Eur J Wildl Res (2008) 54:95–100
DOI 10.1007/s10344-007-0116-0

ORIGINAL PAPER

Endoparasite spectrum of wild cats (*Felis silvestris* Schreber, 1777) and domestic cats (*Felis catus* L.) from the Eifel, Pfalz region and Saarland, Germany

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Received: 20 April 2006 / Revised: 1 June 2007 / Accepted: 11 June 2007 / Published online: 5 July 2007

Abstract Between 1993 and 2002, carcasses from 15 wild cats (*Felis silvestris*) and 17 domestic cats (*Felis catus*) from the Eifel region, Pfalz region and the Saarland were collected and examined for endoparasites. Most cats were road casualties (74%), some died from disease (14%), some were shot (3%), or some died of unknown reasons (9%). Three wild cats were too decomposed for parasitological examination. Endoparasites were recovered in 14 wild cats (n=15) and 11 domestic cats (n=17). A total of eight endoparasite species were found in wild cats and six in domestic cats. The nematodes *Toxocara mystax* and *Toxascaris leonina* and the cestode *Taenia taeniaeformis* were the most prevalent parasites. Other helminths detected were *Capillaria aerophila*, *Capillaria feliscati*, *Capillaria plica* and *Mesocestoides litteratus*. The spiruride *Petrowospirura petrowi* was detected in Germany for the first time. The parasite fauna was more diverse in male than in female cats indicating a male-biased parasitism in the wild cats.

Keywords Causes of mortality · Diseases · Helminths · Male-biased parasitism

Communicated by W. Lutz

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Introduction

The wild cat (*Felis silvestris*) has a patchy distribution throughout Europe including Germany. The largest coherent populations in Central Europe live in Germany in the Palatine Forest (Pfälzer Wald; 200–600 individuals) and in the Eifel-Hunsrueck region (700–1,800 individuals; Herrmann 1998). They are in contact to populations in France, Belgium and Luxembourg. Smaller populations from the Harz, Solling, Kaufungerwald, Reinhardswald, Knuell and Taunus region are now expanding. Some populations were estimated to consist of only 30 individuals during the 1980s. All these populations are classified as endangered (Boye et al. 1998; Piechocki 1990).

Three main causes of mortality in wild cats have been reported: shot by hunters (27–73%), caught in traps (9–25%) and road casualties (19–54%). Other causes of mortality are killings by domestic dogs, electrocution, starvation and unknown causes. Diseases as causes of mortality are rarely reported (Vogt 1984; Pflüger 1987; Piechocki 1990). Reports on the parasite spectrum of wild cats are rare and often based on a small sample size only (Baruš 1961; Hasslinger and Bortenlänger 1996). Our aim was to investigate the parasite spectrum, the prevalences of the parasites, gender-related aspects in the parasite spec-

trum of the cats and the causes of death in wild and domestic cats from the Eifel, Pfalz region and the Saarland.

Materials and methods

The cats originated from the federal states Northrhine-Westphalia, Rhineland-Palatinate and Saarland and were found between 1993 and 2002. A total of 35 carcasses (18 *F. silvestris* and 17 *Felis catus*) were collected by private persons, nature conservation authorities and veterinarians and stored at −20°C until submitted for further investigations to the Leibniz Institute for Zoo and Wildlife Research (IZW), Berlin. There were 17 domestic cats (*F. catus*) and 15 wild cats (*F. silvestris*) finally investigated (Table 1), as 3 cats were already too decomposed for post mortem examination.

Body condition was judged by the thickness of subcutaneous and abdominal fat tissues. All internal organs were checked for pathological lesions. Lung, liver and kidneys were torn in small pieces and scanned for endoparasites through a head held magnifier and a stereo microscope (Zeiss Stemi 11®). Trachea, oesophagus, stomach, urinary bladder, gall-bladder, bile ducts and intestines were opened, flushed with water and were investigated for endoparasites together with the organs using the same method. Direct smears from duodenum, jejunum and rectum were made to test for the presence of intestinal protozoa using a microscope (Zeiss Aixophot®) with magnifications of ×25–1,000. Statistical analyses were performed using SPSS 11.5 for PC. Significance level was set at $\alpha \leq 0.05$.

