Incidence and abundance of certain parasites in wapiti in the national parks of the Canadian Rockies

D. R. FLOOK
Canadian Wildlife Service, Edmonton, Alberta
AND
J. E. STENTON[1]
National Parks Branch, Banff, Alberta

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One hundred and seven wapiti *Cervus canadensis*, collected at different seasons of the year in Banff and Kootenay Parks, and the Ya Ha Tinda Ranch near Banff Park, were examined for helminth and arthropod parasites. Additional data were obtained by inspecting lungs and livers in 1380 wapiti shot in early winter for population control in Jasper, Banff, and Waterton Lakes National Parks. Species commonly found in some areas were *Fascioloides magna*, *Thysanosoma actinoides*, *Echinococcus granulosus*, *Dictyocaulus viviparus*, and *Dermacentor albipictus*. Incidence and abundance of these species are compared between wapiti of different sex and age. Seasonal and spatial distributions of parasites are also discussed.

In an attempt to explain the mechanisms causing a sex differential in survival of wapiti (*Cervus canadensis*) in the national parks of Western Canada, various physical and physiological factors of potential effect on the welfare of the animals were studied. Complete results of the study are reported elsewhere (Flook 1967). The present paper will report on the phase of the study which dealt with parasites, particularly the relationship of incidence and intensity of infections to age and sex of wapiti. The seasonal and spatial distribution of infections will also be discussed.

Materials and Methods

Data were obtained from 1380 wapiti shot in the early winters of 1958 to 1967 for population control in Jasper, Banff, and Waterton Lakes National Parks. These will be referred to as the slaughter series. More detailed autopsies were made of 107 wapiti, older than calves, collected at different seasons of the year from 1961 to 1963 in Banff and Kootenay National Parks and the Ya Ha Tinda Ranch on the Red Deer River east of Banff Park. These will be designated the research series.

In all wapiti the external appearance of the liver was noted, and, if there were discolored areas on the surface, the liver was sliced and inspected for the giant liver fluke (*Fascioloides magna*). Some light infections may have been missed by that procedure. The lungs of all wapiti, except those slaughtered in Waterton Lakes in 1963, were inspected and palpated to search for hydatid cysts (the larval stage of the tapeworm *Echinococcus granulosus*). The bronchi of wapiti taken in Banff and Kootenay and the Ya Ha Tinda Ranch were opened with a boning knife or scissors to search for the thread lungworm (*Dictyocaulus viviparus*).

[1]Deceased.

In the research series, the following procedures were also carried out. The surfaces of the abdominal organs, the mesenteries, and peritoneum were cursorily inspected for nematodes or cysticerci. The heart was sliced at 1- to 2-cm intervals to examine for cysticerci. During removal of the mandible, the masseter muscles were inspected for larval tapeworm cysts. The linings of the rumen and abomasum were examined cursorily for trematodes or nematodes. The duodenum, anterior 3 m of jejunum, and posterior 3 m of ileum were removed and tied off separately, and the contents of each flushed out with water under pressure and screened for helminths. Similarly, the terminal 20 cm of the caecum, as well as a 25-cm section of the colon in the region where the faecal pellets are formed, were removed and tied off, and the contents screened. The tarsals, metatarsals, carpals, and metacarpals were skinned and examined for the deer legworm (*Wehrdickmansia cervipedis*). The nasal passages and retropharyngeal pouches were examined for larvae of the deer nose fly (*Cephenemyia jellisoni*).

Skins of wapiti in the research series, taken from September 1 through June and one taken in July, were sampled for ectoparasites as follows. A collar of skin, 25 cm wide, was removed from the neck immediately posterior to the ears. From all except those taken in December, two rectangular pieces of skin were also removed, one from each side of the body. They were 25 cm long by 12.5 cm deep, and located with the upper margin 12.5 cm below the dorsal mid-line, and so that they were bisected by the posterior rib. In a few specimens in which the skin from one side was rubbed or otherwise damaged in handling, samples were taken from only one side of the carcass. They were stored in separate bags, and processed by the technique of Hopkins (1949), in which the hair is digested by sodium hydroxide. Ectoparasites were screened out, identified, and counted.

Ages were assigned to wapiti on the basis of replacement and wear of the teeth (Quimby and Gaab 1957) and cemental layers in the root of the first mandibular molar (Mitchell 1967).

Results and Discussions

The giant liver fluke (*Fascioloides magna*) was found to be a common parasite of wapiti in Waterton Lakes and Kootenay, and occurred with varying incidence in Banff.

