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GASTROPOD AVAILABILITY AND HABITAT UTILIZATION BY WAPITI AND WHITE-TAILED DEER SYMPATRIC ON RANGE ENZOOTIC FOR MENINGEAL WORM

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ABSTRACT: Gastropod occurrence and the utilization of habitat by sympatric populations of wapiti (*Cervus elephus*) and white-tailed deer (*Odocoileus virginianus*) on range enzootic for meningeal worm (*Parelaphostrongylus tenuis*) were studied on Cookson Hills Wildlife Management Area (WMA) in eastern Oklahoma. Visual observations and fecal pellet group transect data indicated that wapiti spent the majority of their time in open fields and meadows where we recovered the least numbers of gastropods. Although deer were frequently observed in open areas, visual sightings and transect data indicated that they spent more time in forested areas where we recovered the most gastropods. Gastropods harbored low numbers of *P. tenuis* larvae (0.00 to 0.06 larvae/gastropod) in all habitat types with the greatest recovery from red oak white oak-hickory forests (0.34 larvae/gastropod). Our results indicate that the reason a viable wapiti herd exists on Cookson Hills WMA in a *P. tenuis* enzootic area is at least partially because of the habitat preference by wapiti and the reduced availability of infected gastropods in the selected areas prefered by the wapiti. We were not able to detect any free-ranging wapiti that were shedding *P. tenuis* larvae nor were we able to detect past or sub-clinical infections with *P. tenuis* in wapiti.

Key words: *Wapiti, Cervus elaphus*, white-tailed deer, *Odocoileus virginianus*, meningeal worm, *Parelaphostrongylus tenuis*, habitat use, gastropod, epidemiology.

INTRODUCTION

A major problem associated with reestablishment and/or translocation of many species of large ungulates in North America is the nematode parasite, *Parelaphostrongylus tenuis,* which is widespread throughout most of the eastern United States and Canada (Anderson, 1972). *Parelaphostrongylus tenuis* infects white-tailed deer (*Odocoileus virginianus*) with little or no indications of clinical disease. However, in many species of abnormal hosts (i.e., moose (*Alces alces*), wapiti (*Cervus canadensis*), caribou (*Rangifer tarandus*), llama and domestic sheep and goats) infection with third-stage larvae generally results in a fatal neurologic disease. Due to the wide distribution of white-tailed deer in North America and the associated distribution of *P. tenuis,* many areas may not be biologically suitable for translocation of some species of ungulates.

Prior to the arrival of European man in North America, there were an estimated 10,000,000 wapiti of six subspecies that ranged from the east coast to west coast and from Canada to Mexico. By 1922, only an estimated 90,000 wapiti were left; two subspecies were extinct, three were near extinction, and one had been extirpated from most of its original range (Bryant and Maser, 1982). Anderson (1972) posed several important questions related to *P. tenuis* and these wapiti population declines. Although data are not available, the association between *P. tenuis* infected white-tailed deer and the now extinct eastern subspecies of wapiti (*Cervus elaphus canadensis*) or the extirpated Manitoban subspecies (*C. elaphus manitobensis*) may have been a contributing factor. By comparison, these subspecies may have either been suitable hosts for this parasite, resistant to infection, or gastropod availability and differential habitat preferences by these two hosts may have been sufficiently different to preclude infection.

Most translocations of wapiti have occurred since 1900 and many have failed largely due to the suseptibility of wapiti to *P. tenuis* infection (Anderson and Prestwood, 1981). Eveland et al. (1979) concluded that the principal limiting factor for translocated wapiti in Pennsylvania was the presence of *P. tenuis*. Carpenter et al. (1973) indicated that efforts to introduce wapiti in eastern Oklahoma were of limited success primarily because of the enzootic presence of *P. tenuis*.

