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INFECTION OF ROE-DEER IN FRANCE BY THE LUNG NEMATODE, *DICTYOCAULUS ECKERTI* SKRJABIN, 1931 (TRICHOSTRONGYLOIDEA): INFLUENCE OF ENVIRONMENTAL FACTORS AND HOST DENSITY

L. Hugonnet[1] and J. Cabaret[2]

ABSTRACT: The prevalence of the lungworm, *Dictyocaulus eckerti*, was studied in a sample of 603 roe-deer (*Capreolus capreolus*) in the Rhone district of France. The mean prevalence of infection (17%) in deer in a given area fluctuated according to the percentage of the area covered with forest, or lake and river. The density of roe-deer or domestic ruminants, the type of forest and the maximum elevation of the site were not related to the prevalence of infection.

INTRODUCTION

Dictyocaulus eckerti has been reported in roe-deer (*Capreolus capreolus* L.) from the U.S.S.R. (Skrjabin et al., 1971; Kazlauskas and Puzauskas, 1974), Rumania (Stoican and Olteanu, 1959), Bulgaria (Jancev, 1965) and France (Hugonnet et al., 1980). *Dictyocaulus viviparus* and, more rarely *Dictyocaulus filaria* have been reported elsewhere in roe-deer, but misidentification of *D. eckerti* may have occurred.

Only limited information is available on the relationship of local environmental factors (Kazlauskas and Puzauskas, 1974) or host density on infections of *D. eckerti* in roe-deer. However, it is known that host density (Keith et al., 1985) or type of vegetation (Samuel and Trainer, 1969) may influence the prevalence of certain helminths in wild herbivores.

The present study on lungworms of roe-deer was initiated in the Rhone district of France in order to assess the influence of host densities and selected environmental parameters on the prevalence of *D. eckerti*.

MATERIALS AND METHODS

A total of 606 hunter-killed roe-deer was studied from 1981 to 1983. They were obtained from October to January of each year and 47% of them were less than 2 yr old. They originated in 130 parishes distributed throughout seven regions of the Rhone district. Fifty-six percent of the animals came from Beaujolais Mounts, 21% from Plateau and Mounts of Lyon and the rest from other areas (Fig. 1). The protocol for recovery of lung nematodes has been described (Euzeby, 1982); only qualitative information was recorded for each animal (infected or non-infected).

Six parameters were studied in each region of the district (Table 1). These included the number of roe-deer per 100 ha of forest, percentage of area covered with forests, and the respective percentage of oak (*Quercus robur* L.), chestnut (*Castanea sativa* Miller), pines (*Pinus pinaster* Aiton and *Pinus* spp.) and Douglas-fir (*Pseudotsuga menziesiis* (Mirbel) Franca). The percentage of area covered with forest was very high (51%) in the Beaujolais Mounts region and low (9%) in the Saone valley and Beaujolais vineyard regions. Hardwood communities represented 83% of the forest coverage in the two last regions and only 28% in the Beaujolais Mounts. For each parish the following parameters were estimated: minimum and maximum elevation above sea level (m), area covered with lakes or river (percentage of total surface), number of cattle, sheep and goats per ha of pasture, percentage of total area covered with forests.

In parishes of low population density, results of necropsies were grouped in order to have

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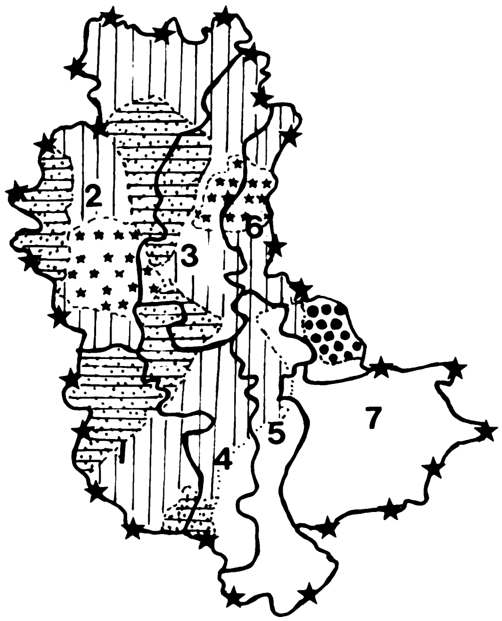

