THE WINTER TICK, DERMACENTOR ALBIPICTUS (PACKARD, 1869) ON MOOSE, ALCES ALCES (L.), OF CENTRAL ALBERTA[1]

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Abstract: Dead or dying moose with massive infestations of the winter tick were found in Elk Island National Park, central Alberta, during March-April, 1977 with evidence of a widespread epizootic of at least 2 years' duration.[2] Skins of 74 moose, most from the Park, were collected from December 1977 to April 1978 and examined for ticks. Methods for determining total numbers and locations of ticks on moose are presented. Concentrations of ticks are correlated with patterns of hair loss in late winter-spring.

[1] This paper was written while the senior author was on study leave at the Wild Animal Disease Center, Department of Veterinary Pathology, Colorado State University, Fort Collins, Colorado.

[2] Aerial observation of moose with hair loss presumably induced by ticks and examination of dead moose with massive numbers of ticks in late winter 1979 (Lynch and Lajeunesse, pers. comm.) indicate an epizootic of at least 3 years' duration. Data for 1979 will be presented at the 16th North American Moose Conference and Workshop.

All age classes of moose averaged over 10,000 ticks/moose with most over 20,000. Some animals were practically hairless by late April, presumably due to ticks, but many apparently survived. Results suggest that D. albipictus is the most serious pest of moose in Alberta. The life cycle is reviewed.

The winter tick, Dermacentor albipictus, is a common ectoparasite on moose and other Cervidae of the northern United States (see review of Anderson and Lankester 1974 and Addison et al. 1979). It is a northern tick, but is uncommon north of 60° latitude; apparently, it is absent from Alaska.

Preferred hosts, other than moose from which D. albipictus was described, include deer (Odocoileus spp.), wapiti (Cervus elaphus canadensis), and horses. Other hosts are beaver (Castor canadensis), cattle, mountain sheep (Ovis canadensis), mountain goats (Oreamnos americanus), bison (Bison bison), pronghorn (Antilocapra americana), black bear (Ursus americanus), caribou (Rangifer tarandus), coyote (Canis latrans), wolf (Canis lupus), and the white-footed deer mouse (Peromyscus maniculatus). As stated, it has a wide geographic range in North America, but is most common in northern states and Canadian provinces. According to Howell (1940), "they (the ticks) follow the mountain ranges south and reach the Gulf of Mexico in hilly areas". Thus, there is a continuous distributional chain of this tick along the Sierra Nevada and Rocky Mountain ranges. Bishopp and Wood (1913) noted that D. albipictus appeared to be most abundant in the mountains and timbered uplands. Dermacentor albipictus extends much further north than Dermacentor andersoni and Dermacentor variabilis (both below 54°N latitude) (Wilkinson 1967).

The winter tick is considered by many to be a serious parasite of moose (Hardy 1869, Cameron and Fulton 1926-7, Wallace 1934, Hatter 1948, Cowan 1951, Peterson 1955, Ritcey and Edwards 1958, Webb 1959, Stelfox 1962, Mech 1966, and Berg 1975). The subject is complex and, unfortunately, has been treated rather superficially in the past. Nonetheless, it is common to find dead or dying northern big game animals, particularly moose, with massive infestations of D. albipictus (or blood-stained beds where these animals have been) in late winter (see the above citations).

In late March and early April 1977, approximately 20 moose were found dead (and an estimated 100 died) in Elk Island National Park (EINP), Alberta. According to Park Wardens, they were heavily infested with the winter tick. Moose with severe hair loss attributed to ticks were observed in the Long Lake region north of EINP at the same time (Rippin, pers. comm.). Since details on age, number and location of ticks on moose, and the relationship to hair loss and mortality of moose were not known, a detailed study was initiated in December 1977. The objectives were to devise techniques for determining the abundance of D. albipictus on moose, determine the prevalence of ticks in the moose population, determine the importance of this parasite for moose of EINP and

other regions of Alberta. Additionally, data on hair loss patterns attributed to ticks, mortality of ticks from the nymphal to the adult stage, sites of attachment and presence on other hosts, were acquired.

