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ORIGINAL PAPER

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Status and origin of Haemonchinae (Nematoda: Trichostrongylidae) in deer: a survey conducted in France from 1985 to 1998

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Abstract During our investigations on helminthofauna in roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*) in France (1985–1998) we isolated nematodes not only of the genus *Haemonchus* Cobb, 1898 but also of the genus *Ashworthius* Le Roux 1930, both of which belong to the same subfamily of Haemonchinae. The prevalence of *Ashworthius* was 22% (65/294) in roe deer and 40% (10/25) in red deer. *H. contortus* was not found in red deer, whereas its prevalence was only 3% (9/294) in roe deer. These data contrast with those observed in other European countries. The presence of *A. sidemi* in red and roe deers in France suggests a case of parasitism imported via sika deer. A hypothesis of their spread is proposed.

Introduction

Species of the genus *Haemonchus* Cobb, 1898 (Nematoda: Trichostrongyloidea) are bloodsucking parasites of the abomasum in domestic ruminants. They are highly pathogenic and cause significant economic loss; exhibiting a cosmopolitan distribution, they are found in numerous domestic or wild ungulates in holarctic, Afrotropical, and even Australasian regions (Anderson 1992).

Two species have been reported in European domestic ruminants (Gibbons 1979): *H. contortus* (Rudolphi 1803) Cobb, 1898 and *H. placei* (Place 1893) Ransom 1911. According to Lichtenfels et al. (1994), in North America a third species has been documented: *H. similis* Travassoss 1914. The taxonomic status of these species has been confirmed by DNA analyses (Stevenson et al. 1995; Blouin et al. 1997).

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H. contortus and *H. placei* are primarily parasites of sheep and cattle but have also been found in other undomesticated ruminants (Boch and Schneidawind 1988). *H. contortus* has frequently been reported in roe deer (*Capreolus capreolus*) (Table 1), in red deer (*Cervus elaphus*), and, sometimes, in fallow deer (*Dama dama*) in Europe (Table 2). In a previous study on the helminthofauna of deer in France (Ferté and Léger 1986) we found no *H. contortus*, although it had previously been reported by Klein (1985), but found species of the genus *Ashworthius* Le Roux, 1930.

Materials and methods

We examined 294 abomasa of wild roe deer and 25 abomasa of wild red deer between 1985 and 1998. The digestive tracts of hunter-killed roe deer were collected in four game-hunting regions of northern France: Bretagne (departments of Ille-et-Vilaine, Côtes d'Armor, Morbihan, and Loire-Atlantique), Ile de France (departments of Essonne and Seine-et-Marne), Champagne [departments of Marne and its surroundings (Aisne, Meuse), Ardenne, and Aube], and Alsace (departments of Bas-Rhin and Haut-Rhin; Fig. 1). A total of 234 abomasa of roe deer were collected during the hunting season (from October to February), but we obtained an additional 28 in spring and 15 in summer within the framework of a culling program (Essonne). In all, 17 samples were taken from animals found dead (Seine-et-Marne, Haut-Rhin, and Aube). Only hunter-killed red deer from the Champagne area (Marne, Aisne, and Ardennes) were examined.

The abomasa were sometimes emptied and washed freshly in the field, but most were defrosted digestive tracts stored at −20 °C before analysis. The contents were examined by naked eye in small portions placed into large petri dishes. The worms (males and females) recovered were stored in 70% ethanol and studied in temporary mounts after clearing with Amman lactophenol (10 g of phenol + 10 g of lactic acid + 20 g of glycerol + 10 g of distilled water). The morphological features used for identification were those proposed in the literature (Durette-Desset and Denke 1978; Ferté and Durette-Desset 1989; Lichtenfels et al. 1994; Jacquiet et al. 1997). Representative specimens were deposited at the Museum National d'Histoire Naturelle, Laboratoire de Biologie Parasitaire, Protistologie, Helminthologie, Paris, France, including *Ashworthius sidemi* Schulz 1933 (MNHN 873 MC and 874 MC), *A. gagarini* Kostyaev 1969 (MNHN 468 MC, 469 MC, 873 MC, and 874 MC), *Ostertagia leptospicularis* Assadov 1953 (MNHN 964 MC), *Spiculopteragia spiculoptera* (Guschanskaya 1931) Orloff