The tapeworm, *Moniezia benedeni*, was noted in only one wapiti examined. That was a female calf shot 16 February 1962, on the Ya Ha Tinda Ranch, and she carried two of those tapeworms in the anterior 3 m of the jejunum.

The fringed tapeworm (*Thysanosoma actinoides*) was found in the duodenum and jejunum of several specimens from Banff and Kootenay.

Hydatid cysts of the tapeworm, *Echinococcus granulosus*, occurred commonly in the lungs of wapiti in Banff and Jasper.

The whipworm (*Trichuris ovis*) was noted in two wapiti. Two whipworms were screened from the ileum of a yearling male killed 4 August 1961, in the Cascade River Valley in Banff, and four, from the caecum of a yearling female collected on the same encounter.

The thread lungworm (*Dictyocaulus viviparus*) was fairly common in wapiti in Banff.

One peritoneal nematode *Setaria cervi* was noted during the study in a yearling female shot 4 August 1961 in the Cascade Valley.

Larvae of the deer nose fly (*Cephenemyia jellisoni*) were found in the pharynges of two specimens, a 23-month-old male taken 30 March, 1962, on the Ya Ha Tinda Ranch, which carried two larvae; and a female of the same age taken 4 days later in the Bow Valley in Banff, which carried five larvae.

Biting lice (*Damalinia concavifrons*) were collected from skin samples of a few specimens from Banff and Kootenay, and one specimen from Banff and Kootenay, and one specimen of *D. longicornis* was taken from a wapiti shot in Jasper in 1966. The winter tick (*Dermacentor albipictus*) was very common on skin samples from Banff, Kootenay, and the Ya Ha Tinda Ranch.

No other parasites were found. Because of the limitations of the inspections of the surfaces of the abdominal organs and the linings of the rumen and abomasum, parasites in those areas could easily have been overlooked. More detailed information will now be presented on infections by the parasites encountered commonly in one or more areas.

Giant Liver Fluke (Fascioloides magna)

Although the livers of 193 wapiti slaughtered in Jasper in 1966–1967 were sliced at 1.5-mm intervals and examined, liver flukes have not yet been found in that park.

Among six wapiti, four males, and two females, all older than calves, taken in Kootenay during late winter 1962, the livers of four contained flukes. Of the other two, the liver of one, a yearling male, had extensive scars, and that of the other, a 10-year-old female, had scars and encysted caseous remains of dead flukes. The only wapiti from Yoho National Park examined during the present study, a 2-year-old male shot in December 1961 carried five flukes. This parasite was previously reported by Cowan (1951) in a moose and a mule deer from the Rocky Mountain Trench in British Columbia, where some wapiti from both Kootenay and Yoho Parks migrate in winter.

Green (1946) reported that he examined the livers of 549 wapiti slaughtered in Banff in 1944–1945 and 1945–1946 for *Cysticercus tenuicollis*. The fact that he did not report liver flukes suggested that they were absent or uncommon in the park at that time.

Of 707 wapiti examined from 1958 to 1963 in the Bow Valley of Banff the incidence of *Fascioloides* averaged 3% (0–5) whereas 21% of 62 animals taken in 1963–1964 and 50% of 52 taken in 1964–1965 were infected. In the data for the whole period 1959–1965 no calves were infected, and yearlings had a lower incidence than adults, 6% as compared to 11%. However, there were no significant differences in incidence between age classes older than yearlings nor between the sexes.

In a sample of 339 wapiti taken from the Cascade and Red Deer drainages from 1960 to 1965, only two were infected with liver fluke. Both were males shot in 1962: a 2-year-old taken near the Cascade River in July, and a 6-year-old taken near the Red Deer River in December.

The previous absence of records of flukes from Banff, the scarcity of the parasite in those drainages of Banff farthest from the Kootenay drainage, the high incidence of infections in the sample of wapiti from Kootenay Park, and the uniform incidence of infections of liver fluke in different age classes of wapiti older than yearlings in the Bow Valley, all suggest that infected wapiti taken in Banff were infected immigrants

from Kootenay Park. Occasionally wapiti have been observed crossing in either direction between the Kootenay and Bow drainages by way of Vermilion Pass. The rather heavy and consistent removals of wapiti from the Bow Valley, beginning in 1957, could be expected to have left space for occupancy by immigrants from the Kootenay drainage. In the latter area winter range is restricted, numbers of wapiti are fairly high, and the only wapiti harvested in recent years have been the six taken for the research series.