Results

The main cause of mortality (Table 1) of the examined wild cats and domestic cats was trauma because of road casualties (74%). The traumatic injuries were dominated by fractures of the skull and vertebral column. Other cats

Table 1 Species, date of finding, habitat, age (a=adult, j=juvenile), sex (m=male, f=female) and cause of death of the examined cats

Species	Date of finding (day, month, year)	Location (city, region, federal state)	Age	Sex	Cause of death
Felis silvestris	11.11.1997	Rinnthal, Pfalz, Rhineland-Palatinate	a	f	Trauma
Felis silvestris	19.01.1999	Marmagen, Eifel, Northrhine-Westphalia	a	f	Trauma
Felis silvestris	04.03.1999	Freilingen, Eifel, Rhineland-Palatinate	a	m	Trauma
Felis silvestris	03.09.1999	Cochem, Eifel, Rhineland-Palatinate	a	m	Shot
Felis silvestris	04.11.1999	Sierscheid, Ahrgebirge, Rhineland-Palatinate	a	m	Trauma
Felis silvestris	11.11.1999	Feusdorf, Eifel, Rhineland-Palatinate	a	m	Trauma
Felis silvestris	22.11.1999	Rinnthal, Pfalz, Rhineland-Palatinate	j	m	Trauma
Felis silvestris	22.11.1999	Rinnthal, Pfalz, Rhineland-Palatinate	a	f	Trauma
Felis silvestris	12.01.2000	Iversheim, Eifel, Northrhine-Westphalia	a	f	Trauma
Felis silvestris	23.02.2000	Feusdorf , Eifel, Rhineland-Palatinate	a	f	Trauma
Felis silvestris	20.06.2001	Kall, Eifel, Northrhine-Westphalia	j	f	Trauma
Felis silvestris	20.08.2001	Schönau, Eifel, Northrhine-Westphalia	a	m	Trauma
Felis silvestris	05.03.2002	Kerschenbach, Eifel, Rhineland-Palatinate	a	m	Unknown
Felis silvestris	04.10.2002	Kermeter, Eifel, Northrhine-Westphalia	a	m	Trauma
Felis silvestris	14.01.2002	Not available	a	m	Unknown
Felis catus	Not available	Not available	a	f	Trauma
Felis catus	Not available	Eifel	a	m	Trauma
Felis catus	12.12.1998	Euskirchen, Eifel, Northrhine-Westphalia	a	m	Trauma
Felis catus	15.12.1998	Mirbach, Eifel, Rhineland-Palatinate	a	m	Trauma
Felis catus	23.06.1999	Stadtkyll, Eifel, Rhineland-Palatinate	a	m	Unknown
Felis catus	24.09.1999	Nettersheim, Eifel, Northrhine-Westphalia	a	m	Trauma
Felis catus	20.10.1999	Schönfeld, Eifel, Rhineland-Palatinate	j	m	Trauma
Felis catus	01.11.1999	Altheim, Saarpfalz, Saarland	a	f	Trauma
Felis catus	13.01.2000	Billig, Eifel, Northrhine-Westphalia	a	m	Trauma
Felis catus	28.08.2000	Feusdorf, Eifel, Rhineland-Palatinate	j	f	Euthanasia
Felis catus	11.10.2000	Kronenburg, Eifel, Northrhine-Westphalia	j	m	Disease
Felis catus	16.10.2000	Steffeln, Eifel, Rhineland-Palatinate	a	f	Trauma
Felis catus	21.11.2000	Feusdorf, Eifel, Rhineland-Palatinate	a	f	Disease
Felis catus	01.01.2001	Eifel	a	m	Trauma
Felis catus	22.04.2001	Eifel	a	f	Trauma
Felis catus	25.05.2001	Salmtal, Eifel, Rhineland-Palatinate	a	m	Trauma
Felis catus	09.11.2001	Reuth, Eifel, Rhineland-Palatinate	a	f	Trauma

Table 2 Endoparasites of wild and domestic cats from the Eifel, Pfalz and Saarland regions

Species	*Felis silvestris* (*n*=15)		*Felis catus* (*n*=17)	
	Prevalence	Intensity (average)	Prevalence	Intensity (average)
Toxocara mystax	11 (73%)	5–79 (33)	9 (53%)	1–22 (9)
Toxascaris leonina	9 (60%)	1–11 (5)	2 (12%)	2
Petrowospirura petrowi	1 (7%)	8	–	–
Capillaria aerophila	2 (13%)	1–3 (2)	1 (6%)	1
Capillaria plica	1 (7%)	2	1 (6%)	25
Capillaria feliscati	1 (7%)	1	–	–
Taenia taeniaeformis	8 (53%)	2–20 (8)	9 (53%)	2–23 (9)
Mesocestoides litteratus	1 (7%)	2	1 (6%)	7

died from disease (14%), were shot (3%), or died of unknown causes (9%).

Histopathological investigations were limited because of the advanced autolysis of the carcasses. However, two wild cats revealed multiple pulmonary granulomas with encapsulated nematode larvae; additionally, one of these cats had intra-bronchial nematodes identified as *Capillaria aerophila*. The lung of a third cat contained multiple protozoa cysts within the alveolar walls. Immunohistochemical staining did not reveal *Toxoplasma gondii*. Another wild cat had a moderate catarrhal enteritis with cross-sections of intra-luminal cestodes, probably *Taenia taeniaeformis*, which were isolated from the jejunum. No other morphologic abnormalities were noted.