Table 1 Comparison of the prevalence and intensity of *Haemonchus contortus* infection in roe deer (*Capreolus capreolus*) in Europe (*Czechoslovakia* Czech Republic and Slovakia)

Countries	Authors	Number examined	Prevalence	Mean (range)
Great Britain	Dunn (1965)	65	18%	
Belgium	Bernard et al. (1988)	36	8%	6
Netherlands	Jansen (1958)	55	22%	
	Borgsteede et al. (1990)	88	3%	
Sweden	Nilsson (1971)	306	0.30%	
Germany	Schultze-Rhonhof (1968)	52	60%	42 (1–340)
	Ilg (1969)	45	47%	125 (1–629)
	Kavasch (1970)	51	58%	225 (2–1786)
	Haupt and Stubbe (1973)	58	17%	56 (1–500)
	Wolf (1976)	65	71%	265 (1–4060)
	Nickel et al. (1978)	91	7%	12 (10–60)
	Büttner (1978)	445	49–70%	131
	Rübsamen (1983)	65	69%	470 (27–3207)
	Zink (1989)	85	41%	49 (3–505)
	Spellmeyer (1996)	49	8%	
Switzerland	Andrews et al. (1974)	15	30%	
	Dollinger (1981)	213	12%	
Italy	Canestri-Trotti et al. (1988)	109	4%	
	Genchi et al. (1990)	24	8%	4
	Poglayen et al. (1996)	60	5%	6
	Zaffaroni et al. (1996)	49	14%	
Austria	Kutzer and Hinaidy (1969)	206	53%	
Bosnia	Delic et al. (1965)	34	3%	
Slovenia	Bidovec (1987)	144	12–85%	
Czechoslovakia	Dyk and Chroust (1974)	27	56%	(2–42)
	Kotrly and Kotrla (1980)	2308	21%	
	Vetyska (1980)	112	11%	(1–29)
	Farkas (1989)	198	63%	
Hungary	Kutzer et al. (1988)	66	18%	
Poland	Drozdz (1966)	93	48%	
	Drozdz et al. (1987)	70	34%	(1–104)
	Drozdz et al. (1992)	20	55%	7 (1–48)
Bulgaria	Jancev (1973)	45	4%	
Rumania	Stoican and Olteanu (1958)	8	42%	
Estonia	Yarvis (1977)	47	21%	
France	Klein (1985)	36	3%	15

Table 2 Inventory of Haemonchinae in red deer (*Cervus elaphus*) and fallow deer (*Dama dama*) in Europe (*Czechoslovakia* Czech Republic and Slovakia, + only mentioned)

Countries	Authors	Red deer		Fallow deer	
		Haemonchus	*Ashworthius*	*Haemonchus*	*Ashworthius*
Great Britain	Cameron and Parnell (1933)	+			
Belgium	Bernard et al. (1988)	12%			
Netherlands	Jansen (1958)	+		+	
Denmark	Guildal (1962)	+			
Germany	Barth (1972)	5%			
Austria	Hinaidy et al. (1972)	+		+	
Slovenia	Brglez and Bidovec (1985)	25%			
Czechoslovakia	Kotrly and Kotrla (1980)	24%	0.6%	4%	
	Farkas (1989)	35%			
Poland	Drozdz (1966)	13%		7%	

1933 (MNHN 965 MC), and *Haemonchus contortus* (Rudolphi 1803) Cobb 1898 (MNHN 966 MC).

Results

Both of the *Ashworthius* species *A. sidemi* and *A. gagarini* were found in the abomasa of roe deer and red deer along with *Spiculopteragia spiculoptera* and *Ostertagia leptospicularis*. *Haemonchus* species, found only in roe deer, were identified as *H. contortus*. We found *H. contortus* only in roe deer in Alsace. Double infections of *Ashworthius* and *Haemonchus* were not found in roe deer.