During the slaughter conducted in Waterton Lakes in 1958–1959, fluke infections were found in 21% of a sample of 147 specimens. During the slaughter in 1959–1960, fluke infections were noted to be common but the incidence was not recorded. In 119 wapiti taken in January 1963, 40% were infected. Within each age group the incidence was higher among females than males. The samples of males were small, however, and none of the differences were significant ($P < 0.05$). However, the incidence in all females older than yearlings was significantly higher than that of males in the same age group, 17% as compared to 48%.

The liver of male wapiti may provide a less favorable environment for flukes than that of females. In mature males, in contrast to females, the liver annually undergoes fatty infiltration during the rut (Flook 1967). However, the tendency of males older than yearling to range, much of the year, at higher elevations than females (Cowan 1950; Flook 1967) probably reduces the opportunities for them to ingest liver fluke cercaria, as the latter are restricted to swampy areas and the margins of bodies of water suitable for the snails which act as intermediate hosts (Soulsby 1965, p. 583). This could have caused the observed sex difference in incidences of infections.

In the sample of males examined in Waterton Lakes in 1963 the incidence of liver fluke infections did not increase in relation to age. However, the number examined was small.

Among the females the incidence was lower in the 12 calves examined (33%) than in the 78 animals older than calves (50%). However, when age classes were compared within the latter group, which ranged to more than 10 years of age, the incidence was fairly uniform.

At least four circumstances could lead singly, or in combination, to the observed relationship of incidence of fluke infections to age. Those are a counterbalancing of new infections by mortality selective for infected wapiti, mortality of flukes, a recent marked increase in exposure to infection, or an age-related resistance to infection.

Swales (1936) reported that the cervid host is protected from undue tissue damage by a capsule which it produces around the parasite. Swales (1935) concluded that infections of giant liver fluke do not impair the health of the cervid hosts except in heavy infections, and that deaths of deer reportedly caused by it probably resulted from lowered resistance to other adverse circumstances under conditions of excessive infections. Similarly, Cowan (1951) reported that deaths in cervids caused by giant liver flukes were infrequent. However, Cheatum (1951), in comparing the incidence of liver fluke infections in white-tailed deer found dead in winter in New York to that in samples shot in the same areas, found that in adults the incidence was significantly higher in winter-killed specimens. As Cheatum did not include data to compare the ages of the two groups, there is a possibility that the winter-killed animals were older and the differences in incidence were age-related. In wapiti in Waterton Lakes, if the annual acquisition of new infections continued in adults at the same rate as occurred in the calves, selective mortality, in order to have prevented an increase in incidence of infection, would have had to be extremely heavy. As the age composition of the sample of females slaughtered in Waterton Lakes in 1962–1963 indicated that mortality was not heavy between the yearling and 6-year-old classes, it is doubtful whether host mortality was the main factor impeding an increase in fluke incidence in relation to age. However, with the information available, it is not possible to isolate the cause(s) of the relationship of incidence of fluke infections to age of wapiti.

Fringed Tapeworm (Thysanosoma actinoides)

Cowan (1951) reported fringed tapeworms in a wapiti from Jasper, in two mountain goats (*Oreamnos americanus*) from Banff, and a bighorn sheep (*Ovis canadensis*) from Kootenay. In the present study, fringed tapeworms were found in some specimens in every month in which

autopsies were made, except March and April. No specimens were examined in January. Within the limitations of the sample size there was little indication of seasonal differences in the incidence of this parasite.

The incidences of infection and the means and ranges of the numbers of fringed tapeworms screened from specimens of different sex and age groups are shown in Table I. There were no significant differences in the incidence of infections between males and females, nor was there any significant difference in incidence between yearlings and 2-year-olds when data from animals of both sexes were combined. However, wapiti 3 years old and older, of both sexes, had a significantly lower ($P < 0.005$) incidence than yearlings and 2-year-olds combined. Yearlings had the highest mean number of tapeworms and the heaviest individual infections, whereas wapiti 3 years old and older had the lowest mean number of tapeworms and the lowest individual loads. Probably the resistance of wapiti to infection with this parasite increases in relation to age. However, the possibility that behavioral traits of young wapiti make them more prone to infection cannot be discounted.

Of the 254 fringed tapeworms screened from samples, 146 were from the duodenum and 108 from the anterior 3 m of jejunum. There was no indication of seasonal changes in the distribution of tapeworms between those two segments of the intestine.

Although this parasite has been reported to damage the health of domestic sheep by blocking the bile and pancreatic ducts (Monnig 1947, p. 101), it has not been observed to cause disease in cervids (Honess and Winter 1956, p. 123).

