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Prevalence of intestinal helminths in Austrian Red Foxes (*Vulpes vulpes* L.)

(Cestoda, Nematoda)

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Abstract

In 307 Red Foxes (*Vulpes vulpes* L.) from six ecologically differing regions in Austria the effects of host-related (age, sex), seasonal and regional factors on prevalences of intestinal helminths were studied. Among the six cestode and six nematode species recovered, *Toxocara canis* (WERNER, 1782), *Uncinaria stenocephala* (RAILLIET, 1884), *Mesocestoides litteratus* (BATSCH, 1786) and *Taenia crassiceps* (ZEDER, 1800) exhibited the highest prevalences. Significant seasonal changes in prevalences were observed for *Toxocara canis*, *Uncinaria stenocephala* and *Taenia crassiceps*. The age of the hosts influenced the prevalence of *Toxocara canis*, *Uncinaria stenocephala* and *Mesocestoides litteratus*. A sex-difference was found in prevalences of *Toxocara canis* and *Taenia crassiceps*. Significant regional differences in prevalences of helminth species were found in *Toxocara canis* and *Mesocestoides litteratus*. Habitat conditions across the regions, however, apparently had no major effect on species composition.

Key words: Cestoda, Nematoda, intestinal helminths, *Vulpes vulpes*, factors of prevalance, Austria.

Zusammenfassung

Von 307 Rotfüchsen (*Vulpes vulpes* L.) aus sechs ökologisch unterschiedlichen Regionen in Österreich wurden die wirtsbezogenen (Alter, Geschlecht), saisonalen und regionalen Einflüsse auf die Prävalenzen der Darmhelminthen untersucht. Unter den sechs Cestoden- und sechs Nematodenarten zeigten *Toxocara canis* (WERNER, 1782), *Uncinaria stenocephala* (RAILLIET, 1884), *Mesocestoides litteratus* (BATSCH, 1786) und *Taenia crassiceps* (ZEDER, 1800) die höchsten Prävalenzen. Signifikante saisonale Unterschiede der Prävalenzen wurden bei *Toxocara canis*, *Uncinaria stenocephala* und *Taenia crassiceps* festgestellt. Das Alter der Wirtstiere hatte Einfluß auf die Befallsraten von *Toxocara canis*, *Uncinaria stenocephala* und *Mesocestoides litteratus*. Unterschiedlicher Befall zwischen den Geschlechtern wurde für *Toxocara canis* und *Taenia crassiceps* festgestellt. Die unterschiedlichen Lebensräume der Regionen scheinen keinen wesentlichen Einfluß auf die Artenzusammensetzung der Darmhelminthen zu haben. Signifikante regionale Unterschiede der Prävalenzen wurden allerdings bei *Toxocara canis* und *Mesocestoides litteratus* gefunden.

Introduction

Red Foxes (*Vulpes vulpes* L.) are hosts of a large number of intestinal helminth species (STUBBE 1965, HEPTNER & NAUMOV 1974, LLOYD 1980, LOOS-FRANK & ZEYHLE 1982, CARVALHO-VARELA et al. 1985) presumably due to their wide distribution, occurrence in numerous habitat types, high level of home range activities, variable diet composition (LLOYD 1980) and a great potential for intraspecific social activity (STORM & MONTGOMERY 1975, MACDONALD 1980). In Austria fox helminths were investigated by HINAIDY (1971, 1976) and PROSL & SCHMID (1991).

This study aims to analyse the effects of short-term temporal and host-related (age and

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sex) factors on gut helminth infections in foxes from ecologically differing regions in Austria (tab. 1). Substantial differences in the intestinal helminth fauna are expected to occur across Austrian fox populations because of habitat and dietary differences (SUCHENTRUNK 1984).

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Material and Methods

A total of 307 Red Foxes (*Vulpes vulpes*) including eight juveniles and 74 cubs were examined for intestinal helminths. Foxes were mainly shot or trapped by local hunters during November 1979 - May 1982 in various parts of Austria. Some were poisoned with a cyanide generating powder in the course of fox control programs, some were found as road kills or obtained by bolting from earths. According to differences in climate and geomorphology, six regions (i.e., regional sample units/ populations) were distinguished (see fig. 1 and tab. 1). These regions also differed with respect to food resources and its availability to foxes (SUCHENTRUNK 1984). Foxes between six and twelve months of age were termed subadult (SA) and older ones were considered as adults (AD). The two age classes were determined by the extent of teeth abrasion (STUBBE 1965, SUCHENTRUNK 1984). Individuals younger than aprox. 6 months were separated into cubs (CU: up to the age of approx. three months) and juveniles (JU: between approx. three and six months of age) based on body weigths and tooth eruption. Since reproduction in Austrian foxes takes place between February and April (cf. SUCHENTRUNK 1991) no SA individuals occurred during the warm period of the year by the above given age classification. Cubs from 32 litters were examined; in 13 litters of these, however, only one cub was investigated, respectively. For details on sex and seasonal composition of the SA and AD foxes see tab. 2.