Translocations of wapiti (*Cervus elaphus*) into eastern Oklahoma occurred between 1969 and 1971 with 391 wapiti trapped from the Wichita Mountains National Wildlife Refuge in southwestern Oklahoma (34°62′N, 99°10′W), an area known to be non-endemic for *P. tenuis* (Kocan et al., 1982). Releases occurred at several locations, including five state owned Wildlife Management Areas (WMA) as well as some private land. Wildlife Management Areas included Cookson Hills WMA (35°41′N, 94°48′W); (21 males, 35 females), Pushmataha WMA (34°30′N, 96°10′W); (22 males, 44 females), Cherokee WMA (35°40′N, 95°50′W); (20 males, 30 females), Spavinaw WMA (36°20′N 95°60′W); (22 males, 34 females), and McCurtain County Wilderness Area (34°40′N, 95°20′W); (33 males, 32 females). At all release sites, wapiti were later observed with typical neurologic disease and confirmation of *P. tenuis* infections was made by Carpenter et al. (1973). In all areas, except for Cookson Hills WMA, mortality associated with *P. tenuis* infection has seriously hampered re-establishment of wapiti. Although no official population data are collected, some deaths from *P. tenuis* are observed annually on Cookson Hills WMA. In spite of these mortalities, the population has continued to increase averaging between 100 and 150 animals. In fact, periodic controlled hunts have been necessary to regulate herd numbers. Routine health evaluations of animals from these areas have not detected any additional mortality factors that could contribute to population declines (Kocan, 1983, 1988). However, illegal poaching has been documented on all areas.

The relationship between moose, another ungulate susceptible to *P. tenuis* induced neurologic disease and white-tailed deer, has been studied. Gilbert (1974) reported the existence of moose "refugia" or areas that sustained moose populations in the presence of deer infected witih *P. tenuis*. Kearney and Gilbert (1976) suggested that differential habitat use by deer and moose during spring and summer provided the ecological habitat separation necessary to sustain moose populations. Upshall et al. (1987) did not recover *P. tenuis* larvae from moose feces in New Brunswick although white-tailed deer from the same area had a prevalence of infection of >50%. They concluded that spatial and/or behavioral separation of deer and moose was the major reason for the low prevalence in moose. No comparable studies have been published for areas where wapiti and white-tailed deer share sympatric range enzootic for *P. tenuis*.

OBJECTIVES AND EXPERIMENTAL DESIGN

Our objectives in this study were to identify habitat use by deer and wapiti on Cookson Hills Wildlife Management Area as determined by visual observation and fecal pellet group surveys. Additionally, we investigated gastropod occurrence in these same habitat types and the occurrence of *P. tenuis* infection in these gastropods.

Observational data were obtained by recording sightings of deer and wapiti along a mobile observational route. The route was established along existing roads. No efforts were made to standardize the amount of open and forested area covered although the route did include all habitat types present on the area. Topography on the refuge limited the extent of the observational route. Although visibility may have been greater on the open areas, these areas comprised only 25% of the total habitat available on the refuge. In an attempt to minimize the bias that might be encountered as a result of the mobile observational route, fecal pellet group transects and circular plots were established that included all habitat types available. Similarly, gastropod collection attempts were made in all available habitat types. It was our conclusion that the use of differing methods of data collection that indicated habitat utilization by both deer and wapiti minimized the bias that might have been encountered if only one method had been employed.

MATERIALS AND METHODS

Study area and habitat type identification

Cookson Hills WMA consists of 5,456 ha of second growth hickory and oak-pine forest. Nine major habitat types have been identified including post oak (*Quercus stellata*)-black oak (*Q. velutina*), post oak-black oak and shallow savannah range, red cedar (*Juniperus virginiana*)-hardwood and very shallow range, shortleaf pine (*Pinus echinata*)-oak, red oak (*Q. rubra*)-white oak (*Q. alba*)-hickory, bitternut hickory (*Carya cordiformis*)-black oak-elm (*Ulmus*. spp), black oak-maple (*Acer* spp), and meadows and old fields (Savage, 1976). Two hundred six ha were classified as meadows and old fields. We included "ecotone" (the transition area between forest and open meadow or fields) as a habitat type in our evaluation. Habitat availability was determined by identifying the habitat type for each of the circular fecal pellet plots and using these data to determine habitat percentages. Habitat percentages were determined for the observational route and along transects by measuring the distance in each habitat type. Habitat type identification followed Savage (1976).

Climate is continental with dry mild winters and hot, dry summers. Winds are generally from the south and evaporation is higher than precipitation (Savage, 1976). The white-tailed deer population is estimated at 1 deer/6 ha (Kocan, 1988) and the wapiti population averages 100 to 150 animals. The *P. tenuis* infection rates in deer were 60% in 1972 (Carpenter et al., 1972), 76 to 100% in 1982 (Kocan et al., 1982) and 80–100% in 1983–1987 (Kocan, 1988). Although wapiti fatalities related to *P. tenuis* are well documented at Cookson Hills WMA (Carpenter et al., 1972), the wapiti herd has continued to increase since its establishment in 1969. Introductions on other management areas in eastern Oklahoma have not been as successful; populations either have remained stable or decreased. The Cookson Hills WMA is closed to public use except during fall deer and wapiti hunts.