The prevalence of *Ashworthius* in roe deer was 22.1% (65/294 deer), but that of *Haemonchus* was only 3%

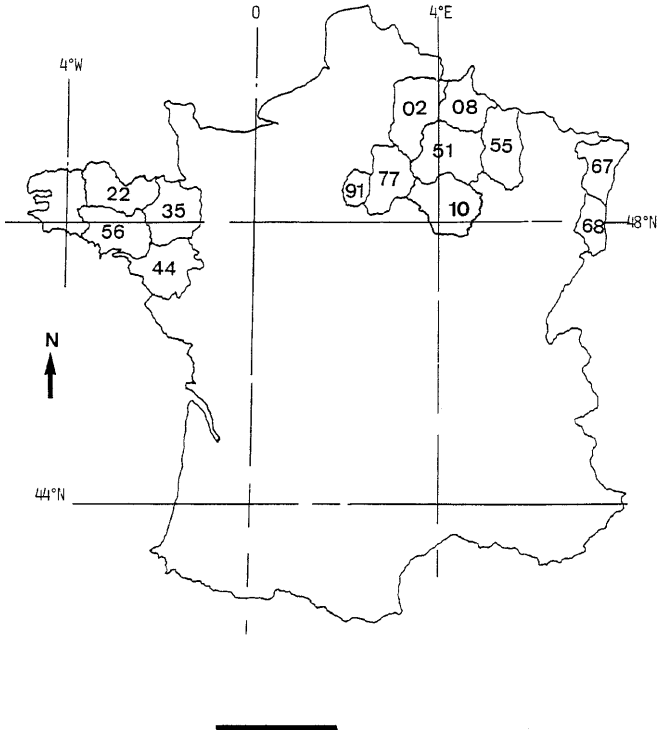

Fig. 1 Distribution of the areas investigated. Administrative numbers of French departments: *02* Aisne, *08* Ardennes, *10* Aube, *22* Côtes d'Armor, *35* Ille et Vilaine, *41* Loir-et-Cher, *44* Loire Atlantique, *51* Marne, *55* Meuse, *56* Morbihan, *67* Bas-Rhin, *68* Haut-Rhin, *77* Seine et Marne, *91* Essonne. *Bar* 200 km

(9/294 deer). Only one *H. contortus* was discovered in each of the two roe deer from Bas-Rhin; in the seven infected animals from Bas-Rhin the intensity was higher (mean ± SE 46 ± 29). In contrast, the mean intensity of *Ashworthius* was high, reaching 391 ± 73 (range 9–1268) in Bretagne, 105 ± 29 (range 3–578) in Marne, and up to 1500 in 4 roe deer found dead in Seine et Marne and in Aube. The ten red deer parasitized by *Ashworthius* spp. were from Marne (Table 3).

Discussion

We now agree with the setting of synonymy proposed by Drozdz et al. (1998), who recognize *Ashworthius gagarini* as a juvenile of *A. sidemi*. Among Cervidae apart from the sika deer, red deer, and roe deer, Drozdz (1973) has reported on *A. sidemi* from the sambar (*Russa unicolor*). The taxonomic status of *Haemonchus cervinus* Baylis and Daubney 1922 from *Axis* deer (*A. axis*) is doubtful because it has been described only from females. It is noteworthy that *Ashworthius* has not been found in cattle, sheep, or goat in Europe except for one experimental infestation. Furthermore, they have been found in two naturally infected, wild ungulate hosts: moufflon and European bison (Kotrla et al. 1976; Drozdz et al. 1998).

When European investigators found *Haemonchus* in wild ruminants they identified it as *H. contortus*. Swierstra et al. (1959) were the only investigators to report *H. placei* in the roe deer. Drozdz et al. (1989) have also identified *H. placei* in the bison (*Bison bonasus*). Moreover, they have previously reported *H. contortus* in the same host (Drozdz 1961).