The author is grateful for a general contract from Parks Canada that financed much of this study. All personnel of EINP were helpful; particular thanks are due Superintendent Fred Bamber, Chief Warden Bob Jones, Wardens Ed Henderson and Fred Dixon and Naturalist Steve Schwartz. The Alberta Fish and Wildlife Division financed and assisted with aerial observations of moose; Bill Hall, Jerry Kemp, Bryan Lajeunesse, Gerry Lynch, Dave Neave and others of the Division were very cooperative. Jean Paul Gaboury, Vicky Glines, S. Ramalingam, Beth Rogers, Stan Rubin, Jonna Samuel and Wendy Stringer provided technical or pilot-study input. Gerry Lynch and Bryan Lajeunesse aged moose by sectioning incisors.

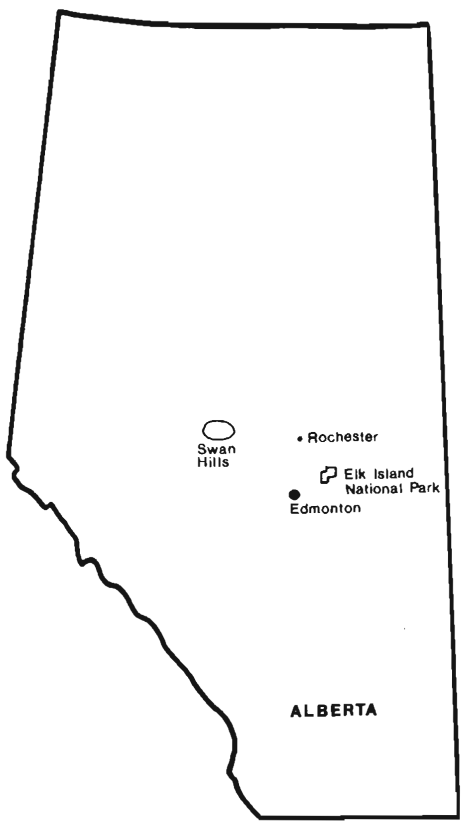
METHODS

Hide Collection

Moose hides or parts thereof were systematically collected during a harvest of moose at EINP (Fig. 1) from December 5 to 19, 1977. The left half of 15 hides and a strip (approximately 10 cm wide) along the perimeter of a skinned hide (again, left side only) from 49 moose were collected. The hides of 3 white-tails and 1 wapiti were also collected.

An additional 2 moose were collected at random on March

FIGURE 1. Major areas of study in relation to Edmonton, Alberta (1977-78).



29 and 31, 1978, from EINP and the entire skins saved. The skins of 3 calf moose found dead in EINP on March 3, April 6 and 13, respectively, were saved.

