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DESCRIPTIVE EPIDEMIOLOGY OF ROE DEER MORTALITY IN SWEDEN

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ABSTRACT: A retrospective epidemiologic study was conducted to examine causes of mortality of 985 wild roe deer (*Capreolus capreolus*) submitted to the National Veterinary Institute (SVA; Uppsala, Sweden) from January 1986 to December 1995. Age, sex, body condition, and geographic distribution as related to disease conditions are reported herein. The most common causes of mortality in roe deer were trauma (19%), winter starvation (18%), gastritis/enteritis (15%), bacterial infections (11%), parasitic infection (11%), systemic diseases (11%), neoplasia (2%), congenital disorders (1%), and miscellaneous causes (6%). Cause of death was not determined in 6% of the cases. The distribution of causes of death reported in this study differ from previous works in Sweden in that infectious and parasitic diseases were more common than winter starvation. The pathologic findings in studies like this do not necessarily represent what is occurring in the natural environment, but they do provide a good indication of distribution of diseases over time as well as age and sex structure in relation to disease conditions. Further research and more detailed studies are in progress to better understand specific mortality factors as well as etiologies of certain described diseases in roe deer in Sweden.

Key words: *Capreolus capreolus,* diseases, malformations, mortality factors, neoplasia, retrospective survey, roe deer, starvation.

INTRODUCTION

The roe deer (*Capreolus capreolus*) population in Scandinavia has steadily increased from near extinction in the late 1800's, following the extermination of large predators and removal of domestic livestock from forest grazing (Wahlström and Liberg, 1995), to stabilizing at approximately 250,000 animals in Sweden by the mid-1900's. A dramatic increase in the population was observed in the 1980's and 1990's. Today, roe deer are the most abundant species of Cervidae in western Europe with about one million animals in Sweden. This population increase is attributed to a reduction in the red fox (*Vulpes vulpes*) population due to an epizootic of sarcoptic mange (Mörner, 1992) and to extremely mild winters for several years.

Studies based on carcass collections generate important data on the relative age and sex structure of dead individuals and provide a method for mortality estimation (Linnell et al., 1995; Mörner, 1992). The distribution of different diseases and causes of death over time provide valuable information on new diseases and environmental factors influencing wildlife health. Winter starvation, during periods of lower roe deer density, hard winters, and deep snow cover, have been reported as the most common causes of death in roe deer from Sweden (Borg, 1970, 1991).

The objective of this retrospective epidemiologic study was to report the results of diagnostic examinations from roe deer submitted for necropsy to the National Veterinary Institute (SVA, Uppsala, Sweden) from 1986 to 1995. In addition, the study provides epidemiologic information on incidence, prevalence, temporal, and geographic distribution of diagnosed conditions.

MATERIALS AND METHODS

We compiled records from 985 post-mortem examinations performed on roe deer carcasses received and stored by SVA from January 1986 to December 1995. These records are part of SVA's wildlife mortality data base for the country and most are kept for diagnostic purposes. The animals submitted were either found dead, euthanized for animal welfare reasons, or shot during the normal hunting season and subse-

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quently submitted when there was evidence of disease. Routine procedures performed upon arrival of dead animals included determination of sex, age, body weight, body condition, and a comprehensive postmortem examination. Tissues and organs were submitted for complete histopathologic, bacteriologic, parasitologic, and toxicologic evaluations. Following detailed gross pathologic examination by a veterinary pathologist, tissues from all organs were collected for histopathological examination and fixed in 10% buffered formalin. Selected tissues were embedded in paraffin, sectioned 6-μm thick and stained with the hematoxylin and eosin stain. Special stains were used following protocols previously established (Luna, 1968). For electron microscopy, tissue blocks were fixed in 2% osmium tetraoxide (OsO_4) in 0.2 M Sorensen phosphate buffer pH 7.3 for 30 min and then washed twice with the same buffer solution for 10 min. Sections one mm-thick were cut and stained with toluidin blue for light microscopy. Ultra-thin sections were cut and stained with uranyl acetate and lead nitrate, and examined with a transmission electron microscope (Brancroft and Stevens, 1992).