Mobile route observations

A 16 km observational route was established along unpaved roads. The route allowed for observations on a large percentage of the open fields available on the area although many other open areas were not accessible. Attempts were not made to equalize the percentage of open fields and forested areas that were visible along the observation route. However, all habitat types were represented along the route and transition between open fields and forested areas was continuous. Observations were made mainly in early morning and late evening, although afternoon observations occurred. Twenty nights of spotlight observations also were made along the same route. Observations were made in all weather conditions between August 1985 and June 1986. Randomization of the order in which areas were observed was not possible but direction of travel on the mobile route was varied.

Fecal pellet group survey

Pellet group surveys were conducted on 204 permanent 0.004-ha circular plots and 13 permanent 2-m wide rectangular transects; they did not overlap. Transects were established on east-west compass bearings, ranging in length from 610 to 1463 m and encompassing changes in elevation. The center of each circular pellet plot was located and marked. Pellet groups were defined following Neff (1968) and Freddy and Bowden (1983). Circular plot boundaries were determined by extending a 3.59-m rope from the stake in the center of the plot. Plots and transects were initially cleared of all pellets then examined four to five times during the course of the study. All pellets encountered were collected, classified by size, shape and consistency as being either deer or wapiti, and stored frozen by group.

Additional collection of wapiti feces

On six separate occasions between May and November 1989, individual fecal samples were collected from wapiti on Cookson Hills WMA. In order to collect samples from individual animals, wapiti were located while bedded and approached until they stood up and defecated.

Five to 10 grams of feces from each animal were evaluated by the Baermann procedure. Samples were allowed to stand over night and microscopic evaluation (20×) was conducted on all fluid collected.

Evaluation of hunter-killed wapiti

Fecal samples and lung tissue were collected from 12 hunter-killed wapiti (eight cows, four bulls) during December, 1989. Additionally, intact heads were collected from four adult cows. Fecal samples were examined by routine Baermann procedures for the presence of larvae. Lung tissue was fixed in 10% formalin and processed using standard histologic procedures and examined microscopically (400×) for the presence of eggs and/or larvae. Heads were dissected and the leptomeningeal areas were examined for adult *P. tenuis* following the procedure of Nettles (1981) and Prestwood and Smith (1969).

Collection of gastropods

Gastropods were collected randomly from beneath rocks, logs, leaves, etc., primarily along transects. Although no efforts were made to standardize the effort spent searching for gastropods in each habitat type, the time spent in each habitat type was approximately the same. Numerous attempts were made to enhance gastropod collections, especially in open meadows, by providing moistened cardboard, covering wet cardboard with plastic sheeting to decrease evaporation and by collecting soil and litter samples that were later moistened. However, the most productive method of obtaining gastropods was by randomly searching suitable areas. Upon collection, gastropods were wrapped in moist paper towels and refrigerated. Representative samples from differing habitat types and differing species were later digested in a solution of 1% pepsin and 1% HCl. To verify that the larvae collected were *P. tenuis*, four species of snails were artificially infected using procedures outlined by Kocan (1985). Seventy-five third-stage larvae recovered from each of two species (*Helicina orbiculata* and *Triodopsis divesta*) were used to expose uninfected captive white-tailed deer. All dorsal spined larvae were considered to be *P. tenuis* since extensive studies in this area have not documented the presence of any other dorsal-spined larvae producing parasites (Kocan, 1983).

Statistical analysis

A chi-square goodness of fit test ($P < 0.05$) was used to determine if there was a significant difference between expected pellet group frequency in each habitat type based on its availabilty and observed pellet group frequency, and to determine if there was a difference between expected use and observed use of all habitat types. When significant differences were found, Bonferroni Z confidence intervals were constructed to evaluate pellet group frequencies and habitat usage and preference based upon observations. Habitat types with no pellet groups or no observations were not included in the chi-square analysis. Our use of these tests paralleled Alldredge and Ratti (1986). Simultaneous confidence intervals constructed around observational data were assumed to reflect habitat use and preference by deer and wapiti. Simultaneous confidence intervals constructed around pellet group frequencies reflected habitat differences in pellet group frequencies and not necessarily actual habitat use.

RESULTS

We enumerated 3,892 adult wapiti observations. During spring and summer combined, wapiti were observed on meadows more than four times as frequently as was expected (Table 1). Old fields were used in proportion to their availability and all other habitat types, including ecotone, were used less than expected. When spring and summer observations were separated (before mid-June and after mid-June) the data were similar to those for spring and summer combined. Observations on adult cows (3,163) were consistent with those for all adult wapiti combined. Observations on adult bulls (246) showed similar results. Meadows were used preferentially by both sexes and all age classes of wapiti.