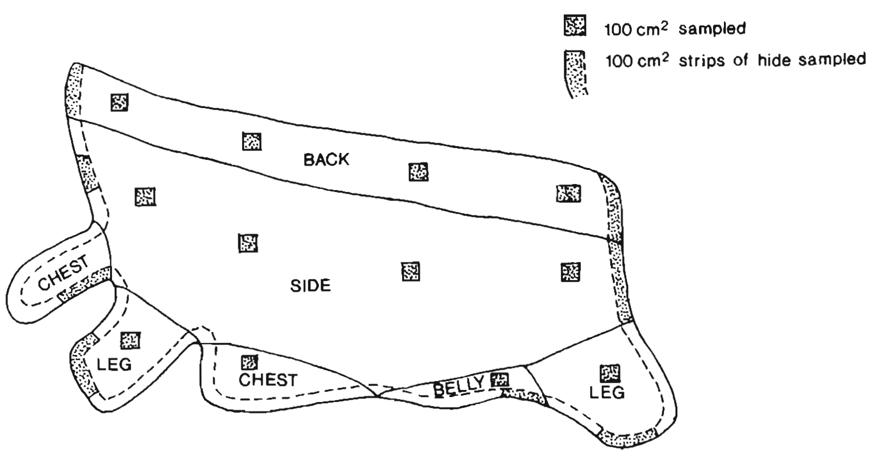
Techniques for Collecting Ticks

The half-hides were divided into 5 regions based primarily on hair type (Fig. 2): long, coarse hair averaging 10 cm in length, 220 hairs/cm^2, and typical of the mid-dorsal neck and body; medium length hair averaging about 7 cm in length, 247 hairs/cm^2, and typical of most of the lateral surface; finer, short hair ($\sim$ 4cm long) typical of the legs (density, front= 306; hind= 422 hairs/cm^2) and chest (192 hairs/cm^2); and soft, long ($\sim$ 9cm), sparse hair typical of the belly.

Three techniques were used to estimate total numbers of ticks. In the first a total of twelve 100 cm^2 pieces of skin was removed as follows: 4 from along the back; 4 from along the side; 2 from the legs; 1 from the chest; and 1 from the belly. The total surface area of each region was determined.

The twelve 100 cm^2 pieces of hide were examined for ticks as follows: each piece of skin was placed in 800 ml of KOH solution (5% by weight) and this was placed in a 90^{o}C waterbath for 1 hour. The solution was poured through a 180 μm sieve (No. 80 mesh of the Canadian Standard Sieve Series). Ticks were washed into a white pan from the inverted sieve, then aged, sexed and counted. This technique was used on 15 moose, 1 wapiti and 3 white-tailed deer collected in EINP in December 1977.

FIGURE 2. Diagram of moose skin showing subsamples examined by Techniques 1 (100 cm^2 - 12 samples) and 2 (8 perimeter strips).



Technique number 2 involved use of the perimeter strips. A total of 8 subsamples was taken along each strip (Fig. 2). The entire strips of the back (~ 60 cm^2) were sampled for ticks while 100 cm^2 were removed and examined for ticks from the other 6 regions. All subsamples of skin were dissolved and examined using procedures just described for the subsamples of the half-hide. Forty-nine moose collected in December were examined in this fashion.

A third technique was more detailed than the others; it was used for 5 adult moose shot in December, 2 adults shot in March, and 3 calves found dead or dying in March-April. It involved dissolving 16 cm^2 of every 100 cm^2 section of skin on a half-hide. The flesh side of each of 10 half-hides was scored with a scapel until the entire hide was gridded into 100 cm^2 blocks. The total surface area of each half-hide was determined. A 16 cm^2 sample was taken from the upper left corner of each 100 cm^2 block.

The hair was clipped to within 2 cm of the skin and the skin placed in 50 ml of KOH solution (5% by weight) in a 90^oC waterbath for 1/2 to 3/4 hour. The solution was poured through a 180 µm sieve and the ticks treated as described previously.

Ticks collected were separated according to life stage (larvae, nymphs, or adults) and sex (only for adults). Ticks were studied and identified following descriptions of Gregson (1956), Arthur (1960) and Diamant and Strickland (1965).

Estimating Numbers of Ticks

For the 15 moose examined using Technique 1 (twelve-100 cm^2 pieces of skin), total numbers were estimated by: 1) calculating the total number of ticks in the skin subsamples from each region and total surface area of each region; 2) estimating the total number of ticks in each region; 3) summing all totals for all regions, and; 4) multiplying by 2 (to estimate numbers on the right side of the moose).

For the 49 moose examined by the strip census, the total surface areas of the half-hides of calves, yearlings and adults were estimated at 8,661, 13,859 and 15,556 cm^2, respectively (based on averages from other moose Isee aboveI). Using the proportion of the number of ticks in the areas subsampled over the total area subsampled, the total number of ticks was estimated and multiplied by 2.