For bacteriology, pieces of selected organs were aseptically collected and placed in Modified Stuart's Bacterial Transport Medium for anaerobic and aerobic bacteria (COPAN, Uppsala, Sweden). In addition, fecal material and sections of gastrointestinal tract were placed in commercial Amies transport medium for *Salmonella* spp. and other aerobic and anaerobic bacteria (COPAN). Following incubation of tissues or materials in transport media, these were cultured on blood agar (5% sheep blood), MacConkey agar for *Salmonella* and trypticase soy agar (Unipath Ltd., Hampshire, UK). Plates were incubated at 37 C aerobically, then examined after 24 hr. If there were little or no growth, plates were incubated for an additional 24 hr. Each distinctive colony, based on color, texture, and growth pattern was treated as a separate organism. Microorganisms were separated based on Gram reaction and morphology. Gram negative bacteria were biochemically identified following the traditional system or by the API 20E System (Sherwood Medical, Plainview, New York, USA). Gram positive bacteria were identified based on colonial and cellular morphology. Virologic examinations were not performed during this time period.

For parasitology, fecal samples were examined using direct microscopic examination, sodium nitrate flotation, and sedimentation (Georgi, 1985). In addition, adult nematodes, cestodes, acanthocephalans, trematodes, and ectoparasites were removed during gross necropsies and fixed in 5% warm buffered formalin, glycerin or AFA solution prior to identification by the parasitologist at SVA. Histopathological examination for specific parasites was performed from lesions in lungs, liver, bile duct, kidneys, heart and spleen. Hematozoan parasites were identified by light microscopy of blood, liver, and/or spleen smears.

The primary diagnosis was described as the main disease of the animal and the probable cause of death. This diagnosis was based on the postmortem examination and, when available, combined with histopathologic findings and laboratory results. Diagnoses were divided into major categories including traumatic injuries, starvation, gastritis/enteritis, bacterial infections, systemic diseases, parasitic diseases, neoplasia, congenital disorders, and miscellaneous causes. Definitive diagnosis of specific conditions was not always possible due to autolysis of the carcass or lack of extensive laboratory work. In these cases we designated the cause of death as unknown.

Age was determined by inspection of tooth replacement and wear in the mandible teeth (Ratcliffe and Mayle, 1992). Age classification included four categories: fawns (<1-yr-old), yearlings (1- to 2-yr-old), prime-age adults (2- to 7-yr-old), and old adults (>7-yr-old). Physical condition was assessed by deposition of adipose tissue, muscle mass, and body weight. Condition categories included (1) emaciation, (2) poor, (3) good or normal, and (4) excellent. Geographic distribution is reported based on the number of animals submitted from each of the 25 Sweden Administrative Divisions (Fig. 1). Statistical analyses were performed using Excel version 7.0 (Microsoft Corp., Roselle, Illinois, USA). Statistical analyses applying one-way ANOVA, Kruskal-Wallis, and Student's *t*-tests were performed. Differences were identified for mean values among groups related to physical condition, geographic distribution, age, sex, weight, and disease condition. Results were considered statistically significant at $P \leq 0.05$. Data were expressed as mean and standard deviation (SD) of values for each parameter.

RESULTS

Most roe deer carcasses were submitted from Uppsala (26%), Stockholm (19%), Kalmar (8%), Alvsborgs (6%), Malmohus (5%), Sodermanland (5%) and Ostergotland (5%) counties (Fig. 2). The lowest number of roe deer carcasses was submitted from the four north counties (Vastermorrland, Jamtland, Vasterbotten and Norrboten).

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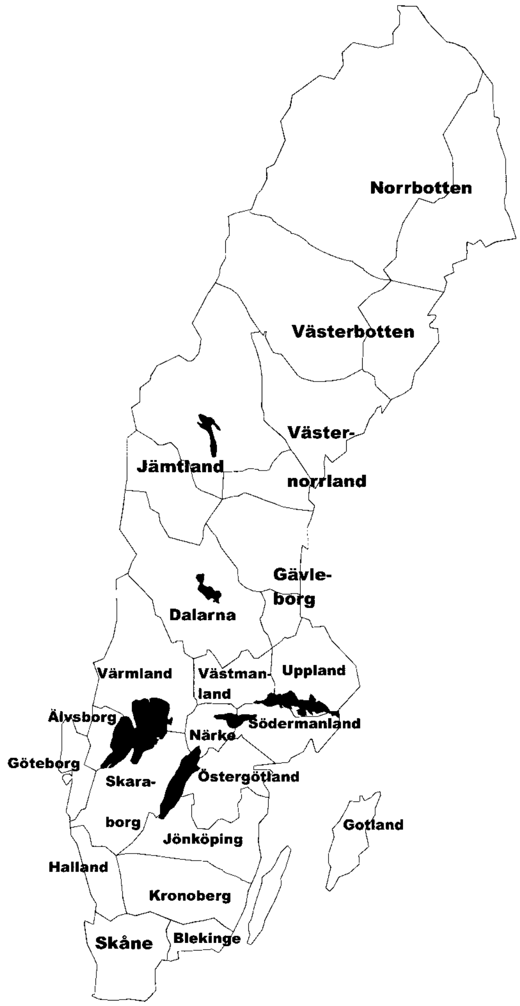