As determined from the literature, the prevalence of *H. contortus* in roe deer is variable (0.3–70%). Nilsson (1971) has found only one roe deer with *H. contortus* in Sweden and notes that the parasite is equally rare in sheep. According to him, this is the consequence of the climate, which is too cold for the free stages of the parasite to thrive. On the other hand, at least one of two roe deer is infected by *H. contortus* in Austria (Kutzer and Hinaidy 1969), and the mean intensity is generally high in Slovakia (Farkas 1989) and in Germany (Schultze-Rhonhof 1968; Kavasch 1970; Büttner 1978; Rübsamen 1983; Zink 1989). In some countries the degree of prevalence may be locally high or low and, thus, the infection can be missed (Bidovec 1987). It seems that *H. contortus* has not been reported from red deer in either Switzerland (Dollinger 1985), Italy

Table 3 Results obtained in the present investigation in different areas of France

Regions	Departments	Roe deer			Red deer		
		Number examined	Prevalence *Ashworthius*	Prevalence *Haemonchus*	Number examined	Prevalence *Ashworthius*	Prevalence *Haemonchus*
Bretagne	Ille-et-Vilaine	15	13%	0			
	Côtes d'Armor	5	40%	0			
	Morbihan	28	82%	0			
	Loire-Atlantique	24	0	0			
Ile de France	Essonne	83	0	0			
	Seine-et-Marne	8	75%	0			
Champagne	Marne	49	45%	0	11	90%	0
	Aisne	6	16%	0	6	0	0
	Ardennes	11	0	0	8	0	0
	Aube	11	82%	0			
	Meuse	8	0	0			
Alsace	Bas-Rhin	5	0	40%			
	Haut-Rhin	41	0	17%			

(Genchi et al. 1990), or Bulgaria (Jancev 1976). The degrees of prevalence and intensity of *H. contortus* are lower in red deer than in roe deer, the highest rates being reported in Slovenia (Brglez and Bidovec 1985) and Slovakia (Farkas 1989). Other wild ungulates such as moufflon (*Ovis musimon*) and bison (*B. bonasus*) are also considered good hosts of *H. contortus*. The infection of deer is considered to be a consequence of sympatry with these hosts (Bernard et al. 1988).

As a result of our investigation we find that the genus *Ashworthius* is common in French cervids, in contrast to what has been reported in other European countries. Kotrla and Kotrly (1973) have mentioned the presence of *A. sidemi* in sika deer and, later, in red deer and moufflon sympatric with sika deer (Kotrla et al. 1976). Thus, the presence of *A. sidemi* in roe and red deer in France suggests the possibility of the parasitic transfer from introduced sika deer suggested by Kostyaev (1969) and Ryskoskii (1986) in Russia and by Kotrla and Kotrly (1977) in Czechoslovakia.

The predominant subspecies of sika deer introduced in occidental Europe is represented by the Japanese sika deer *Cervus nippon nippon*, Temmink, 1838 (= *C. nippon*); this does not apply to Russia, where the Dyboswski sika deer *C. n. hortulorum* Swinhoe, 1864 (= *Pseudaxis hortulorum*) is more abundant. In general the history of the first introduction is known worldwide; nevertheless, the history of acclimatization and population dynamics is not well documented (Lever 1985). In 1890, one male and three females were introduced into France as a gift from the Emperor of Japan to President Sadi Carnot. These sika deer (*C. nippon*) thrived well in the national game-hunting reserves of Marly and Rambouillet. Thus, according to Beaufort (1984), sika deer would have three geographic origins in France: Japan (*C. n. nippon*), Manchuria (*C. n. mantcharicus*), and Tonkin (*C. n. hortulorum*). This quick adaptation allowed further releases of animals from the initial population, first in enclosed areas such as Chambord and then in open forests at the beginning of the twentieth century. Until World War II their distribution was known (Vidron 1939). However, it is presently difficult to report precisely the size of a population of sika deer in France. The latest data suggest that since 1920, releases have been made in 28 departments, particularly in the Northeast. Furthermore, 4 populations have been documented in Seine-et-Marne, Var, Alpes-Maritimes, and Haut-Rhin (Beaufort 1984).