Endoparasites were recorded in 14 (93%, *n*=15) wild cats and in 11 (65%, *n*=17) domestic cats. A total of six endoparasite species were found in the domestic and eight in wild cats (Table 2).

The nematode *Mastophorus spec.*, which was detected in both cat species, is a mouse parasite and not regarded to be parasitic in cats but being a spurious parasite. Multiple infections with two to four parasite species dominated, whereas mono-infections were observed only three times in domestic cats and four times in wild cats. *Toxocara mystax*, *Toxascaris leonina* and *T. taeniaeformis* were the most prevalent parasites in both species of cats.

Prevalence of parasites were higher in male than in female cats. Sex-specific differences between the parasite diversity were significant in wild cats (p=0.0310, chi-square test, n=8) and quite not significant in domestic cats (p=0.0662, chi-square test, n=6). Six parasite species were diagnosed in male domestic cats and eight parasite species in male wild cats, whereas female domestic cats harboured only two and female wild cats harboured three parasite species, respectively (Table 3).

Discussion

The most important mortality factors in this study were the road casualties. Other mortality factors such as disease seem to be less important, but the role of road kills in relation to other causes of death is unknown. Illegal persecution because of hunting of wild cats still occurs in Germany, which is evident by one wild cat that was shot.

Table 3 Sex-specific aspects of the parasite fauna of wild and domestic cats

Parasite species	Prevalence			
	Felis silvestris		*Felis catus*	
	Female (*n*=6)	Male (*n*=9)	Female (*n*=7)	Male (*n*=10)
Toxocara mystax	3 (50 %)	8 (89%)	3 (43%)	6 (60%)
Toxascaris leonina	3 (50%)	6 (67%)	–	2 (20%)
Petrowospirura petrowi	–	1 (11%)	–	–
Capillaria aerophila	–	2 (22%)	–	1 (10%)
Capillaria plica	–	1 (11%)	–	1 (10%)
Capillaria feliscati	–	1 (11%)	–	–
Taenia taeniaeformis	3 (50%)	5 (56%)	4 (57%)	5 (50%)
Mesocestoides litteratus	–	1 (11%)	–	1 (10%)

Compared to older studies by Vogt (1984), Pflüger (1987) and Piechocki (1990), one could assume that the wild cat population benefits from the protection by law, and the main causes of mortality have shifted to indirect anthropogenic factors. The results on the causes of death presented here may not be representative for the wild cat population because the sample size was relatively small, and sample collection (carcasses) was biased.

The high prevalence of endoparasitic infections of 93% in wild cats (n=15) observed in this study was similar to levels of infections found by others in Europe. Mituch (1972) found a prevalence of 87% in wild cats from Slovakia (n=155). The prevalence of 65% in domestic cats (n=17) was lower than in wild cats. A possible explanation could be an anthelmintic treatment provided by their owners. Feeding exclusively on wild prey as the wild cats do increases the probability of getting infected by parasites. Interestingly, Hasslinger and Bortenlänger (1996) found three helminth species in wild cats held in captivity compared to four helminth species found in wild cats from the park of Wiesenfelden Castle (Bavaria). The parasites with the highest prevalence were *T. mystax* and *T. taeniaeformis* in free-living wild cats and *T. mystax* and *Ancylostoma tubaeformes* in captive wild cats kept in captivity. Baruš (1961) detected three helminth species in wild cats from the territory of the former CSSR. Große and Böckler (1979) diagnosed a prevalence of 75.2% for endoparasites in domestic cats from the Kiel region. Hiepe et al. (1988) described a higher prevalence and a broader parasite spectrum in stray (domestic) cats from the countryside compared to stray cats from urban areas.

The most abundant nematode species in wild cats in this study were *T. mystax* (73%) and *T. leonina* (60%), and the most abundant cestode species was *T. taeniaeformis* (53%), which is in concordance to the results from wild cats from the Harz region (Schuster et al. 1993). To the authors' knowledge, *Petrowospirura petrowi* was detected in Germany for the first time. This nematode was described from the jungle cat (*Felis chaus*) from Azerbaijan (Skrjabin et al. 1967). The absence of any intestinal protozoan parasites here may be explained by the small sample size. We diagnosed six endoparasite species in the domestic cats and eight in wild cats from the Eifel and Pfalz region. In a much larger sample of domestic cats (n=1,484) from southern Germany, Heinrich-Blanché (1998) reported eight helminth species in domestic cats based on faecal examinations with *T. mystax* being the dominant nematode and *T. taeniaeformis* the dominant cestode, which is in concordance with other studies from European domestic and wild cats. No trematodes were found in the cats in this study. Reports on trematodes in cats are generally rare. A former study on wild cats from Germany (Schuster et al. 1993) did not list