FIGURE 1. Distribution map of the administrative divisions of Sweden.

Number and sex of roe deer submitted to SVA were compiled for each year (Fig. 3) and each month (Fig. 4). During the 10 yr period, 506 females and 452 males were examined (Fig. 5). The sexes for 27 deer were not recorded. Although significantly more yearling males (M) than females (F) and more old females than males were submitted in the ten-year period ($P \leq 0.05$), the sex ratio 0.9M:1.0F using all individuals sexed was not statistically different from 1:1.

Assessment of physical condition showed 519 roe deer were emaciated, 184 deer in poor condition, 229 deer in good condition, and one deer in excellent condition. The body condition of 52 deer was not recorded. Significant differences ($P \leq 0.05$) were found when mean weights were compared between fawns ($n = 350$; $\bar{x} \pm \text{SD} = 11.4 \pm 0.2$ kg), yearlings ($n = 105$; 16.6 ± 0.5 kg) and prime age adults ($n = 237$; 20.3 ± 0.3 kg), but not between the later group and old adults ($n = 180$; 20.2 ± 0.3 kg). In addition, mean weight differences were significant between deer we classified as emaciated ($n = 530$; 14.7 ± 0.2 kg,), poor condition ($n = 186$; 17.5 ± 0.4 kg), and in good condition ($n = 211$; 19.6 ± 0.5 kg).

Mortality factors identified in roe deer are given in Table 1. Traumatic injuries were a result of predation, motor vehicles, gunshot, or antler punctures from other roe deer bucks. Mortality due to starvation occurred during late winter and early spring, with 87% of the cases occurring between January and April. At necropsy, starvation was characterized by atrophy of body muscles, reduced amount of fat (body fat, bone marrow fat, and cardiac fat), little contents in the rumen, hard and dry ingesta in the intestines and absence of major pathologic changes or infections. The age class distribution of animals dying of starvation was 51% fawns, 9% yearlings, 12% prime age adults, and 24% old adults. Age was not recorded in 4% of the winter starvation cases.

Several of the cases diagnosed with gastroenteritis (50/144) have been associated with a chronic wasting condition of unknown etiology characterized by catarrhal to hemorrhagic gastroenteritis, diarrhea, colitis/typhlitis, and occasionally, ulceration of the oral mucosa, abomasum, and rumen, lymphadenopathy, and hepatic disease. Of the deer diagnosed with bacterial infection, pneumonia was the most common lesion ($n = 77$). The etiologic agent of infectious pneumonia was in most cases not identified due to tissue autolysis and overgrowth of unspecific bacterial flora; however, *Haemophilus* spp., *Pasteurella haemolytica, P. multocida*, and *P. pneu-*