When technique 3 was used, the following was determined: 1) the surface area of the half-hide; 2) the subsampled surface area; 3) and the number of ticks in the subsampled areas. Using proportions as described above, the total numbers were estimated.

Patterns of Hair Loss on Moose

Aerial observations were conducted at EINP (April 21, 1978), east of the towns of Rochester (April 26, 1978) and Swan Hills (May 12, 1978) in an attempt to determine patterns

of hair loss possibly attributable to ticks. Helicopters were used. Diagrams of hair loss were made for each moose observed and photographs taken for comparison. A total of 44 moose was observed in EINP, 28 at Rochester and 25 at Swan Hills.

Additional information was provided by Stringer and Rubin (unpub.) who conducted a pilot study on moose ticks in our laboratory in 1976-77; from a calf moose found dead near Athabasca, Alberta, with "1,000's" of nymphal D. albipictus on Feb. 20, 1978; from a moose killed on Highway 16 near Edson, Alberta, on April 30, 1978; from 2 tame moose (1 of which died the week of April 10, 1978) and 9 tame wapiti in a 1.6 km^2 pen near Ministik Lake east of Edmonton, Alberta, all of which were infested with ticks (Gates, pers. comm.); and from discussions with Blair Rippin, Regional Biologist, St. Paul, Alberta, Bob Stewart, Saskatchewan Department of Tourism and Natural Resources, and Gary Wobeser, University of Saskatchewan, Saskatoon. Data of Gaboury (unpub.), who conducted a pilot study in our laboratory on moose ticks, hair length, diameter and density, and skin thickness, were also provided. He made four anterior-to-posterior transects, 10 cm wide, extending from the dorsal to the ventral midlines of an adult moose collected at EINP in December 1977.

RESULTS

The skins of 74 moose (15- Technique 1; 49- Technique 2; 10- Technique 3), 1 wapiti and 3 white-tailed deer were digested for tick examination. All moose, the 1 wapiti (∿ 2000 nymphs), and 2 of the 3 white-tailed deer (146 and 1779 nymphs, respectively) were infested with D. albipictus.

Location of Ticks

Nymphal D. albipictus from the December collection at EINP were not distributed randomly on moose. When the half-hides were divided into twelve 100 cm^2 subsamples (Technique 1), ticks were found in the highest numbers on the shoulders, base of neck, and whithers (Fig. 3). They were relatively uncommon on the legs, belly, hip and mid-lateral side. However, when the perimeter strip was subsampled (Technique 2), ticks were clumped around the anus, belly (nipple area), and anterior sternum. Although skin from the head was not sampled, nymphs were not abundant there based on the casual examination in the field.

The more detailed examination (=Technique 3) of 10 half-hides was employed because of the apparent discrepancies in results using Techniques 1 and 2 relating to locations of ticks. Five adult moose from the December 1977 collection and 1 calf found dying on March 3, 1977 at EINP (Fig. 4) were examined. There was no noticeable hair loss in these or any

FIGURE 3. Mean number of nymphal D. albipictus in subsamples of skin examined by Techniques 1 and 2.