Pulmonary Hydatid Cysts (Echinococcus granulosus)

In the sylvatic cycle of *E. granulosus* in North America, the intermediate host is usually a member of the Cervidae, the usual site of the infection being the lung, and the definitive host is commonly the wolf (*Canis lupus*) (Cameron and Webster 1961). The first record of this parasite from the Canadian Rockies was reported by Cowan (1948), who identified hydatid cysts in wapiti in both Jasper and Banff in 1944. He examined one wolf, one cougar (*Felis concolor*), and six coyotes (*Canis latrans*) from Jasper and found *E. granulosus* in the wolf only. Holmes and Podesta (1968) found *E. granulosus* in 4 of 23 coyotes examined from Banff between 1959 and 1967. As normally developed ova were present in a small proportion of the worms (Holmes 1961), the results indicated that coyotes could be locally important in maintaining sylvatic echinococcosis. As wolves have been present in Banff Park only intermittently and in very small numbers since 1956, coyotes have probably been the major definitive host in that park in recent years. In Jasper, on the other hand, a wolf population has persisted and has no doubt shared with coyotes the role of definitive host of *E. granulosus*.

Opinions have varied concerning the effects of hydatid cysts on the welfare of the host. Cowan (1951) noted that black-tailed and mule deer and wapiti infected with hydatid cysts were usually impoverished and of low vitality, and considered it almost certain that their ability to survive other adverse circumstances was impaired. However, Rausch (1952), on the basis of examinations of moose, reported, "The

TABLE I

Incidence and numbers of fringed tapeworms (*Thysanosoma actinoides*) in intestinal samples* from wapiti collected in the research series in Banff and Kootenay National Parks, and Ya Ha Tinda Ranch, 1961 to 1965

	Age and sex of wapiti					
	1 year		2 years		≥ 3 years	
	♂	♀	♂	♀	♂	♀
Incidence†	11/15	5/10	4/10	4/7	1/17	1/20
Average no.	10.4	6.7	1.6	1.6	0.12	0.10
Range	(0–54)	(0–24)	(0–8)	(0–5)	(0–2)	(0–2)

*Duodenum and anterior 3 m of jejunum.
†Number of specimens containing tapeworms /number examined.

larvae of *Echinococcus granulosus* appear to be essentially non-pathogenic in their natural mammal hosts." Rausch suggested that because older ungulates had a greater probability of being infected, the tendency of hydatid infections to be associated with poor physical condition of the host could be attributed entirely to the general effects of old age on the host.

The only heavy hydatid infection noted in the research series occurred in a 21-year-old female from the Cascade Valley. Its perinephric fat deposits compared favorably with those of other wapiti in the series, indicating that the energy balance was not adversely affected.

In any case, displacement of part of the lung tissue by hydatid cysts can be expected to reduce the capacity of the host for oxygen exchange (Guyton 1956, p. 457). Writing of hydatid cysts in horses, Soulsby (1965) stated, "A marked infection of the lungs may lead to dyspnoea on exercise . . . ." Pulmonary hydatid infections can therefore be expected to increase the vulnerability of the hosts to predation by wolves, as that usually involves pursuit (Cowan 1947; Mech 1966). Cowan (1947) found that a substantial proportion of the wapiti killed by wolves in Jasper from 1943 to 1946 were in the "prime" age group, and suggested that the vulnerability of those animals to predation may have resulted from the effects of hydatid infections. Ritcey and Edwards (1958) reported an instance in which a fat young cow moose with an extremely heavy hydatid infection died in a corral trap when approached by the captors. Mech (1966, pp. 144–150) examined two intact carcasses of wolf-killed adult moose, and both carried heavy hydatid infections.

No hydatid cysts were found in the lungs of 147 wapiti slaughtered in Waterton Lakes in 1958–1959, nor in those of six wapiti, all older than calves, collected in Kootenay in 1962. Green (1949) reported incidences of hydatid infections in wapiti slaughtered in Banff in the four winters between 1944 and 1948 as 1.7%, 6.8%, 6.06%, and 4.9% respectively. In the present study, hydatid cysts were found in the lungs of wapiti from the Bow, Cascade, Panther, and Red Deer Valleys in Banff and from Jasper (Table II).