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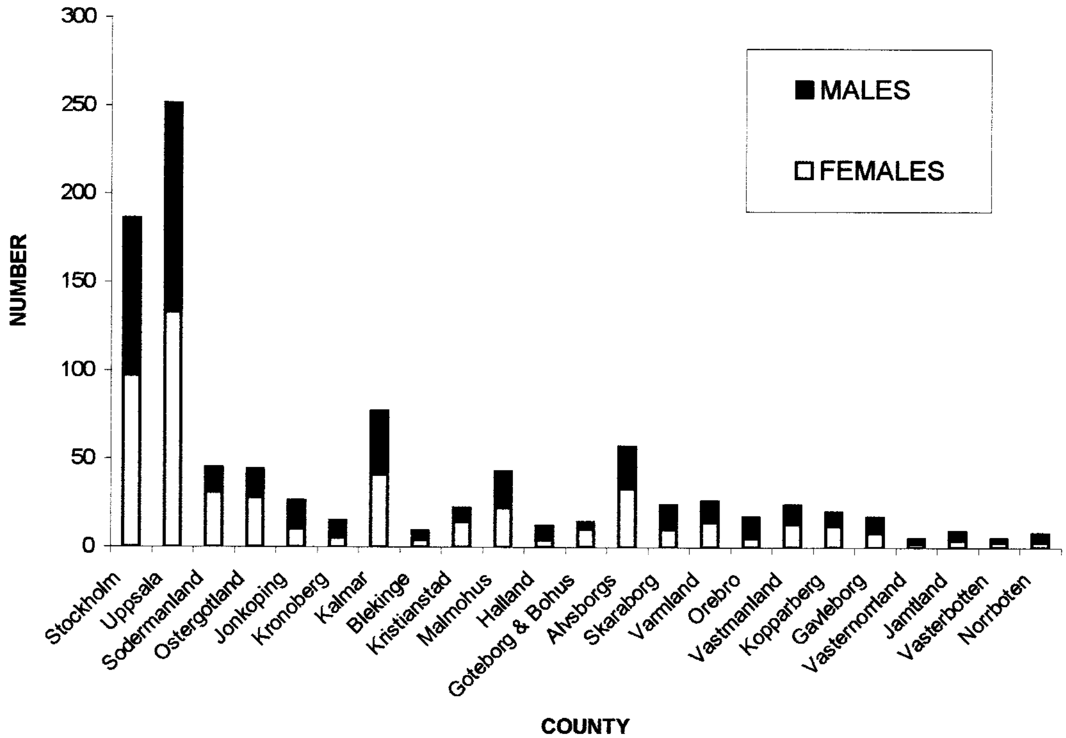

FIGURE 2. Total number of roe deer carcasses classified by county and sex submitted to the National Veterinary Institute, Uppsala, Sweden, 1986–1995.

motropica were isolated in eight cases of purulent pneumonia. In cases where no bacteria could be isolated or overgrowth of unspecific flora occurred, the diagnosis was based on gross/histologic findings. Systemic bacterial infections were seen with *Escherichia coli* (n = 10), *Listeria monocytogenes* (n = 8), *Mycobacterium avium* (n = 5), *Actinobacillus* sp. (n = 4), *Yersinia pseudotuberculosis* (n = 4), and *Clostrid-*

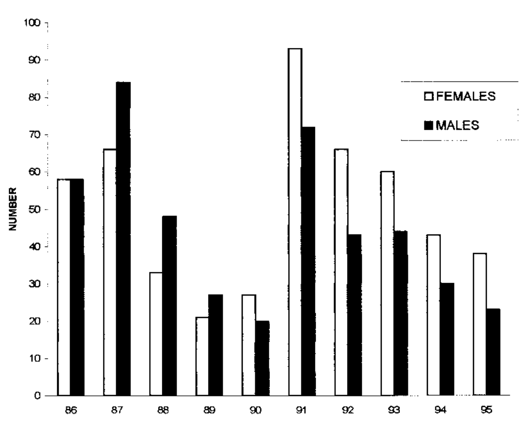

FIGURE 3. Total number of roe deer carcasses classified by sex class and year submitted to the National Veterinary Institute, Uppsala, Sweden, 1986–1995.

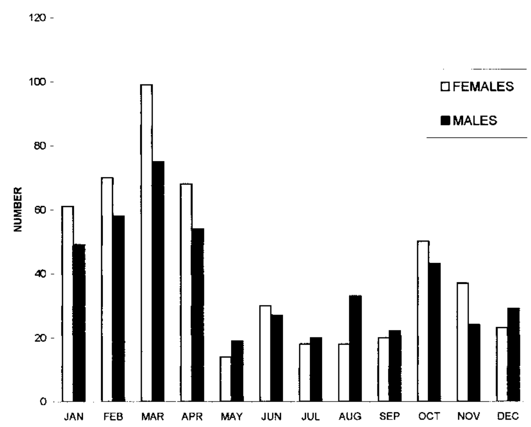

FIGURE 4. Total number of roe deer carcasses classified by sex class and month submitted to the National Veterinary Institute, Uppsala, Sweden, 1986–1995.

