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## Factors Affecting *Dirofilaria immitis* Prevalence in Red Foxes in Northeastern Spain

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**ABSTRACT:** We determined the prevalence of *Dirofilaria immitis* (Nematoda, Filariidae) among 433 red foxes (*Vulpes vulpes*) in northeastern Spain, between 1990 and 1992. Forty-six (11%) of 433 foxes were infected; the intensity ranged from 1 to 36 (mean  $\pm$  SE;  $4.39 \pm 0.92$ ) nematodes per host. The prevalence of *D. immitis* was higher in foxes inhabiting riparian zones of the study area. This population has a very high juvenile/adult ratio. Heartworm prevalences did not differ among host sex, weight, or fat condition categories.

**Key words:** Heartworm, *Dirofilaria immitis*, red fox, *Vulpes vulpes*, prevalence.

*Dirofilaria immitis* (Nematoda, Filariidae) has been reported parasitizing a variety of wild canids (Agostine and Jones, 1982; Starr and Mulley, 1988).

In the red fox (*Vulpes vulpes*), the canine heartworm has been found with 8.8% prevalence in Australia (Mulley and Starr, 1984), 6% in Missouri (USA) (Wixsom et al., 1991) and, more recently, 21% foxes imported into South Carolina (USA) (Davidson et al., 1992). In Spain some communications on red fox parasites have been presented at national meetings, but this is the first detailed survey published on dirofilariasis in red foxes in Spain.

Prevalence of infection may vary with geographic location, habitat, densities of mosquito vectors and definitive hosts, and climatic conditions (Wixsom et al., 1991). Our objective was to describe the differences in heartworm prevalence in foxes from different habitats and in different host age classes.

Red fox carcasses were collected from

hunters between January 1990 and June 1992. The geographical origin of the 433 specimen was classified into four main habitats: Pyrenee Mountains and their surroundings, in the northern part of the study area (42°15' to 42°45'N, 1°00'W to 0°30'E;  $n = 17$  carcasses); semiarid cereal land ( $n = 233$ ) and irrigated land close to the main rivers of the region ( $n = 130$  carcasses) in the Central Ebro Valley (41°00' to 42°15'N, 1°45'W to 0°30'E) and the Iberian Mountains, in the southern part of the study area (40°30' to 41°00'N, 1°30'W to 0°30'E;  $n = 52$  carcasses).

Each fox was weighed, measured (total length in cm), and its sex determined. We estimated fat condition by inspecting visually the opened abdomen assigning each animal to one of five categories (1: no fat at all; 2: small amounts of fat present only at kidneys; 3: kidneys partially covered by fat, small amounts of visceral fat present; 4: kidneys nearly completely covered by fat, abundant visceral fat and some abdominal subcutaneous fat present; category five: very fat on all three). When the head was available, teeth from adult foxes and those of questionable age were aged histologically at Matson's Laboratory (Milltown, Montana, USA) by counting the cementum rings (Jensen and Nielsen, 1968). The heart, pulmonary artery and lungs of the 433 red foxes were opened carefully with scissors and examined visually for the presence of *Dirofilaria immitis* adults. *Dirofilaria immitis* adults were stored in 2% formalin before deter-

mining sex using the appearance of the tail region of the nematodes. Poor condition of most carcasses did not allow the detection of microfilariae in blood. Parasite specimens were deposited in the Unidad de Parasitología y Enfermedades Parasitarias (Zaragoza University, Spain) with the accession numbers VVDI01 to VVDI46.

The chi-square test was used for comparing categorical data and Student's *t*-test was used for comparing numerical data (Sokal and Rohlf, 1979).

Total *Dirofilaria immitis* prevalence for the whole study area was 46 (11%) of 433 foxes, varying greatly with habitat. Sixty-nine foxes from the Iberian and Pyrenee Mountains had no *D. immitis*. Foxes from the cereal land of the Middle Ebro Valley had a very low prevalence, with only four (1.7%) of 233 animals infected. Foxes collected on the irrigated land had the highest prevalence with 42 (32%) of 130 animals infected.

The prevalence of infection with *D. immitis* varied significantly with age of the host. The youngest fox with adult heartworms was an 8-mo-old male with three nematodes in his right ventricle. Foxes <13 mo had a significantly ( $P < 0.05$ ) lower prevalence (22%,  $n = 63$ ) than those >13 mo (42%,  $n = 41$ ). *Dirofilaria immitis* occurred in 29 (41%) of 70 males and in 14 (23%) of 60 females. The difference was not significant. Fat condition and weight of adult males and females of endemic area did not vary significantly ( $P > 0.60$ ) among infected and non-infected foxes.

Intensity varied between 1 and 36 adult nematodes per host, with a mean ( $\pm$ SE) of 4.39 ( $\pm 0.92$ ). This intensity did not vary significantly with geographical origin, age, sex, weight or fat deposits of the foxes. Frequency of unisexual infestations was 43.5%. Twelve times only females and eight times only male nematodes were collected.

Intensity was lower than that reported by Arriolabengoa Igarza et al. (1992) in stray dogs (*Canid familiaris*) of north-eastern Spain (range 1 to 41, average 11.1). Intensities given by Wixsom et al. (1991)

and Davidson et al. (1992) in red foxes were similar to our findings. Frequency of unisexual infestations was similar to the values reported for *Canis latrans* by Weinmann and García (1980) and for dingos (*Canis familiaris dingo*) by Starr and Mulley (1988).

In the endemic irrigated land, the prevalence of foxes >3 yr old (4 out of 128, 3%) was lower than in areas where the heartworm was nearly absent (26 out of 202; 13%) in the semiarid land. Juveniles made up 75% (96 of 128) of the winter population in the riparian area and only 48% (98 of 202) in the semiarid area. Fox populations with a high predominance of young individuals usually are associated with heavy hunting (Harris and Smith, 1987). Nevertheless, the apparent hunting pressure was much lower in the irrigated area than in other habitats in our study area. Considering this, we suggest that *D. immitis* could be an important direct or indirect cause of mortality in adult foxes of this local population. Agostine and Jones (1982) reported similar age-related differences in the prevalence of *D. immitis* among coyotes (*Canis latrans*), and speculated that the increased young/adult ratio may reflect a population decrease due to a stress factor such as heartworm. Other authors (Wixsom et al., 1991) also propose that *D. immitis* may be an important factor in mortality of wild canids.

Nevertheless, other unidentified factors also could contribute to the age structure of the irrigated land fox population, such as increasing accident ratios due to higher human presence, high immigration of dispersing young foxes from surrounding areas, and other parasitic or infectious agents. Identification of *Dirofilaria immitis* as a major factor in red fox population dynamics in endemic areas needs more investigation, especially the study of differential mortality in radio-tagged infected and non-infected individuals.

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