In the sample from the Cascade and Red Deer drainages the incidence of infection of females was significantly higher ($P < 0.05$) than that of males, in the group 6 to 9 years old and in all animals older than yearlings. However, among wapiti from either of the other areas there were no significant differences between incidences of infection in males compared with females. The incidence of infection failed to increase consistently with increases in age in any of the samples. There are a number of factors which may have influenced the incidence of hydatid infections in wapiti of different sex and age, and in different areas. They are age-related resistance to infection, mortality selective for infected wapiti, variations in the abundance of wolves and coyotes, and differences in the distribution of wapiti of different sex and age in relation to the distribution of the canids. Because the only difference in incidence related to sex was restricted to one population of wapiti, it is probably attributable to the last mentioned explanation.

Thread Lungworm (Dictyocaulus viviparus)

This parasite was found in wapiti from all areas from which they were examined for it, i.e.

TABLE II

Percentage incidence of pulmonary hydatid infections in wapiti from three areas. Numbers examined in parentheses

Age, yr	Cascade and Red Deer valleys, 1966–67		Bow Valley, 1958–68		Jasper Park, 1966–67	
	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀
<1	0(24)	0(24)	0(83)	0(71)	10(10)	0(14)
1	0(26)	0(22)	4(75)	4(67)	33(21)	50(10)
2	7(13)	11(28)	17(41)	18(89)	14(7)	46(11)
3–5	10(20)	6(49)	23(93)	29(172)	53(15)	50(50)
6–9	0(15)	28(64)	18(61)	18(121)	25(4)	33(33)
≥ 10	0(4)	24(50)	29(14)	24(62)	67(3)	47(15)
≥ 2	6(52)	19(191)	20(209)	23(444)	41(29)	44(109)

Banff, Kootenay, and the Ya Ha Tinda Ranch. No differences in incidence related to sex or age were evident. That is in agreement with the findings of McBee, Worley, and Barrett (*cited by* Barrett and Worley 1966). Calves were autopsied only from November to February and of 108 male and 96 female calves, only 2 males were infected. Wapiti from the older classes were autopsied throughout the year, and when data from them are consolidated (Table III), a seasonal cycle in incidence of infection becomes evident. A peak of incidence was reached in July and August. That was followed by a decline through autumn and winter, and a buildup beginning in May. When the incidence of infections in specimens taken from October to April was compared with that of specimens taken from May to September, the difference was significant ($P < 0.005$). The seasonal cycle of incidence suggests that few if any wapiti became infected during the winter. According to Monnig (1947), the larvae of *Dictyocaulus filaria* rarely live through the winter in cold climates. *D. viviparus* is probably similar in that respect.

A number of workers have reported frequent and heavy infections of thread lungworms in wapiti which died in winter (Schwartz and Mitchell 1945; Banfield 1949; Cowan 1951; Honess and Winter 1956, p. 178). Schwartz and Mitchell and Banfield described overstocking of wapiti and depletion of forage stands associated with their observations. Similar circumstances probably prevailed in the instances reported by Honess and Winter, and Cowan. Longhurst and Douglas (1953) reported "most infections in winter" for *D. viviparus* in samples of Columbian black-tailed deer collected year-round in northern coastal California. As the range was severely depleted, lowered host resistance no doubt contributed to the high winter infections in that situation, and also, a milder climate may have permitted the survival of infective larvae on the range in winter.

The data collected in the present study were from wapiti populations on generally moderately stocked ranges in satisfactory condition. Evidently under those circumstances most wapiti were successful at ridding themselves in autumn of the lungworm loads which they acquired during the previous summer. This interpretation is consistent with findings of Barrett and Worley (1966) which indicated that the incidence and average worm burden of *Dictyocaulus* sp. in wapiti in winter tended to vary directly with the previous and current use of the range.

Biting Louse (Damalinia concavifrons)

Lice of the above species were found on eight neck samples and 10 chest samples from 12 wapiti of 51 collected from September through June. Samples from only one animal carried more than 23 lice. That was a very emaciated female almost 19 years old, collected in May, and the sample taken from only one side of the chest carried 459 lice. The neck sample was free of lice. The condition of this wapiti conformed with Cowan's (1951) observation that *Damalinia* spp. tended to be more numerous on hosts in poor physical condition.

Winter Tick (Dermacentor albipictus)

Winter ticks were found on wapiti from all areas of collection represented in the research series, and occurred in one or more life stages on skin samples of 34 of 45 wapiti examined that were taken during the period 1 October to 30 June. From September and July only six and one skin samples, respectively, were processed, and none of them carried ticks.