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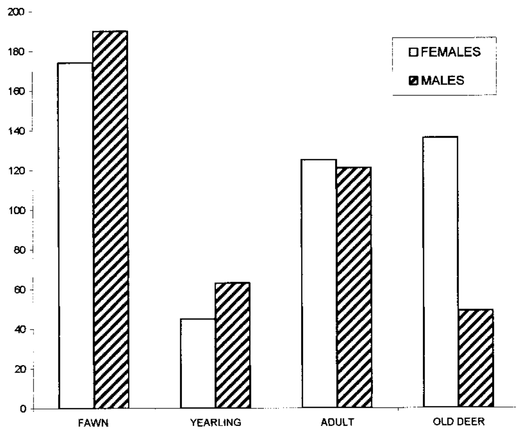

FIGURE 5. Total number of roe deer carcasses classified by sex and age classes submitted to the National Veterinary Institute, Uppsala, Sweden, 1986–1995.

ium perfringens ($n = 2$). All cases of mycobacteriosis herein were associated with the wood pigeon (*Columba palumbus*) *Mycobacterium avium*-like bacteria (Jorgensen and Clausen, 1976). No cases of *Mycobacterium bovis* or *Mycobacterium paratuberculosis* were observed in our study.

Systemic disease was diagnosed in 12% of the deer; herein we included cases of septicemia or generalized hemorrhagic conditions ($n = 52$) or conditions of unknown etiology ($n = 46$) including pericarditis, peritonitis, nephritis, and hepatitis among others. Verminous pneumonia was the most common parasitic disease found ($n = 86$). Etiology was primarily *Varestrongylus capreoli* and *Dictyocaulus noerneri.* Gastrointestinal and lung parasites were identified associated with other primary disease conditions in roe deer (Table 2). The conditions included gastroenteritis of unknown etiology ($n = 81$), winter starvation ($n = 25$), trauma ($n = 19$), colibacillosis ($n = 10$), pasteurellosis ($n = 6$), and senility ($n = 3$). Ectoparasitic infestations with lice (*Damalinia cervi*) and ticks (*Ixodes ricinus*) occurred in seven cases in which the roe deer ultimately died

TABLE 1. Primary disease diagnoses in 985 roe deer submitted to the National Veterinary Institute, Sweden, 1986 to 1995.

Primary Disease Diagnosis	Number (%)
Trauma	189 (19)
Starvation	173 (18)
Gastroenteritis	144 (15)
Systemic disease	114 (12)
Bacterial infections	110 (11)
Parasitic diseases	99 (11)
Neoplasia	19 (2)
Congenital disorders	10 (1)
Miscellaneous	63 (6)
Unknown	64 (6)
Total	985 (100)

TABLE 2. Endoparasites identified in pathologic records of 144 roe deer submitted to the National Veterinary Institute, Sweden, 1986 to 1995.

Parasite	Number (%)[a]
Nematoda	
Capillaria sp.	2 (1)
Chabertia ovina	4 (3)
Cooperia curtisei	3 (2)
Dictyocaulus noerneri	35 (24)
Elaphostrongylus cervi	5 (3)
Nematodirus filicolis	13 (9)
Nematodirus spp.	23 (16)
Ostertagia circumcincta	3 (2)
Ostertagia lasensis	4 (3)
Ostertagia leptospicularis	12 (8)
Ostertagia ostertagi	24 (17)
Ostertagia trifurcata	2 (1)
Protostrongylidae	24 (17)
Setaria cervi	8 (6)
Strongyloides spp.	1 (1)
Trichostrongylus axei	36 (25)
Trichostrongylus capricola	6 (4)
Trichostrongylus colubriformis	17 (12)
Trichostrongylus vitrinus	1 (1)
Trichuris ovis	15 (10)
Trichuris ovis	1 (1)
Varestrongylus capreoli	43 (30)
Cestoda	
Dicrocoelium dendriticum	2 (1)
Moniezia expansa	3 (2)
Acanthocephala	
Spiculopteragia bohmi	1 (1)
Spiculopteragia mathevossjani	10 (7)
Spiculopteragia spiculoptera	6 (4)
Protozoa	
Eimeria spp.	13 (9)
Sarcocystis gracilis	2 (1)

[a] Number infected (% prevalence).

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of starvation. Blood parasites were not common; five cases were diagnosed with hemolytic anemia, jaundice, and hematuria associated to *Babesia capreoli*.

Neoplasms described included adenoma ($n = 1$), brain tumors ($n = 2$), bileduct carcinoma ($n = 1$), fibropapillomas ($n = 1$), hemangiosarcoma ($n = 2$), lymphoma ($n = 3$), osteosarcoma ($n = 1$), rhabdomyosarcoma ($n = 1$), and unclassified ($n = 7$). Congenital anomalies included anophthalmia ($n = 3$), clubbed foot ($n = 2$), heel contractures ($n = 2$), lordosis ($n = 2$), and ventricular septal defect ($n = 1$).