Complete gut contents were rinsed through a 0.5 mm sieve. The entire gut contents were then placed in Petri dishes and flooded with water. The dishes were scanned for helminths using a dissecting microscope. In some cases tiny trematodes such as *Alaria alata*, which was already recorded in foxes from Austria (HINAIDY 1971, 1976, FRANK 1977), might have been overlooked by this technique. However, *Echinococcus multilocularis*, a tiny cestode which was expected to occur in some guts, should have been collected by this technique, because infections with this species are in part of high intensity and the mass of individuals should have been visible by using a dissecting microscope (Prosl, pers. comm.).

Helminths were fixed, preserved in 75% alcohol and stored under "NHMW Evertebrata Varia 16235 - 16669, 3. Zool. Abt." (Naturhistorisches Museum Wien). For microscopical analysis nematodes were mounted in glycerine. The cestodes were stained in lactic-acid-carmine and scolices were mounted separately in Berlese fluid or glycerine.

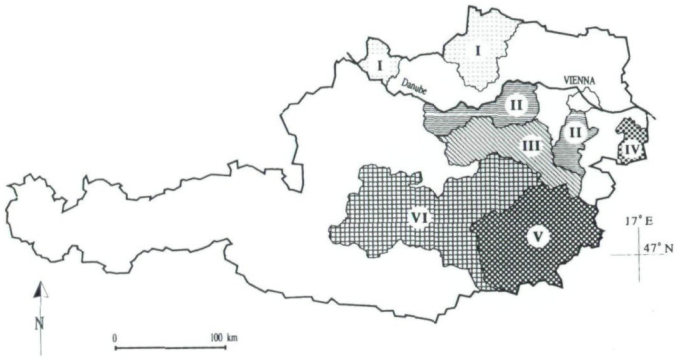

Figure 1: The six regions in Austria where foxes were sampled: I = Waldviertel/Mühlviertel, II = Alpenvorland/southern Wiener Becken, III = northern Kalkalpen/Alpenvorland, IV = Seewinkel, V = Südsteiermark/Südburgenland, VI = Niedere Tauern, alpine valleys.

Ascarids were determined according to HARTWICH (1975) and taeniids according to VERSTER (1969). The prevalence of each helminth species was calculated as the percentage of foxes infected with the appropriate species (MARGOLIS et al. 1982). All helminths found in foxes from a particular region constituted the respective "component community" (HOLMES & PRICE 1986, ESCH & al. 1990). Foxes from comparable seasons of different years were pooled into winter (December - March), spring/summer (April - July), summer/autumn (August - November). Apart from this seasonal classification, a warm (May - October) and a cold (November - April) period of the year were discriminated. For testing differences in prevalences, chi^2-, Fisher- and G-tests (WEBER 1980) were used. Generally, results were considered significant at the $p<0.05$ level unless otherwise indicated.

Tab. 1: Geomorphology and climate of the collecting areas (cf. fig. 1 and SUCHENTRUNK 1984).

region	altitude	landscape main landuse	mean air temp., annual precipit.	mean duration snow cover (days)
I	500 - 900 m	hilly, forests, pastures, arable land	6,5 °C, 654 mm	51
II	300 - 500 m	flat, hilly, arable land, forests	9,0 °C, 700 mm	28
III	500 - 1400 m	mountains, narrow valleys, forests	7,9 °C, 1177 mm	39
IV	120 - 180 m	flat, arable land	9,8 °C, 625 mm	19
V	250 - 450 m	gently rolling, hilly forests, arable land	8,9 °C, 953 mm	48
VI	600 - 2800 m	mountainous, valleys, forests	6,2 °C, 757 mm	78

Tab. 2: Seasonal sample distribution of juvenile, subadult and adult male/female foxes. w = winter (December - March), s/s = spring/summer (April - July), s/a = summer/autumn (August - November).

	population					
season	I	II	III	IV	V	VI
w	17/18	6/9	13/10	4/6	15/23	11/17
s/s	0/0	2/3	5/10	4/0	4/2	1/1
s/a	2/3	1/0	8/11	2/2	7/8	3/5
sum.	19/21	9/12	26/31	10/8	26/33	15/23

