OCCURRENCE OF PROTOSTRONGYLID NEMATODES IN SYMPATRIC POPULATIONS OF MOOSE AND WHITE-TAILED DEER IN MAINE

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ABSTRACT: Occurrence of protostrongylid larvae in sympatric populations of moose (Alces alces) and white-tailed deer (Odocoileus virginianus) was studied in Baxter State Park, Piscataquis County, Maine from January - March 1984. A significantly ($P < 0.001$) larger proportion of deer fecal groups (50% of 104) contained-first stage larvae than did those of moose (9.6% of 594). Larvae per gram of feces was significantly ($P < 0.001$) lower for moose ($\bar{X} = 1.3$, SD = 4.14) than deer ($\bar{X} = 26.2$, SD = 29.42). The proportion of moose fecal groups containing protostrongylid larvae (10.4% of 499) was higher ($P = 0.054$) in areas where their distribution overlapped that of deer, compared to areas without deer (5.3% of 95). Frequency of moose feces with protostrongylid larvae was significantly higher ($P < 0.001$) in March than other months; number of larvae per gram of feces was greatest in February. Moose and nematode may be developing a more tolerant relationship in Maine.

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The meningeal nematode, Parelaphostrongylus tenuis, parasitizes white-tailed deer (Odocoileus virginianus) without pathological effects, but may cause a debilitating neurologic disorder in moose (Alces alces) (Anderson and Lankester 1974). Activities of the nematode in the central nervous system of moose can cause lesions and hemorrhage in the brain and spinal cord (Anderson 1964, 1965b); damage also is caused by eggs deposited on or near the brain parenchyma. One result of such an infection is "moose sickness," which is characterized by paralysis of the hindquarters or circling behavior (Anderson 1965a). Gilbert (1974) reported 28% of 153 moose in Maine had at least one adult P. tenuis in the brain or spinal cord, but no evidence was presented that the parasite completed its life cycle in moose. Further, Karns (1967) suggested the frequency of infection in moose was directly correlated with the density of white-tailed deer where their geographic ranges overlapped. The frequency of P. tenuis infections in white-tailed deer increased with deer density. Moreover, the increased prevalence of P. tenuis larvae released by deer resulted in a greater infection rate for moose (Gilbert 1973). Thus, the degree of overlap in ranges of moose and white-tailed deer and the prevalence of P. tenuis in deer may influence rates of infection in moose (Behrend 1970).

Moose populations in Maine recently have expanded into the range of white-tailed deer (Monthey 1984) without an apparent increase in moose mortality. One possibility is that P. tenuis and moose have reached a more symbiotic relationship. Brown (1982) reported that P. tenuis completed its life cycle in moose. Thus, the pathological consequences of a P. tenuis infection in moose may have lessened. The purpose of this study was to examine moose feces for the occurrence of first-stage

protostrongylid larvae and to determine the levels of infection in feces of sympatric populations of moose and white-tailed deer during winter.

METHODS

Research was conducted from January - March 1984 in Baxter State Park, Piscataquis County, Maine at an elevation of approximately 244 m in a 6 by 1 km area along Roaring Brook Road. The area is dominated by balsam fir (Abies balsamea), red maple (Acer rubrum) and beech (Fagus grandifolia), and contains high densities of moose and white-tailed deer.

Fresh samples of moose and white-tailed deer feces were collected from areas with both herbivores present and where moose occurred alone; distributions of these ungulates were determined easily from their tracks in the snow. Fecal samples were gathered off snow to prevent contamination with soil nematodes and were stored frozen. Subsamples from each moose ($\bar{X}$ - 11.2 g, SD = 1.8 g) and deer ($\bar{X}$ = 11.1 g, SD = 1.6 g) fecal group were subjected to standard Baermann techniques for 24 h. First-stage larvae of Parelaphostrongylus were identified by their characteristic size and morphology (Anderson and Prestwood 1981). A two sample Z - test was used to compare proportions of infected moose and deer feces, and a t - test (Remington and Schork 1970) was used to compare differences in mean number of larvae per gram of feces between these two ungulates.

RESULTS

Overall, 9.6% of 594 moose and 50% of 104 deer fecal groups contained first-stage protostrongylid larvae during winter; this

difference was highly significant ($P < 0.001$). Infected feces from moose contained significantly ($P < 0.001$) less larvae per gram ($\bar{X}$ = 1.3, SD = 4.1, range = 0.1-29.8) than those from infected deer ($\bar{X}$ = 26.2, SD = 29.4, range = 0.1-136.4).