Miscellaneous diagnoses were observed in 63 deer and included senility (25%); uterine disorders (17%) such as dystocia, metritis, pyometra, and uterine rupture; eye disorders (17%) such as cataracts, keratoconjunctivitis, and ophthalmitis; stress/circulatory collapse (17%), actinomycosis/tooth impaction (10%), and phlegmon (6%) which is a condition characterized by antler deformity. The cases reported as poisoning (5%) referred to a case of tanic acid poisoning, a case of phenol poisoning, and a case of oilseed rape (*Brassica napus*) poisoning. In addition, drowning (3%), intestinal torsion (3%), and a case of hemolytic anemia (2%) were reported.

The primary causes of mortality by sex were statistically compared. In females, trauma (18%), gastroenteritis (18%), starvation (17%), verminous pneumonia (10%), and infectious pneumonia (8%) were the primary mortality causes. The distribution of mortality factors for males was similar and included trauma (22%), starvation (21%), gastroenteritis (14%), verminous pneumonia (9%), and infectious pneumonia (7%). We detected significant differences ($P \leq 0.05$) in the frequency of primary causes of mortality by age class (Fig. 6). We also detected differences in body condition scores associated with several selected diseases (Fig. 7).

DISCUSSION

Studies of wildlife based on carcass collection have proven to be useful in determining causes of death (Borg, 1991; Weidenmuller, 1971). We document causes of mortality of roe deer submitted to the SVA for necropsy from 1986 to 1995. The geographic distribution reported likely does not accurately reflect the roe deer population density and mortality distribution. Rather, it reflects the fact that more animals are submitted from areas near to SVA, Uppsala and transportation is therefore easy and cheap. The lowest number submitted from the north counties, reflected the low human population in this subarctic part of Sweden.

Observed yearly trends demonstrated a substantial decrease in submissions from 1987 to 1989, then an abrupt increase between 1990 and 1991, steadily declining again during recent years (Fig. 3). It is not known with certainty why the numbers vary, but these trends may be correlated with weather patterns or public awareness.

Traumatic injuries (19%) and winter starvation (18%) were the major causes or contributing causes of death in roe deer submitted to SVA between 1986 and 1995. Previous studies (Borg, 1970, 1991) which summarize diagnoses of roe deer mortality in Sweden between 1947 and 1982, found that starvation accounted for 51% to 59% of deaths and traumatic injuries for 25% of deaths. The decreased proportion of starving deer and proportionate increase in parasitic and infectious diseases (including gastroenteritis) could perhaps be explained by the increased roe deer population density which has intensified contact between individuals and in turn resulted in greater risks for infection. Alternatively, it may reflect a change in types of cases submitted to SVA due to public awareness or better diagnostic efforts at SVA.

Despite physiological adaptations to survive harsh winters, starvation was diagnosed as one of the major cause or contributing cause of death in roe deer in this study. As previously reported (Borg, 1970, 1991), more fawns and old animals die of starvation than adult animals. Winter starvation is one of the most important mor-