Results

Six nematode and 6 cestode species were recovered (tab.3). A few unidentified nematode specimens belonged to the Spiruroidea (Moravec, in lit.). Those nematodes were too decomposed to permit exact identification. In tab. 3, species prevalences in JU, SA and AD foxes are listed for each regional population. Overall prevalences did not differ between AD, SA and JU foxes (69,5%) on the one hand and cubs (75.7%) (tab.4) on the other. Furthermore, overall prevalences were similar in SA and AD foxes. However, they differed both among fox populations (tab. 3, $p<0.001$) and seasons (w = 64.2%, s/s = 70.0%, s/a = 84.1%; $p<0.05$, G-test). While SA and AD female foxes were less frequently ($p<0.01$) infected (60.8%) than males (79.6%), no sex-specific prevalence was found in cubs. Prevalence in females (AD and SA) was lower in winter (53.0%) than in the warm seasons (s/s = 73.3%, s/a = 78.3%). In males (SA and AD) no such seasonal differences were apparent. Multiple infections occurred in 47,1% of all JU, SA and AD foxes harbouring intestinal helminths and only in 17,9% of all infected cubs. Infected JU, SA and AD foxes harboured a mean of 1,6 species and infected cubs harboured a mean of 1,3 species.

Prevalences in adults, subadults and juveniles

Toxocara canis (WERNER, 1782)

Generally, a significant seasonal influence on the prevalence was found (w = 60.8%, s/s = 37.9%, s/a = 38.5%, $p<0.025$). Moreover, prevalence was significantly lower during the warm period of the year (May - October = 22.5%) than during the cold season (November - April = 44.7%). During the cold season, prevalence was significantly higher ($p<0.001$) in males (58.9%) than in females (30.7%). While no sex-specific difference was found in prevalence among adults (41.0%), SA males were significantly ($p<0.0001$) more often (70.5%) infected than SA females (20.0%). Also, SA males (70.5%) were more often infected than AD males (48%). In females, no age-specific prevalence was found. Prevalence of SA and AD females examined within the period of reproduction (February -April) was 26.5%.

Tab. 3: Prevalences of helminth species in JU, SA and AD Red Foxes (sexes and seasons combined). Regional differences significant at * $p<0.05$, ** $p<0.001$; n = 233.

regions:	total	I	II	III	IV	V	VI
	n=233	40	21	57	18	59	38
overall prevalence	69.5	55.0	81.0	75.4	83.3	61.0	76.3
*Toxocara canis***	42.9	34.1	57.1	52.6	27.8	29.3	57.9
Toxascaris leonina	0.4	0.0	0.0	1.8	0.0	0.0	0.0
Uncinaria stenocephala	27.5	12.5	28.6	35.1	16.7	28.8	34.2
Molineus patens	1.3	0.0	0.0	1.8	0.0	1.7	2.6
Heligmosomum costelatum	0.4	0.0	0.0	1.8	0.0	0.0	0.0
Syphacia montana	0.4	0.0	0.0	1.8	0.0	0.0	0.0
Spiruroidea indet.	0.4	0.0	0.0	1.8	0.0	0.0	0.0
*Mesocestoides litteratus***	24.9	12.5	38.1	40.4	50.0	11.9	15.8
*Taenia crassiceps**	14.6	7.5	28.6	17.5	16.7	11.9	13.2
Taenia polyacantha	2.1	0.0	0.0	1.8	0.0	5.1	2.6
Taenia taeniaeformis	0.9	2.5	4.8	0.0	0.0	0.0	0.0
Taenia serialis	0.4	0.0	4.8	0.0	0.0	0.0	0.0
Taenia ovis	0.4	0.0	0.0	1.8	0.0	0.0	0.0

Uncinaria stenocephala (RAILLIET, 1884)

Prevalences differed significantly ($p<0.025$) between SA (37.5%) and AD (28.0%) individuals. But no sex-specific prevalences were found either in SA or AD foxes. Prevalences were higher ($p<0.025$) during the warm period (May - October: 50%) than during the cold (November - April: 21.8%). During the denning period (April - June), prevalence of SA and AD female foxes was 42.0%.

Mesocestoides litteratus (BATSCH, 1786)

Prevalences did not differ significantly between sexes or between age classes (SA vs. AD). There was no significant variation among the seasons. During the denning period prevalence in SA and AD foxes was 34.6%. For significant regional differences see tab. 3.