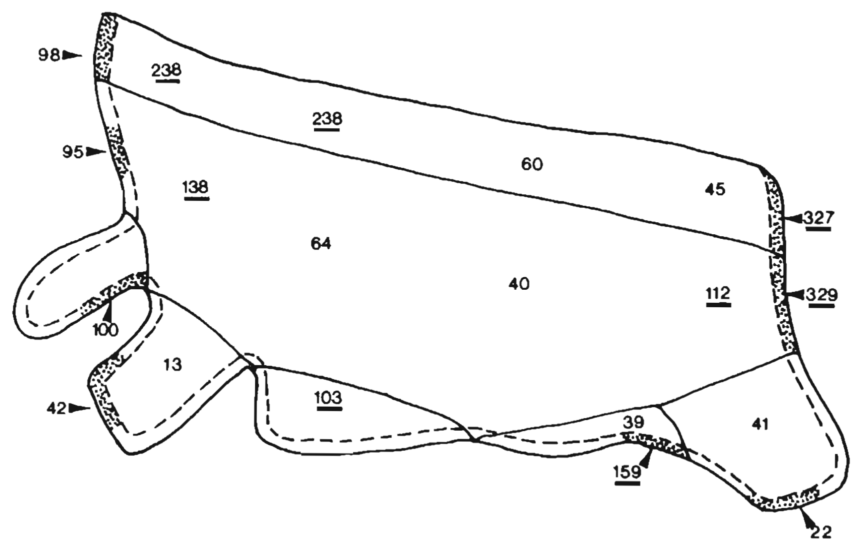
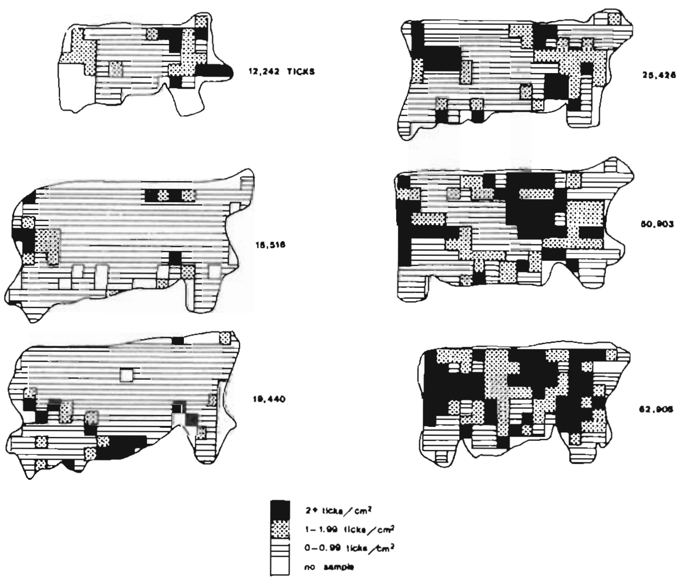


FIGURE 4. Locations, densities and total numbers of D. albipictus on moose found dying on March 3, 1978 (1 calf) or collected in December, 1977 (5 adults) in EINP as determined by Technique 3.



of the moose examined by Technique 3. Note that as total tick populations increased, ticks (99% of which were nymphs in the December collection) were most numerous (=dense) on the shoulders, side, whithers, and near the anus. Thus, use of this technique indicated that Techniques 1 and 2 were most useful when both were run. Obviously, Technique 3, although more time consuming, was much more accurate.

Densities of ticks were highest on the shoulders and sternum of the one moose examined by Technique 3 in late winter (Fig. 4). This male calf died of emaciation with severe hoof abnormalities to all four limbs (Lewis, pers. comm.); it had an estimated 6390 adult (none engorged) and 5852 nymphal D. albipictus.

Two moose, both adults, were shot at random in EINP in late March 1978 in order to compare tick ages, numbers and locations with those from moose found dead in April, 1978 (see below) and those collected in December 1977 in the Park. Both moose had moderate hair loss (apparently caused by rubbing) around the anus, neck and shoulders. The moose with the greatest hair loss had 8,641 ticks (estimated by Technique 3) scattered over the body (75% adult ticks, only 4% of 2710 adult females engorged), while the other had 13,863 ticks (86% adults, 11% of 5789 adult females engorged) with aggregations on the shoulders and lower anterior regions. This suggests that what we now recognize as relatively few ticks can induce hair loss.

Two calves found dead on April 6 and 13, 1978 were very emaciated with severe hair loss (Figs. 5 and 6). Examination of Fig. 5 and comparison with Fig. 4 revealed that hair loss, apparently caused by rubbing against trees (Schwartz, pers. observ.), resulted in either tick movement to other areas or, more likely, tick dislodgement. The shoulders of these calf moose were essentially hairless and tick densities there were low. Both calves had high tick densities on ventral and posterior surfaces where there was little hair loss. They had an estimated 22,194 and 27,525 ticks, of which 11 and 9% of 6529 and 11,401 adult females were engorged. The ears of the calf found on April 6 were digested and an average density of 3.83 ticks/cm^2 computed; all were adults.