Seven hundred forty-two adult deer observations were made. During spring and summer combined, deer used meadows and old fields preferentially. Deer used ecotone, red cedar-hardwood forest types, and shallow range type in proportion to their availabilities, and all other habitat types less than their availabilities (Table 2). Data for spring alone were similar to those of spring and summer combined. During summer, deer used meadows and old fields preferentially, but all other habitat types less than their availabilities. Meadows and old fields were used preferentially by both sexes of deer throughout spring and summer.

TABLE 1. Adult wapiti habitat use as determined by observational data on Cookson Hills Wildlife Management Area.

		Season					
		Spring		Summer		Combined	
Habitat type	% Available	Wapiti seen	Habitat[a] selectivity	Wapiti seen	Habitat[a] selectivity	Wapiti seen	Habitat[a] selectivity
Post oak	13	5	–	8	–	13	–
Red cedar	3	7	–	0	–	7	–
Pine	8	2	–	0	–	2	–
Red oak	26	0	–	2	–	2	–
Hickory	8	7	–	1	–	8	–
Black oak	7	32	–	0	–	32	–
Meadow	21	1,634	+	1,888	+	3,522	+
Field	4	65	0	105	0	170	0
Ecotone	10	104	–	32	–	136	–

[a] Chi-square analyses followed by Bonferroni confidence intervals; + preferred, 0 no preference, – used less than expected ($P < 0.05$).

Four hundred ninty-one wapiti and 154 deer pellet groups were found on pellet transects. Deer pellet groups were distributed in proportion to habitat availabilities throughout forests and fields. However, wapiti pellet groups appeared on meadows and old fields more frequently than they did on forested habitat types (Table 3). When habitat types were analyzed and evaluated individually, deer pellet groups were found on meadows more than expected and on old fields, red cedar-hardwood forest types, and very shallow range type less than expected. On all other habitat types including ecotone, deer pellet groups were found in proportion to availability.

One hundred seventy-four wapiti and 42 deer pellet groups were found on circular plots. Results for circular pellet plots and pellet transects generally agreed. When forested and ecotone habitat types were combined and meadows and old fields were combined, deer pellet groups occurred on forest and meadows and old fields in proportion to availability. However, wapiti pellet groups occurred on meadows and old fields more than expected and forested plots less than expected (Table 4). When habitats were an-

TABLE 2. Adult deer habitat use as determined by observational data on Cookson Hills Wildlife Management Area.

		Season					
		Spring		Summer		Combined	
Habitat type	% Available	Deer seen	Habitat[a] selectivity	Deer seen	Habitat[a] selectivity	Deer seen	Habitat[a] selectivity
Post oak	13	11	–	14	–	25	–
Red cedar	3	9	0	5	–	14	0
Pine	8	13	–	2	–	15	–
Red oak	26	10	–	5	–	15	–
Hickory	8	8	–	15	–	23	–
Black oak	7	10	–	12	–	22	–
Meadow	21	171	+	294	+	465	+
Field	4	55	+	44	+	99	+
Ecotone	10	40	0	24	–	64	0

[a] Chi-square analyses followed by Bonferroni confidence intervals; + preferred, 0 no preference, – used less than expected ($P < 0.05$).

TABLE 3. Distribution of deer and wapiti pellet groups from pellet transect data (spring and summer combined) on Cookson Hills Wildlife Management Area.

		Species			
		Deer		Wapiti	
Habitat type	% Available	Pellet groups	Habitat[a] selectivity	Pellet groups	Habitat[a] selectivity
Post oak	13	20	0	11	–
Red cedar	3	1	–	0	–
Pine	8	9	0	0	–
Red oak	26	38	0	17	–
Hickory	8	14	0	3	–
Black oak	7	7	0	3	–
Meadow	21	50	+	422	+
Field	4	1	–	19	0
Ecotone	10	14	0	16	–

[a] Chi-square analyses followed by Bonferroni confidence intervals; + preferred, 0 no preference, – used less than expected ($P < 0.05$).

TABLE 4. Distribution of deer and wapiti pellet groups from circular pellet plots (spring and summer combined) on Cookson Hills Wildlife Management Area.