Taenia crassiceps (ZEDER, 1800)

No significant regional variation of prevalences was found. Prevalences did not differ significantly between SA and AD foxes. While SA individuals showed a significant sex-difference (males: 22.0%, females: 5.5%), in AD foxes (14.2%) there was none. A seasonal change in prevalence was noted in SA and AD specimens (November - April: 16.3%, May - October: 40.0%; $p<0.025$). During the denning season 30.8% of SA and AD foxes were infected.

Tab. 4: Prevalences of gut helminth species in fox cubs (n = 74).

Toxocara canis	62.6%
Toxascaris leonina	1.4%
Uncinaria stenocephala	5.4%
Mesocestoides litteratus	2.7%
Taenia crassiceps	17.6%
Taenia taeniaeformis	1.4%

Infection of cubs

Prevalences of helminth species are given in tab. 4. No sex-specific difference in overall prevalence was found.

In 88.1% of all litters at least one cub was infected. In 84% of the infected cubs, only one helminth species was found, in 9% two, in 5% three and in 2% four helminth species were recovered. Prevalences of *T. canis* and *U. stenocephala* (tab. 4) differed significantly ($p < 0.001$). Prevalence of *T. crassiceps* was significantly higher than *M. litteratus* (tab. 4; $p < 0.01$).

Discussion

The overall prevalence of intestinal helminth infections in Austrian foxes (69,5%) is in good accordance with values reported for foxes from various parts of the world, e.g. LOOS-FRANK & ZEYHLE (1982) for southwestern Germany and COMAN (1973) for Victoria, Australia. However, it could not be compared to values given previously for Austrian foxes (HINAIDY 1971, 1976) because in those studies overall prevalences were based on both endo- and ectoparasites. The comparatively low prevalence of intestinal helminths in foxes from population I (tab. 3) is likely to be due to the preponderance of foxes sampled during winter when infections were generally somewhat reduced. In cubs, infections occur already with the same high prevalence as in AD, SA and JU specimens. This was also found in fox cubs from southwestern Germany (prevalence = 69.9%; recalculated from table 5 of LOOS-FRANK & ZEYHLE (1982) by adjusting for cubs in our terminology). However, the high prevalence in cubs is mainly due to infections with *Toxocara canis* (tab. 4).

As in Red Foxes from Australia (COMAN 1973) and North America (SMITH 1943), overall prevalence in SA and AD foxes was generally lower in females than in males. This is chiefly an effect of sex-specific prevalences of *T. canis* and *T. crassiceps* in SA foxes. It corresponds to the inhibition of the development of some cestode species in castrated domestic dogs, rats and mice (PFLUGFELDER 1977). Since there was no marked sex-specific diet composition (intermediate hosts) in the investigated foxes (SUCHENTRUNK 1984), we suggest a physiological/immunological component to be responsible for the different prevalences of male and female foxes. Particularly, in females infections were generally reduced in winter, obviously due to few infections with *T. canis* and *T.*

crassiceps. Male foxes maintained a high level of prevalence of *T. canis* during their first year of life whereas in females infections were already reduced at an age of six to 12 months. Likewise, prevalences of *T. canis* in Red Foxes from Iowa, U.S.A. (SMITH, 1943) and Wales, Great Britain (HACKETT & WALTERS 1980) were higher in males than in females in winter. In growing domestic dogs, prevalence is reduced more quickly in females than in males (BOCH & SUPPERER 1983). However, in foxes from southwestern Germany no age difference was found in prevalence of *T. canis* (LOOS-FRANK & ZEYHLE 1982).

Toxocara canis infections occurred in 26.5% of all females during the period of reproduction. Thus, because of the possibility of prenatal and lactational transmission of *T. canis* larvae (BURKE & ROBERTSON 1985), one female out of four, plus an unknown number of females without mature *T. canis* but harbouring somatically incubated larvae, provide an ample source of infections to neonates. In contrast to the high prevalence of *T. canis* in cubs (tab. 4), *Uncinaria stenocephala* (the second prevalent nematode species found) is rare in cubs, although there is an expected chance of 42 % for SA and AD females to be infected with this hookworm during the denning period and thus to spread eggs. However, the chance of an infection of cubs may be reduced since females probably don't drop scats within the den and cubs would not emerge from the den before about six weeks of age (LLOYD 1980). Also, it is possible that eggs are either not shed from adults, or eggs and larvae do hardly develop infectious stages at that time of year. Eggs of this hookworm species develop best at warm temperatures (REP & BOS 1979). This is paralleled by a higher prevalence of *U. stenocephala* in foxes during the warm period of year than during the winter. Nevertheless, although SA foxes occur only during the cold period they exhibit a higher prevalence of *U. stenocephala* than adults. This suggests an increase in immunocompetency against *U. stenocephala* with age. The two nematode species *T. canis* and *U. stenocephala* exhibited some sort of "seasonal vicariance" in foxes with the former species more prevalent during the cold season and the latter during the warm season.