Table 4 Prevalence of endoparasites in wild cats in different regions of Europe

Source	Brglez and Železnik (1976)	Schuster et al. (1993)	Hasslinger and Bortenlänger (1996)	Leple (2001)	This study
Region	Slovenia	Harz, Germany	Harz, Eifel, Pfälzer-wald, Spessart, Bavarian forest, Germany	France	Eifel, Germany
Sample size	n=12	n=25	n=14	n=39	n=15
Toxocara mystax	8 (67%)	20 (80%)	10 (71%)	30 (77%)	11 (73%)
Toxascaris leonina	2 (17%)	–	–	–	9 (60%)
Petrowospirura petrowi	–	–	–	–	1 (7%)
Capillaria aerophila	–	–	–	–	2 (13%)
Capillaria plica	–	3 (12%)	–	–	1 (7%)
Capillaria feliscati	–	–	–	–	1 (7%)
Capillaria hepatica	–	–	–	7 (21%)	–
Capillaria spec.	–	6 (24%)	–	23 (59%)	–
Ancylostoma tubaeformae	–	–	–	4 (10%)	–
Ollulanus tricuspis	2 (17%)	–	2 (14%)	–	–
Mesocestoides litteratus	2 (17%)	10 (40%)	–	–	1 (7%)
Taenia taeniaeformis	10 (83%)	18 (72%)	9 (64%)	23 (59%)	8 (53%)
Taenia crassiceps	–	2 (8%)	–	–	–
Taenia martis larv.	–	1 (4%)	–	–	–
Isospora rivolta	–	–	–	12 (36%)	–
Isospora felis	–	1 (4%)	1 (7%)	1 (3%)	–
Isospora bigemina	1 (8%)	–	–	–	–
Total	–	88%	–	–	93%

any trematodes, too. Schuster et al. (1999) described a severe *Ophistorchis felineus* infection in a domestic cat from the federal state of Brandenburg, Germany and discussed coproscopical examination techniques as reason for the rare detection. A study focused on trematodes in 22 stray cats (*F. catus*) did reveal *O. felineus* and *Metorchis bilis* at 41 and 23%, respectively (Hering-Hagenbeck and Schuster 1996). Andrejko (1973) diagnosed *Metorchis albidus* in wild cats and *O. felineus* and *Pseudamphistomum truncatum* in domestic cats from Moldavia. Parasite prevalence and diversity differ among wild cats in Europe (Table 4). However, prevalence in general seems to be high in the wild cats.

The higher parasite burden and diversity in wild cats can be explained by the broader spectrum of prey species as potential intermediate hosts in the diet of wild than in domestic cats. The infection with *C. aerophila* in the cats may be explained by the fact that the cats feed on paratenic hosts (e.g. insectivore), which have ingested earthworms being the intermediate hosts for this nematode (Skrjabin et al. 1957; Eckert et al. 2005). Schuster et al. (1993) suggested that no mutual infections occur between wild and domestic cats because they use different habitats and "exclude themselves ecologically." They argued that hybrids between wild and domestic cats were found only at the periphery of the wild cat distribution. It is very likely that the infections with the same endoparasite species do not occur directly from wild to domestic cats or vice versa but because of intermediate hosts; so, there could be an indirect exchange of parasites between wild and domestic cats.

Prevalence of parasites were higher in male than in female cats. Sex-specific differences were found between wild and domestic cats but were only significant for wild cats. Reasons for gender-related differences in parasite infections are explained either by ecological or physiological causes. The association of testosterone and the immune system may result in a higher susceptibility to parasite infections in sexually mature male vertebrates (Zuk and McKean 1996). Hormonal differences between female and male cats may be responsible for the sex-specific differences found in our study. Poulin (1996) reported higher prevalences and intensities of helminths, especially nematodes, in males of mammals and birds after an extensive literature survey analysed with meta-analytical techniques. He discussed possible reasons for the male-biased parasitism (MBP) to be hormone, immune system, behavioural, territorial, movement, social or diet related. Hoby et al. (2006) were able to correlate the higher levels of cortisol metabolites in male chamois (*Rupicapra rupicapra*) with a higher output of lungworm larvae, demonstrating the MBP in polygynous animals with male–male competition for females. Further studies should consider gender-related differences and their underlying causes in wild cats.

Acknowledgements We are grateful to Dr. J. Priemer and P. Esterried for translating several parts of the Russian parasitological literature and to Dr. R. Will for suggestions regarding related literature. We would also like to thank M. East for helpful comments regarding the manuscript and K. Totschek and K. Blank for technical assistance. Three unknown referees improved the quality of the manuscript with their valuable suggestions.

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