When the data on mean numbers of ticks of each life stage per sample from wapiti of both sexes and all ages are consolidated (Table IV) the phenology of the three life stages of the ticks is indicated. Larval ticks first appeared in October. The only wapiti from a later month on which larval ticks were found was one taken in

TABLE III

Incidence of thread lungworms (*Dictyocaulus viviparus*) in wapiti older than calves from Banff and Kootenay National Parks and the Ya Ha Tinda Ranch, December, 1958, to January, 1966

Period of collection	Incidence, %	No. examined
June	33.3	6
July	83.3	6
August	80.0	5
September	18.8	16
October	6.2	16
November	2.7	110
December	2.1	525
January	0.3	380
February	0.0	8
March and April	0.0	7
May	20.0	5

April that was carrying 200, the largest number of that stage found on a sample from a single host. Nymphs were present on some specimens in each period from October through June, but reached peak numbers in December. Adults first appeared in December samples, reached a peak in March and April, and occurred in small numbers on some May and June specimens. No samples from January or November were examined. The observations on the seasonal distribution of the life stages of the winter tick are consistent with Gregson's (1956) discussion of the life cycle of this species. He noted that the larvae are very tolerant of snow and low temperature and unless brushed onto a host may remain on the ends of grass and twigs until spring.

Because of marked individual variation no meaningful comparison could be made between numbers of ticks infecting wapiti of different sex and age.

The incidences of ticks on the skin samples studied are given according to sex and age of the host in Table V. The only sex–age group in which all the wapiti studied carried ticks was the males 16 to 25 months old, represented by 12 animals. The lowest incidence was in adult females, of which 5 of 10 were infected. Samples from individual sex–age groups were too small for meaningful statistical comparison. Data from males of all ages were therefore compared with data for all ages of females. Among 26 males taken from October through June, 23 were infested with ticks, whereas among 19 females taken during the same period, only 11 carried ticks. The difference was significant ($P < 0.05$).

It is not known what factors might cause male wapiti to have a higher incidence of infection than females. Perhaps males have a lower resistance to the attachment and survival of ticks. That could be related to the lower fat reserves of males in winter. On the other hand, the use of different habitats, or more travel on the part of males, might increase the probability of contact with tick larvae.

Cowan (1951) considered the winter tick one of the most serious parasites of big game mammals in Western Canada. Honess and Winter (1956) reported evidence that heavy tick loads

TABLE IV

Average number of ticks (*Dermacentor albipictus*) on skin samples* of wapiti 16 months old and older collected in Banff and Kootenay National Parks and the Ya Ha Tinda Ranch, 1961 and 1962

Period of collection	Stage of ticks				No. wapiti sampled
	Larvae	Nymphs	Adults	All stages	
September	0	0	0	0	6
October	6	10	0	16	14
December	0	677	14	691	10
February	0	194	138	332	5
March, April	33	40	266	339	6
May, June	0	1	1	2	10
July	0	0	0	0	1

*December samples consisted of collar 25 cm wide immediately posterior to ears. Other samples included collar plus rectangle 25 cm by 12.5 cm, taken from each side of chest.

TABLE V

Incidence* of ticks (*Dermacentor albipictus*) of all stages on skin samples† of wapiti collected in Banff and Kootenay National Parks and the Ya Ha Tinda Ranch, October through June,1961 and 1962

Sex of host	Age of host			
	16–24 months	28–36 months	≥ 40 months	Total
Male	12/12	3/4	8/10	23/26
Female	4/6	2/3	5/10	11/19

*Number of specimens carrying ticks /number sampled.
†December samples consisted of collar, 25 cm wide immediately posterior to ears. Other samples included collar plus rectangle 25 cm by 12.5 cm, taken from each side of chest.

caused hemoglobin depletion and extreme weakness in wapiti calves, on artificial feeding grounds. They pointed out that the engorgement of adult female ticks takes place from mid-winter until spring, a period when the host is already in its poorest condition.

Published observations of dead or dying wapiti carrying heavy infections of winter ticks seem mostly to have been made under circumstances in which the host population was dense and the forage stands depleted (Banfield 1949; Love 1955; Murie 1951, p. 166). Peterson (1955, p. 185) similarly noted that the heaviest tick infestations reported in moose in Canada were coincident with high population levels of moose.

The data from the present study show that a large proportion of a wapiti population can contract substantial loads of winter ticks under conditions of moderate stocking on a range in satisfactory condition. While tick infections are probably seldom the sole cause of mortality, they could combine with other adverse circumstances to cause mortality. A sex difference in the incidence of tick infections such as is indicated here could contribute to making mortality heavier in late winter among males than among females.

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