Comparison of hair length and density with tick densities indicates that generally, ticks were most dense in all but the very short and dense hair of the legs (Fig. 7). Hair densities were generally lowest in dorsal regions (~ 230 contour hairs/cm^2 for adult moose) and higher in ventral regions (~ 300 hairs/cm^2) (Gaboury, unpub.).

Since D. albipictus is a blood feeder, skin thickness and locations of blood vessels were determined for various regions of the body. Variations in skin thickness were related to variations in the thickness of the dermis only (Table 1). Since blood vessels were closely apposed to the epidermal layer, it seems unlikely that skin thickness is a major factor in where ticks were found.

FIGURE 5. Locations, densities and total numbers of D. albipictus and hair-loss patterns on two calf moose found dead in EINP in early April, 1978.

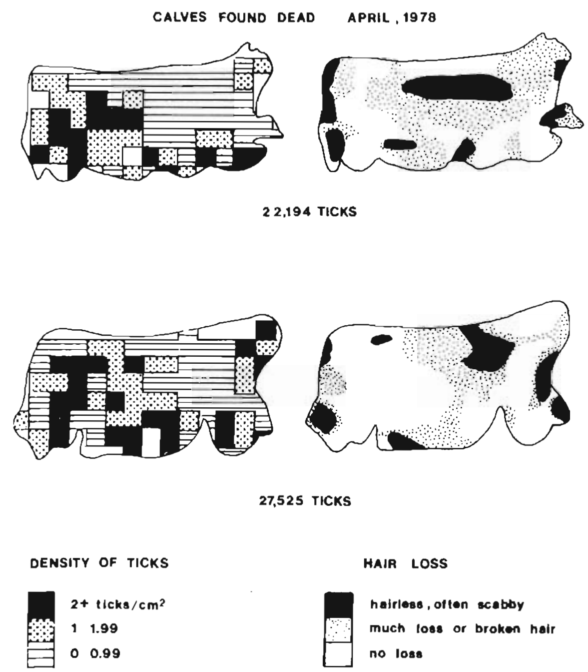


FIGURE 6. Posterior ventral surface of calf moose found dead in EINP, April 5, 1978. Note the clusters of ticks around the anus (arrow), on the medial surface of both hind legs, and on the belly.

FIGURE 7. Possible relationship of numbers of D. albipictus to density and length of moose contour hairs.

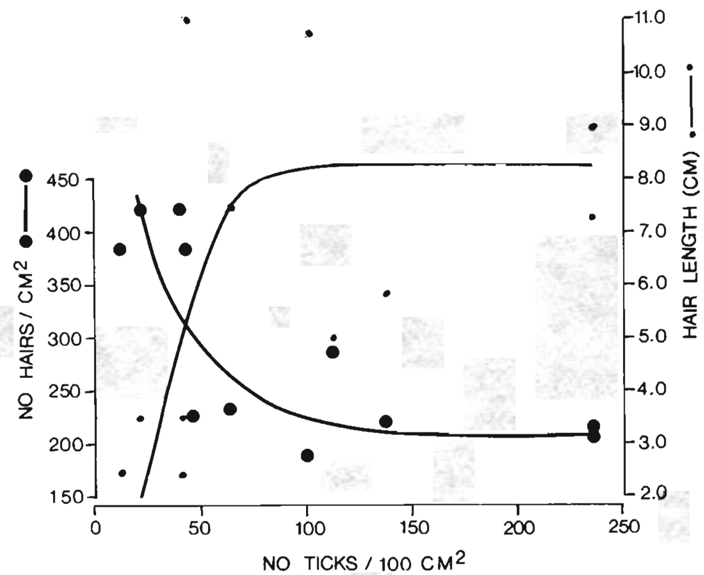


Table 1. Variations in the dermal and epidermal thickness on the half-hide of a moose (Gaboury, unpub.).