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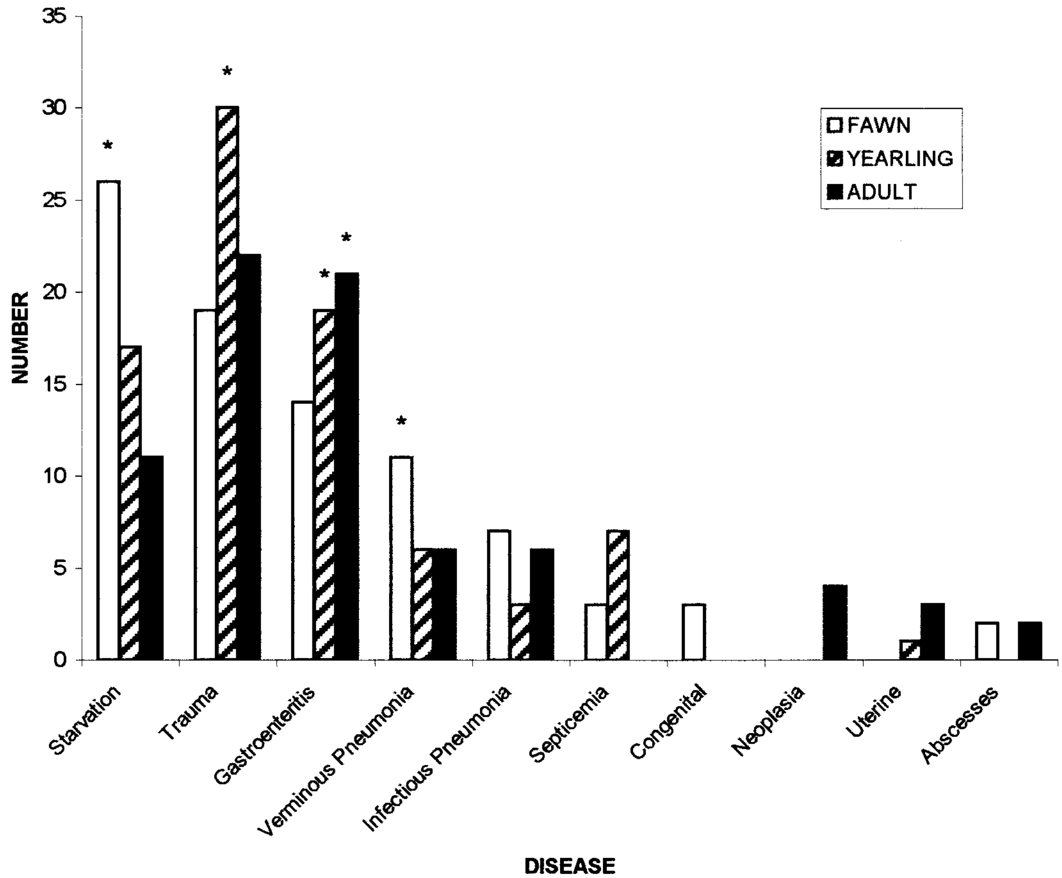

FIGURE 6. Disease conditions reported in roe deer carcasses classified by age class submitted to the National Veterinary Institute, Uppsala, Sweden, 1986–1995. Old age deer were included in the adult category due to sample size. Significant differences ($P \leq 0.05$) of diseases between ages are marked (*).

tality factors in temperate wild ungulates (Ratcliffe and Mayle, 1992).

Secondary effects of disease due to lower resistance in deer in poor condition were difficult to quantify; however, lungworms and other endoparasites were highly prevalent in cases reported as starvation. In other studies, lower prevalence of pulmonary nematodes were identified in Swedish roe deer when compared to other European studies (Poglayen et al., 1988; Misiewicz and Demiaszkiewicz, 1993). Verminous pneumonia has been reported as the principal cause of wild roe deer mortality (16–57%) in Europe (McDiarmid, 1975; Sterba and Zamek, 1984). The difference in prevalence from Sweden to central Europe may be due to the relatively colder climate in the north and the heterogeneity of habitats covered by forest, lakes, or rivers. Future studies could be designed to identify parasite densities associated with type of habitat cover (Hugonnet and Cabaret, 1987). The significance of protostrongylids is unknown in roe deer. This family of lungworms has shown to be potentially harmful for deer in poor condition (Munro and Hunter, 1983). Presence of the juvenile phase of lungworm species in roe deer with other primary diagnosis may be regarded as latent infection. Parasites could infect deer during feeding on dry grass and short shrubs covered by snow in which hibernating snails, the intermediate hosts, occur (Svarc and Pajersky, 1990).