		Species			
		Deer		Wapiti	
Habitat type	% Available	Pellet groups	Habitat[a] selectivity	Pellet groups	Habitat[a] selectivity
Post oak	12	2	0	1	–
Red cedar	3	1	0	1	–
Pine	7	2	0	0	–
Red oak	26	9	0	5	–
Hickory	10	6	0	6	–
Black oak	7	2	0	0	–
Meadow	20	10	0	132	+
Field	4	0	0	14	0
Ecotone	11	10	0	15	0

[a] Chi-square analyses followed by Bonferroni confidence intervals; + preferred, 0 no preference, – used less than expected ($P < 0.05$).

alyzed individually, there were no differences between deer pellet group distribution and the availability of each habitat. Similar to pellet transects, circular plots showed that wapiti pellet groups were found on meadows more than expected. Wapiti pellet groups were found on old fields and ecotone in proportion to their availability and in all forest habitat types less than were available.

Two thousand five hundred thirteen gastropods of 15 species were collected. The most common species was *Helicina orbiculata*. Gastropods were found most often in red-cedar-hardwood forest and very shallow range type, but also were found in most forested habitat types (Table 5). Gastropods appeared to be most abundant in areas of red oak-white oak-hickory that were on north and east facing slopes. Only four gastropod specimens were recovered from meadows or fields (3 *Triodopsis divesta* and 1 *Stenotrema stenotrema*) and only two specimens were found in the ecotone between food plots and forest (1 *T. divesta* and 1 *Mesodon inflectus*).

Sixty-five *P. tenuis* larvae were recovered from 959 digested gastropods; larvae were not recovered from seven species of gastropods (Table 6). *Triodopsis divesta* contained the largest number of larvae (0.30 larvae/snail). The prevalence of gastropod infection could not be determined because gastropods were digested in groups, by species. Gastropods from most habitat types had low numbers of *P. tenuis* larvae/gastropod (0–0.06 larvae/gastropod) except those from the red oak-white-oak-hickory forests which had an average of 0.34 larvae/gastropod (Table 5).

Gastropods experimentally infected with

TABLE 5. *Parelaphostrongylus tenuis* larvae recovered from gastropods from differing habitat types on Cookson Hills Wildlife Management Area.

Habitat	Number gastropods found	Number gastropods digested	Larvae found	Larvae/ gastropod
Post oak	291	181	7	0.04
Red cedar	873	292	14	0.05
Pine	24	8	0	0
Red oak	649	74	25	0.34
Hickory	311	197	11	0.06
Black oak	174	83	3	0.04
Meadow	4	1	0	0
Field	0	0	0	0
Ecotone	2	0	0	0
Unknown	185	123	5	0.04
Total	2,513	959	65	0.07

TABLE 6. *Parelaphostrongylus tenuis* larvae recovered from differing gastropods from Cookson Hills Wildlife Management Area.

Species	Number gastropods found	Number gastropods digested	Larvae found	Larvae/ gastropod
Anguispira alternata	19	7	0	0.00
Bulimulus dealbatus	28	21	0	0.00
Deroceras laeve	46	13	0	0.00
Discus cronkhitei	9	9	0	0.00
Discus patulus	637	129	1	0.01
Helicina orbiculata	797	263	9	0.03
Mesomphix cupreus	10	10	1	0.10
Mesodon inflectus	52	33	8	0.13
Mesodon thyroidus	2	1	0	0.00
Polygyra dorfeuilliana	172	113	11	0.10
Polygyra jacksoni	303	194	7	0.04
Stenotrema stenotrema	139	70	3	0.04
Triodopsis albolabris	21	9	0	0.00
Triodopsis divesta	250	83	25	0.30
Zonitoides arboreus	12	4	0	0.00
Total	2,513	959	65	0.07

P. tenuis larvae included *Bulimulus dealbatus, Helicina orbiculata, Mesodon cupreus* and *T. divesta*. *Mesodon cupreus* contained 0.4 larvae/snail while *H. orbiculata, B. dealbatus* and *T. divesta* were able to maintain infections of 10.87, 18.50 and 71.04 larvae/gastropod, respectively. Larvae taken from *H. orbiculata* and *T. divesta* were used to experimentally expose captive white-tailed deer. At 157 days after exposure, both deer were shedding detectable *P. tenuis* larvae in their feces. Necropsy evaluation of these deer confirmed the presence of adult *P. tenuis*.

Forty-eight individual wapiti fecal samples were examined for the presence of *P. tenuis* larvae. These included 35 samples collected from live individuals and 12 samples obtained from hunter-killed wapiti. All samples were negative for larvae. Examination of heads and lung tissue from hunter killed wapiti provided no indications of past or present infection with *P. tenuis*.

