parva*, and in northeastern Spain, Miquel et al. (1992) found three species in 21 individuals: the cestodes *T. parva* and *Joyeuxiella pasqualei* Diamare, and the nematode *Mastophorus muris* Gmelin. Small sample sizes may account for these differences between studies, and also for the differences in stone marten parasite composition regarding other populations (Loos-Frank and Zeyhle 1982, Miquel et al. 1992). Yet, the small number of parasite species found in several genet populations in the Iberian Peninsula suggests important geographic variations at least in their prevalence.

Overdispersion of intestinal parasites has been frequently found in carnivore host species (e.g. Burt et al. 1980, Waid and Pence 1988, Müller-Graf 1995). In contrast, the distribution of parasitic forms was not overdispersed in the fecal samples of our study. An effect of the small sample size on this result cannot be discarded, as some individual hosts were known to actually harbour a high number of adult parasites. Two samples collected 25 days apart from the same wildcat did not reflect, through a very high number of eggs, a strong infection with *Physaloptera* sp. revealed a few days later in its necropsy. The number of reproductive stages present in feces depends not only of the number of adult parasites living inside the host but also on their reproductive status. Such possible explanation implies that there must be a synchronous production of eggs in this parasite species, and that samples were taken by chance in periods of low egg production.

There were no sexual differences in the number of parasites or in their prevalence for any host species. Both abundance and prevalence of helminths are usually similar in male and female carnivore hosts (Smith et al. 1986, Zarnke et al. 1995), and when sexual differences are found they are difficult to explain (Waid and Pence 1988) as feeding habits and, consequently, exposure to infection are similar in both sexes. It is generally considered that adult hosts are more resistant to parasitism than young ones, due to immune mechanisms which may or not be related to previous exposure to parasites, and very young animals can be infected with helminths through direct transmission from their mother or through early acquisition in the environment (Noble et al. 1989). We have found a higher mean intensity of coccidian infection in adults than in subadults. We have also found that the number of parasite species increases with the host's age, suggesting that repeated exposure to free-living infective stages or to intermediate hosts along the life can override the effects of increased resistance in adults. Consistently, prevalence and abundance of several helminths were significantly higher in the adult cohort of several carnivore populations than among the youngs (Burt et al. 1980, Waid and Pence 1988, Zarnke et al. 1995).

Parasite helminths cause a constant loss of energetic resources in their hosts that may result in an important decrease in the host's rates of growth and reproduction

(Dobson et al. 1992). Although these effects depend mostly upon the intensity of infection (Noble et al. 1989), we have found that also the number of parasite species in a particular carnivore is negatively correlated with host physical condition. When the intensity of infection is particularly high parasites may cause disease and death (Waid and Pence 1988). In our study, however, visible pathological signs which might be partly attributed to the parasites affected to a very low proportion of the host population and, anyway, a causal relationship between parasitic infection and harmful effects could not be established.

Finally, the description of parasitic faunas by using fecal samples has several advantages and disadvantages. Among the latter, it is difficult to estimate accurately from a single sample the parasitic burden, and even the whole parasite species composition, as samples taken the same day or a few days apart had few species in common. This may be due to fluctuations in the reproductive status of adult parasites as well as to other factors. However, this shortcoming can be reduced or eliminated when it is possible to keep the animals in captivity for a longer period (i.e. two or three days) before release. On the other hand, fecal analysis is the only method that does not involve the death of protected host carnivore species. In long term carnivore population studies, monitoring of the evolution of the number and intensity of parasite species in particular individuals may help to describe the pattern, and to understand the effect, of infections in wild conditions, given enough recapture success. Collection of feces directly from caught animals (soon after defecation) is likely preferable to collection of droppings in the field, as some larvae and oocysts deteriorate with time and may be difficult to identify (Skírnisson et al. 1993).

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