Sample sizes were too small to allow monthly comparisons for first-stage larvae in white-tailed deer feces, but moose exhibited distinct monthly differences in both the proportion of fecal groups infected, and larvae per gram of feces (Table 1).

Table 1. Monthly variation in percent occurrence, and intensity of infection (larvae per gram of feces) of protostrongylid larvae in moose, Baxter State Park, Piscataquis County, Maine, winter 1984.

Month	N[a]	% moose infected	N[b]	Intensity $\bar{X}$	Intensity SD	Intensity range
January	371	4.9	18	0.72	0.83	0.04- 2.45
February	122	6.6	8	5.40	10.60	0.14-29.78
March	101	30.7	31	0.57	0.50	0.08- 2.12

[a] total number of samples
[b] number of samples with protostrongylid larvae

The occurrence of first-stage larvae in moose fecal groups was significantly lower in January ($P < 0.001$) and February ($P < 0.001$) compared to March; the difference between January and February was not significant ($P > 0.50$). Larvae per gram of feces for pellet groups with

larvae present (Table 1), however, were significantly ($P < 0.001$) higher in February than in March ($P < 0.001$) or January ($P < 0.05$); the difference between January and March was not significant ($P > 0.70$) (Table 1).

The role of white-tailed deer in the occurrence of Parelaphostrongylus in moose was evaluated further by comparing parasitism for moose in areas with and without deer. Overall, 10.4% of 499 moose fecal groups collected from areas with deer had first-stage larvae, whereas 5.3% of 95 moose fecal groups possessed larvae in areas without deer; this difference was nearly significant ($P = 0.054$).

DISCUSSION

Moose and deer populations often are allopatric and exhibit different habitat requirements (Telfer 1970); it is widely believed that P. tenuis influences the distribution of these ungulates (Anderson 1972, Karns 1967). Overlap in the distribution of deer and moose during winter may not result in transmission of the nematode between these herbivores at this time of year because the intermediate gastropod hosts are absent. Yet, winter distributions of these cervids may be indicative of greater overlap during spring when deer are not restricted by deep snow, and appropriate gastropods are present (Telfer 1970). Further, such overlap in winter could account for transmission of the nematode after the gastropods became active, even if one of the ungulates was absent.

Numbers of protostrongylid larvae per gram of feces reported in this study most likely were higher in deer than in moose because these nematodes were better adapted to white-tailed deer (Anderson 1979).

Winter diets of moose and deer in this area overlaped by about 40% (Ludewig and Bowyer 1985), and higher numbers of larvae in deer feces also may have occurred because deer tend to feed nearer the ground where infected gastropods presumably were more abundant. Unfortunately, the relationship between number of adult nematodes and larvae they release has not been quantified.

The possibility exists that some deer fecal samples contained first-stage larvae of P. andersoni; these cannot be distinguished morphologically from first-stage P. tenuis (Anderson and Prestwood 1981). Whether P. andersoni occurs in deer of Maine is unknown; it has been found as far north as New Jersey (Anderson and Prestwood 1981). Such an occurrence, however, does not explain higher rates of infection in moose sympatric with deer, or why moose are rapidly extending their distribution into deer range.

A significantly higher proportion of moose feces contained protostrongylid larvae in March than in January or February. Although the time and conditions that induce the release of P. tenuis are not fully understood, larvae may be released in late winter to infect suitable intermediate hosts in spring. Seasonal variation in the occurrence of other metastrongylid larvae in the feces of herbivores is well-documented (Uhazy and Holmes 1973). A tendency exists for "moose sickness" in Maine to be reported in late winter and early spring (pers. comm. Karen Morris).

The increase in moose numbers in the last 10 years in Maine commonly is believed to be caused by changes in habitat (Monthey 1984), but also may have resulted from a reduced physiological effect upon moose by P. tenuis. In the parasite-host relationship, it often is

beneficial for the parasite to successfully exploit the host without seriously affecting its survival (Pimentel and Nagel 1963). Adaptations to allow P. tenuis to reproduce without a debilitating effect on moose would benefit both moose and nematode (Read 1970). Gilbert (1974) documented that adult P. tenuis occurred in brains of moose in Maine, and this study indicates that a protostrongylid nematode matured in moose sympatric with white-tailed deer. Thus, some likelihood exists that coevolution favoring a reduction in the debilitating effect of P. tenuis upon moose may have occurred.

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