DISCUSSION

It is generally believed that infections with *P. tenuis* in abnormal hosts such as wapiti and moose result in death (Anderson, 1972). Mortality has been attributed to abnormal migration of the *P. tenuis* larvae through neural tissue, which causes physical damage to this tissue. Most animals are believed to die before migrating larvae reach sexual maturity and complete their life cycle. Woolf et al. (1977) found adult *P. tenuis* in the cranial cavity of naturally infected wapiti, but they did not determine if eggs and/or larvae were present in lungs or feces. Karns (1966) reported dorsal-spined larvae present in the feces of some naturally infected wapiti in Minnesota, although he did not determine if these were in fact *P. tenuis* larvae. Pybus et al. (1989) reported dorsal-spined larvae from field collected feces from Manitoba (Canada) that were identified as wapiti feces and the larvae were later confirmed as *P. tenuis* larvae. However, no other reports are available that document free-ranging wapiti with patent *P. tenuis* infections.

Previous studies dealing with natural infection rates in gastropods in *P. tenuis* enzootic areas indicate that the number of larvae/infected gastropod is low. Upshall et al. (1986) reported that <3% of the gastropods collected in New Brunswick contained *P. tenuis* larvae. Maze and Johnson (1986) found that 9% of all gastropods collected from a *P. tenuis* enzootic area in Pennsylvania contained larvae. In the present study we did not determine the number of infected gastropods per species recovered. We did determine the average number of larvae per gastropod by species examined and these ranged from 0.0 to 0.30. However, experimental exposures of gastropods to *P. tenuis* larvae indicated that most species could harbor larger numbers of larvae than were detected in natural infections.

Observational data and fecal pellet group and circular plot data for deer and wapiti on Cookson Hills WMA indicated that use of specific habitat types and snail availability may be important in *P. tenuis* infections for both species of hosts. Observations indicate that both deer and wapiti were seen in meadows and fields more than expected but that wapiti were observed in these areas far more frequently than were deer. Wapiti were observed on meadows and fields 3,522 times while deer were seen only 465 times. By comparison, deer were observed more frequently in forested areas than were wapiti. However, it is possible that observational data may have been biased due to the study design employed. Gastropod recovery data indicated that all species of gastropods were more easily recovered from forested areas than open fields and meadows. The more favorable microenvironment of forested areas, specifically moisture content, evaporation, and temperature may contribute to a non random distribution of gastropods over the study area. As such, gastropod availability in open meadows appears to be considerably less than in forested areas, reducing the likelihood of exposure to gastropods for animals that utilize these areas. Although the design of this study can not exlude other contributing factors, our data support the possibility that availability of gastropods in general and probably *P. tenuis* infected gastropods is lower for animals spending more time in open meadows and fields than it is for those that spend more time in forested areas. Factors that could be equally important may include seasonal movement patterns of deer, wapiti, and/or gastropods, food preferences, and selectivity for gastropods by the two hosts. Because a large percentage of the deer on Cookson Hills WMA are infected with *P. tenuis*, it appears that infection rates in gastropods are sufficient for natural transmission to routinely occur. Because wapiti occupying the same area as deer are apparently less frequently infected than the deer, it is suspected that wapiti exposure to infected gastropods may be substantially lower. Alternatives may include that larvae ingested by the wapiti die before reaching the central nervous system or that wapiti are capable of developing patent non-clinical infections. However, we found no indications that waipiti were shedding *P. tenuis* larvae, that they become infected with *P. tenuis* without showing clinical signs, nor did we detect any evidence of past or sub-clinical infections.

It appears that at least on Cookson Hills WMA, a viable populatiion of wapiti exists in a *P. tenuis* enzootic area. Our findings suggest that gastropods may not be distributed evenly throughout all available habitat types. Likewise, habitat use by wapiti and deer does not appear to be random. If our ability to recover gastropods is indicative of gastropod availability, and if our observations of wapiti occurrence in open fields and meadows are indicative of preference for these habitat types, wapiti exposure to potentially infected gastropods would appear to be restricted. These data suggest that managers interested in maintaining wapiti, and perhaps other abnormal hosts susceptible to *P. tenuis*, may increase the likelihood of successful translocations by creating large grassy openings or other similar habitat manipulations in *P. tenuis* enzootic areas. This is particularly applicable if the climatic situation favored hot dry conditions similar to those in eastern Oklahoma.

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