Chambord in Loire-et-Cher and Petite Pierre in Bas-Rhin are considered as stock reserves where red deer are being caught for subsequent introduction or reintroduction into different French departments (Bonnet and Klein 1991). Between 1955 and 1991, red deer from Chambord were sent to Marne ($n = 224$ animals), Aube ($n = 77$), and the forest of Paimpont in Bretagne ($n = 26$). The presence of *Ashworthius* in red deer was again reported in Chambord in 1987 as well as in the departments of Marne, Aube, and Bretagne (forest of Paimpont). This suggests that they originated from the newly introduced, infected red deer. Likewise, releases in the Seine-et-Marne department have been carried out close to the territory in which most of our observations on the presence of *Ashworthius* in roe deer have been made. The contamination might also be attributable to the population of sika deer in Armainvilliers and Ferrières. Although red deer from Chambord have been introduced in Essonne, in Ardennes, in Meuse, and in Loire-Atlantique, the absence of *Ashworthius* can be explained by the relatively great distance between the sectors of study and the introduction sites, most of which involve private parks. In Alsace the population of sika deer in the forest of Hardt is geographically well isolated from the northwestern part of the area of our study, particularly from the reserve of Petite Pierre, where red deer from Chambord and sika deer have never been introduced (Fig. 2). Our results do not differ from those reported by Klein (1985). On the other hand, infection of roe deer by *Haemonchus* can be explained mainly by the presence of domestic ruminants as reservoirs.

In our opinion, the main spread of *Ashworthius* is a consequence of the behavior of the red deer (*C. elaphus*), which is a gregarious species capable of traveling a great distance to settle in a new habitat. In most cases the establishment of infection in roe deer is certainly secondary. Currently, the effect of parasitism by *Ash-*

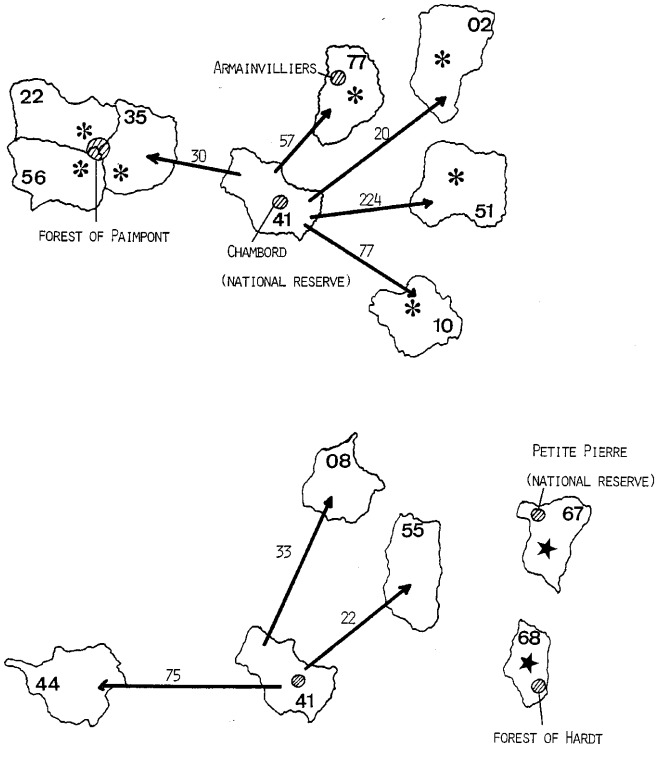

Fig. 2 Release of red deer (*Cervus elaphus*) from Chambord in the areas investigated. *Asterisks* indicate the presence of *Ashworthius sidemi* in roe deer (*Capreolus capreolus*), *stars* signify the presence of *Haemonchus contortus* in roe deer (*C. capreolus*), $^{30}\rightarrow$ indicates the number of red deer (*C. elaphus*) originating from Chambord that were located to different areas

worthius on the physical condition of wild animals cannot be exactly assessed. Nevertheless, the discovery of many of these bloodsucking worms in roe deer found dead indicates that their pathogenicity is comparable with that of *H. contortus* in sheep. Other helminth parasites have been successfully introduced via exotic deer (Suarez et al. 1991; Rickard et al. 1993). Although the impact differs from that of *Fascioloides magna* in Italy (Balbo et al. 1987, 1989), this situation must be taken into account in the management of free-living populations.

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