Hair Type	Mean Dermis Thickness (1μm)	Mean Epidermis Thickness (μm)
a*	6727	134
b*	5052	86
c*	4177	129
d*	3768	115

a*= back; b= between back and side; c= side; d= transitional zone, ventral to side anteriorly; belly and mid-leg posteriorly.

Total Numbers of Ticks

Only 854 of the 85,243 ticks (=1.0%) collected from moose shot in December (5th to the 19th) were adults. Only 5 were larvae. Thus, practically all ticks were in the nymph stage during the December collection period at EINP.

Regardless of the crudeness of the techniques employed to determine total numbers of ticks, it is obvious from Table 2 that moose of EINP were loaded with ticks in December 1977 and that counts were similar to those obtained using the more detailed examination (Technique 3) (Table 3). Following Technique 1, which seems the most conservative, numbers varied from 3,478 to 66,230 nymphs per moose, while numbers ranged from 4,123 to 178,123 and 8,641 to 62,905 for Techniques 2 and 3, respectively. The estimated average number of nymphs on adult moose at EINP was around 30,000. The average density of nymphs for 5 calves, 1 yearling, and 9 adults as determined by Technique 1 was 1.4, 0.7, and 0.6 ticks/cm^2, respectively. Host-age was not an important factor (Table 2) although densities of ticks on calves were probably higher than older moose because they were so much smaller than older moose yet had similar total numbers of ticks.

Although one moose (4-year-old male) had an estimated 178,000 ticks, the next highest infestation was 78,000.

Table 2. Estimates of total numbers of D. albipictus nymphs on moose of EINP determined by Techniques 1 and 2 (see text).

Moose No.	Moose Age	Surface Area (cm^2)	Estimated No. Ticks #1	Estimated No. Ticks #2
56	½	-	-	23858
780	½	-	-	45577
375	½	10920	24008	19954
363	½	17844	13082	12886
29	½	17138	42176	45056
20	½	16326	15202	17727
187	½	16382	26276	39015
53	½	-	-	13372
			x̄= 24149	27181
218	1½	-	-	29825
82	1½	-	-	41130
7	1½	27718	20862	36666
64	1½	-	-	57380
			x̄= 20862	41250
756	2½	-	-	40272
217	2½	-	-	25284
141	2½	-	-	36784
206	2½	-	-	33350
			x̄= -	33923
770	3½	-	-	24621
777	3½	-	-	42010
511	3½	30288	27596	27503
362	3½	26206	3548	4123
85	3½	-	-	39659
			x̄= 15572	27583
359	4½	33260	15134	25198
737	4½	29738	20000	39995
750	4½	26936	6874	17660
743	4½	-	-	66137
748	4½	-	-	36178
992	4½	-	-	18972
800	4½	-	-	69156
370	4½	-	-	178123*
			x̄= 14003	39042

Moose No.	Moose Age	Surface Area	Estimated No. Ticks #1	Estimated No. Ticks #2
221	5½	36370	66230	60987
185	5½	30014	3478	9789
744	5½	-	-	14053
			x̄= 34854	30682
19	6½	34558	21680	36153
371	6½	-	-	35523
738	6½	-	-	53435
142	6½	-	-	25406
146	6½	-	-	17895
228	6¼	-	-	18549
			x̄= 21680	31160
15	7½	32684	8000	28322
765	7½	-	-	23367
747	7½	-	-	78059
787	7½	-	-	16114
			x̄= 8000	36446
78	8½	-	-	47590
788	9½	-	-	14410
797	10½	-	-	31327
374	10½	-	-	16363
742	10½	-	-	13433
740	12½	-	-	64286
			x̄= -	31235

*Not included in determination of mean

SUMMARY:

	Mean No. #1	Mean No. #2
Calves	24149	27181
Ylg.	20862	41250
Young ad. (2-5 yrs.)	20409	33481
Old ad. (6+)	14840	32514

Table 3. Estimates of total numbers of densities of D. albipictus on moose of EINP as determined by digestion of an average of 15.3% of each half-hide (=Technique 3).