Several species of the genus *Mesocestoides* have been described for Europe; however, the old descriptions of *M. lineatus* (GOEZE, 1782) and *M. litteratus* (BATSCH, 1786) are very poor. Different descriptions and incorrect identifications from later authors have further confused the situation. According to PRIEMER (1983) the new species *M. leptothylacus* created by LOOS-FRANK (1980a) should be synonymized with the old taxon *M. litteratus* which has priority. Following the nomenclature and determination key of PRIEMER (1983), only *M. litteratus* was found. Due to bad fixation some of the specimens could not be identified exactly. Among cubs only few individuals were infected with *M. litteratus* (see also LOOS-FRANK & ZEYHLE 1982) although this tapeworm was quite common during the denning season in AD foxes. In contrast, *T. crassiceps* was fairly prevalent in cubs. A reasonable interpretation of this finding needs more detailed ecological informations. Generally, the somewhat raised prevalences of *T. crassiceps* during summer and autumn may be caused by increased predation on voles (SUCHENTRUNK 1984), which constitute the primary intermediate host of this parasite (VERSTER 1969, WANDELER & HÖRNING 1972).

When applying the concept of core and satellite species in parasite component communities (HANSKI 1982, HOLMES & PRICE 1986, ESCH et al. 1990), four core species (*T. canis*, *U. stenocephala*, *M. litteratus*, *T. crassiceps*) and eight satellite species were

recovered in the foxes. In cubs, the only species frequent enough to be considered as core species was *T. canis*. Among the satellite species, three (*Syphacia montana* YAMAGUTI, 1943, *Heligmosomum costelatum* DUJARDIN, 1845, *Molineus patens* TRAVASSOS, 1921) are likely to occur accidentally in the foxes through predation on intermediate (rodents) or definitive (mustelids, small carnivores) hosts. Among the remaining five satellite species, one was a nematode (*Toxascaris leonina*, LINSTOW, 1902) and the rest were taeniid cestodes. Although a great many of foxes prey on Roe Deer (*Capreolus capreolus*) (SUCHENTRUNK 1984), *Taenia cervi* (CHRISTIANSEN, 1931), which uses that cervid as intermediate host (BOCH & SCHNEIDAWIND 1988), was detected only in 0.3% of the foxes. This low prevalence is concordant with the view that this tapeworm does not develop very well in foxes (BOCH & SCHNEIDAWIND 1988). Interestingly, *T. pisiformis* (BLOCH, 1780) was not recovered from foxes in the present study, even though lagomorphs (*Lepus europaeus* and *Oryctolagus cuniculus*), which are their intermediate hosts, were consumed by 27.9% of all investigated foxes (SUCHENTRUNK 1984). Susceptibility of foxes to infections with *T. pisiformis* is mostly limited to cubs (BEVERIDGE & COMAN 1978). Obviously, this cestode species is adapted to other canids as its definitive host (wolves, coyotes; HOLMES & PODESTA 1968, PENCE & WINDBERG 1984).

All four core species were recovered in each of the six Austrian fox populations. This indicates a rather low differentiation among the intestinal helminth component communities from the six regions. However, a gradual decrease of prevalences of *M. litteratus* in Austria appears to occur from east to west (tab. 3). The somewhat reduced frequencies of one or the other core species in some component communities is likely to result from disproportional seasonal sample sizes (tab. 3). Each of the core species can be considered rather as a generalist than as a specialist with regard to the carnivore species as their definitive hosts. The four core species are also core species in other intestinal helminth communities of Red Foxes from Central Europe (LOOS-FRANK & ZEYHLE 1982). According to their respective species composition, the six component communities of intestinal helminths do not appear to be substantially influenced by the varying habitat conditions for the foxes. This is particularly evident in community V and VI, which are very similar in respect of helminth communities, although the corresponding fox habitats differ substantially (tab. 1); the same holds for community I and IV, with the exception of different prevalences of *M. litteratus*. In view of the general occurrence of all four core species in the six component communities, we conclude that there is no principal differentiation among the intestinal helminth communities in large parts of Austria paralell to the habitat characteristics of fox populations. However, it should be emphasized that typical wetland habitats, where trematodes particularly can be expected to occur, have not been covered by our study. According to the overview of gut helminths of foxes from various parts of Europe (LOOS-FRANK & ZEYHLE, 1982), the intestinal helminth component communities are likely to show distinct differences across larger geographic distances than presently considered.

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