FIGURE 1. Density of roe-deer in the seven regions of the Rhone district in France. The regions as numbered are: 1. Lyonnais Mounts, 2. Beaujolais Mounts, 3. Beaujolais Vineyards, 4. Lyonnais Plateau, 5. Fruit production area, 6. Saone Valley, and 7. Plain of Lyon. Densities of roe-deer are indicated as follows: Solid circles (5–10 deer/ha), stars (3–5 deer/ha), horizontal lines and stipples (2–3 deer/ha), perpendicular lines (1–2 deer/ha) and clear areas (<1 deer/ha). Solid lines indicate limits of regions and lines with large stars indicate limits of the district.

figures established on at least five animals. Thus, 59 geographical groups (parishes or groups of similar parishes) were analyzed using ordinary coefficient of correlations or Spearmann rank correlations when distributions of data were aggregated. A multilinear model (Lebart et al., 1982) was utilized also on crude or transformed data.

Representative specimens of the lungworms recovered in this study were deposited in the Museum National d'Histoire Naturelle (Zoologie-Vers), 61 Rue de Buffon, 75231 Paris, France (*Capreolus capreolus*, "Les sauvages" France; *Dictyocaulus eckerti* Poumons 503 MC).

RESULTS

The characteristics of infections by *D. eckerti* are presented in Table 1. The heterogeneity of geographical units is partic-

TABLE 1. Infection of roe-deer in France by the lungworm, *Dictyocaulus eckerti*, and various characteristics of the environment.

Parameter	Average (range)	Coefficient of variation
Prevalence of *D. eckerti*	17 (0–100)	118
Regional parameters		
No. of roe-deer/100 ha of forest	2.6 (1–6)	22
Forest: percentage of total area	38 (9–51)	46
Percentage of forest covered with oak	30 (22–52)	37
Chestnut	5 (2–11)	67
Pine	24 (0–36)	66
Douglas-fir	13 (0–18)	56
Parish parameters		
Maximum elevation above sea level (m)	783 (310–1,012)	20
Difference between max-min elevation above sea level (m)	373 (105–625)	34
Area covered by lakes or rivers (% of total area)	1.5 (0–14)	173
Forest: percentage of total area	37 (6–71)	50
No. of cattle (per ha of pasture)	1.1 (0.4–2)	33
No. of goats	0.2 (0–0.6)	77
No. of sheep	0.6 (0–4.1)	107
No. of roe-deer shot per ha of forest	0.04 (0.01–0.20)	76

ularly high for the percentage of area covered with lakes or rivers, the number of small ruminants per hectare of pasture and the number of roe-deer shot per hectare of forest.

The density of deer and various environmental parameters were interrelated. The following significant relationships were recorded: (1) The density of the populations of roe-deer (estimated per 100 ha

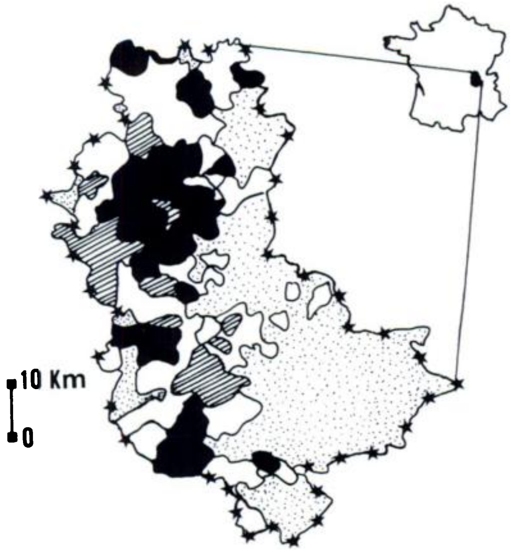

FIGURE 2. Geographical distribution and prevalence of *Dictyocaulus eckerti* in roe-deer in the Rhone district, France. Mean prevalences (%) are indicated as follows: solid black (>20), cross hatching (1–20), clear areas (0), and stippling (areas not sampled). Lines with stars indicate limits of the district.