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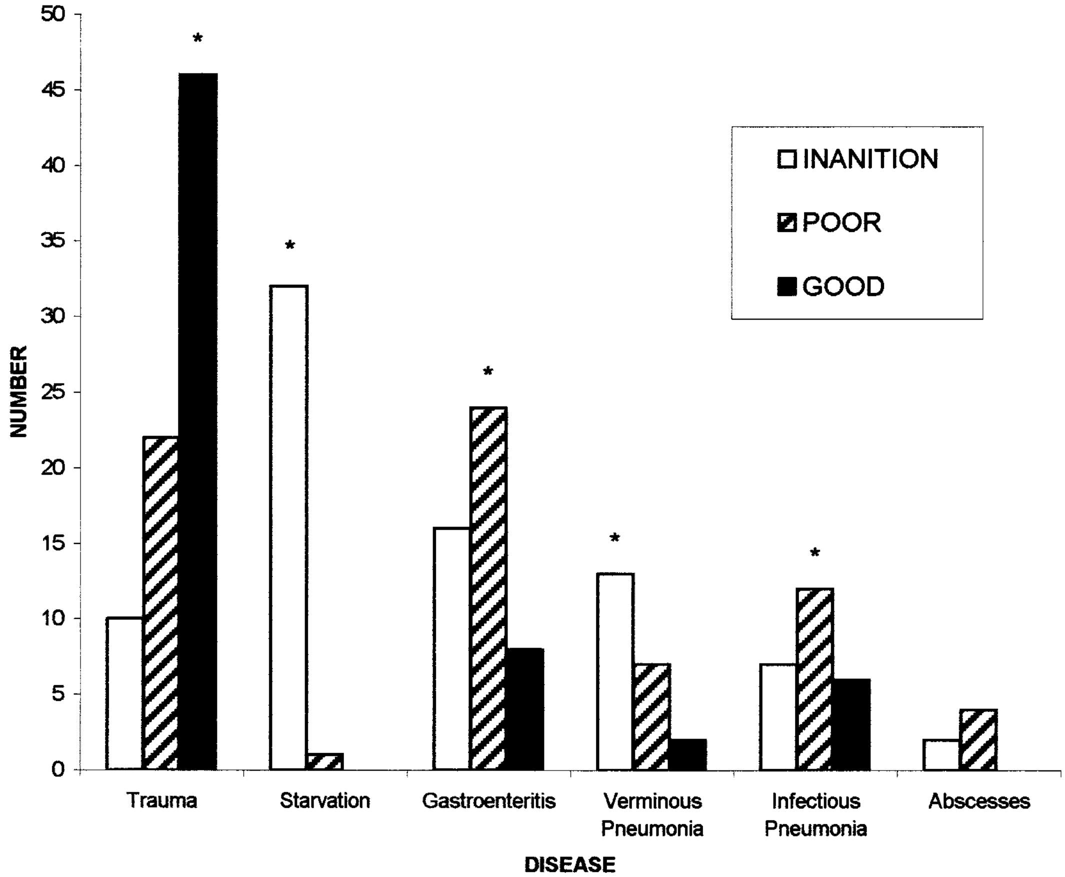

FIGURE 7. Disease conditions reported in roe deer carcasses classified by body condition submitted to the National Veterinary Institute, Uppsala, Sweden, 1986–1995. Significant differences ($P \leq 0.05$) of diseases between body condition scores are marked (*).

It has been demonstrated that *Ixodes ricinus* act as an important vector of *Babesia capreoli* (Nikolskii and Pozov, 1972). Babesiosis has previously been observed in roe deer in Sweden (Christensson and Järplid, 1979) and was recorded in five cases in our study. These cases originated from coastal areas in the southeast where babesiosis in cattle is common and tick intensities are heavy.

All gastrointestinal parasites identified in this study have been previously recorded for roe deer in Sweden and other European countries (Nilsson, 1971; Buttner, 1975; Schroder, 1981; Barth et al., 1982; Rosef et al., 1985; Bidovec, 1987; Bernard et al., 1988; Kutzer et al., 1988; Drozdz and Dudzinski, 1993). It was concluded that gastrointestinal parasitism diagnosed in roe deer submitted to SVA was in many instances secondary or incidental to the primary cause of death. Further research should be focused on the prevalence and intensity of parasitic infections for each species as related to habitat, seasonal changes and host age, weight, and condition.

Neoplasia has been reported with low frequency in roe deer in Sweden (Borg and Nilsson, 1985). The proportion of tumors diagnosed between 1986 and 1995 was 2% which is the same as that found in roe deer between 1947 and 1982 (Borg 1991). Mortality caused by bacterial diseases where the etiologic agent is known represented 11% of total mortality factors

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diagnosed at SVA. Mycobacteriosis and listeriosis are among the important diseases in this group previously reported in roe deer in Europe (Kemenes et al. 1983; Saxegaard, 1981).

The pathologic findings in this study provide a good indication of age structure, sex structure and a subjective but useful technique for mortality estimation in the population (Ratcliffe and Mayle, 1992; Linnell et al., 1995). We stress the importance of continuous surveillance of wildlife diseases. Necropsies provide information on the cause of death, and on the long run information on the biodynamics of the species. They also serve as an indication of diseases transmitted to or from domestic animals and humans, and may provide a tool for identifying new diseases and potentially assessing their effects on the population.

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