of forest) was negatively correlated with the altitude ($r = -0.32$) and to the percentage of the area covered by lakes or rivers ($r = -0.28$). (2) The density of cattle populations (estimated per ha of pastures) was negatively correlated with the percentage of forest cover and to the density of the population of small ruminants in the parish; higher densities of goats were associated with the percentage of forest cover, altitude and a reduced percentage of the area with lakes and rivers. The number of sheep per ha of pasture was independent of any environmental factors. (3) The percentage of forest cover was highly correlated ($P < 0.01$) to the presence of fir ($r = 0.99$) or absence of oak ($r = -0.99$) or chestnut trees ($r = -0.75$), to altitude ($r = 0.40$), and to the difference between maximum and minimum elevation above sea level ($r = 0.60$).

The prevalence of *D. eckerti* was unevenly distributed in the study area (Fig. 2) and was positively correlated with the percentage of area covered with forests ($r = 0.32$), the percentage of pine cover ($r = 0.29$) or Douglas fir, differences between maximum and minimum elevation above sea level and negatively to abundance of oaks in forests ($r = 0.31$). As the characteristics were interrelated, several sets of multilinear regressions were established (Table 2). Prevalence of infection was best related to the percentage of the total area of the region covered by forest and the percentage of the area covered by lakes or rivers in the parish.

DISCUSSION

The prevalence (103/606 = 17%) of roe-deer infected by *D. eckerti* was higher than the 10% observed in roe-deer of Lithuania (Kazlauskas and Puzauskas, 1974) and lower than the 25–50% observed in Rumania (Stoican and Olteanu, 1959).

TABLE 2. Quantitative relationships between prevalence of infection by the lungworm *Dictyocaulus eckerti* in roe-deer in France and selected variables of the environment.

Regressions[a]	R^2[b]	P[c]
PINF = −0.73 + 0.05FOREr	0.10	0.01
PINF = −0.80 + 0.05FOREr − 0.24WATEp	0.14	0.02
PINF = −10.04 + 1.88DMMEp − 0.25WATEp	0.13	0.02

[a] Abbreviations are as follows: PINF = Percentage of infected roe-deer (Neperian logarithm, constant: +0.1); FOREr = percentage of total area covered by forest; WATEp = area covered by lakes or rivers (Neperian logarithm, constant: +0.01); DMMEp = difference between maximum and minimum elevation above see (m); indices r and p stand, respectively, for region or parish.

[b] R^2 = square of multiple coefficient of correlation.

[c] P = level of significance.

There could be a sampling bias as deer in poor condition were selectively shot, especially at the beginning of the hunting season. Thus it is possible that our figures overestimated the prevalence of *D. eckerti.*

Attempts to relate parasitic risk and environmental characteristics are rare for wild ruminants but this approach may prove worthy. Samuel and Trainer (1969) demonstrated that infections of *Nematodirus fillicollis* in white-tailed deer (*Odocoileus virginianus*) were more prevalent in southern oak prairie vegetation than in central pine and northern hardwood communities of Wisconsin. Regions at risk for *D. eckerti* infection were characterized by the percentage of forest cover, the absence of lakes and rivers, and the existence of a high difference between maximum and minimum elevation above sea level. The type of vegetation did not seem to exert any direct influence on infection in our case. The relationship between lungworm infections and the percentage of the area covered by pines was probably a reflection of the fact that large forests were mostly composed of pines. The density of deer was not related to the prevalence of *D. eckerti*; this may have been due to the narrow range of density. The way we assessed risk factors has certain limitations and accurate data on the ethology of roe-deer are required, especially during the rut when deer concentrate on smaller areas.

The prevalence of *D. eckerti* in roe-deer was not related to the presence of domestic ruminants and this finding may partially support the idea that roe-deer and domestic ruminants harbor different species of *Dictyocaulus* (Stoican and Olteanu, 1959; Jancev, 1965; Hugonnet et al., 1980). This question is still open, however, and might be answered by experimental attempts at cross-transmission between roe-deer and cattle.

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