Moose No.	Moose Sex-Age (Yr.)		Total Surface Area of Hide (cm^2)	Estimated No. of Ticks	Density (ticks/cm^2)
December, 1977:					
74	F 3½		27180	25426	0.9
177	M 3½		27296	62905	2.3
?	? Ad.		31064	19440	0.6
21	F 5½		33450	15516	0.5
?	? Ad.		33990	50903	1.5
		x̄=	30596	34840	1.2
March-April, 1978:					
1 (Mar. 29)	M Ad.		20564	13863	0.7
2 (Mar. 31)	F Ad.		23272	8641	0.4
		x̄=	21918	11252	0.55
5 (Mar. 3)	M 9 mos.		11782	12242	1.0
3 (Apr. 6)	F 10 mos.		15202	22194	1.5
4 (Apr.13)	M 10 mos.		17000	27525	1.6
		x̄=	14661	20664	1.4

Age, Sex Ratio and Mortality of Ticks

Practically all ticks recovered from moose in December at EINP were unfed nymphs (Table 4); there were very few adults and no engorged females. By February, many nymphs were engorged or had become adults. Surprisingly, engorged adult females never exceeded 4.3% of the total adult tick population in late March-early April.

The ratio of adult male to adult female ticks varied over time (Table 5) with a 1.2:1 ratio during the critical March-April period. Thus, we can assume that slightly less than half the ticks on moose in March-April will become engorging females (assuming that all females take a blood meal).

Nymphs were 245X more numerous than adults in December (Table 5), equal in number in February, and 30% of the adult population in March-April. Whether or not many of the nymphs die during maturation to the adult stage and how many adult ticks dropped or had been rubbed off the host cannot be answered with certainty. The two adult moose shot in EINP on March 29 and 31, 1978, had fewer ticks (13,863 and 8,641) than adults in December 1977 ($\bar{x}$= 34,840) (Table 3), suggesting that many nymphs die before becoming adult ticks.

The two calves found dead on April 6 and 13 had extensive regions of hair loss suggesting that many ticks were rubbed off. Although their tick load of 22,000 and 27,500 (Table 3) was similar to that on calves in December (24,149 or 27,181-Table 2), it is likely that they probably went into winter

Table 4. Age structure of Dermacentor albipictus on moose (Sept.-Apr.).

Date of Collection	Total No. Moose Examined	% ticks that were: Larvae	Nymphs	Adults
Sept. 1975*	1	0	0	0
Nov. 1975*	2	0	100(0)**	0
Dec. 1977	49	<1	99(0.05)	<1(0)**
Feb. 1976* & 1978	3	0	50 (57)	5(0)
Mar. 1978	3	0	32 (48)	68(3.3)
Apr. 1978	2	0	21 (61)	79(4.3)

* Unpub. (Stringer and Rubin).

**( )= % engorged.

Table 5. Sex and age ratios of D. albipictus on moose of central Alberta.

Date of Collection	Sex Ratios Male: Female	Age Ratios Adult: Immature
Nov - Dec	2.1 : 1	1 : 245
Feb	2 : 1	1 : 1
Mar - Apr	1.2 : 1	1 : 0.3
Grand Mean	1.3 : 1	1 : 3.7

with higher than average numbers of nymphs (~ 40,000; see Table 2) and, thus, rubbed-off many ticks.

Hair Loss Patterns

Beginning in March 1978 we observed moose with hair loss in areas on moose where ticks had been most numerous in December. Hair loss patterns were ranked (Fig. 8) from "light" to "very severe". A total of 97 moose was observed, photographed and/or hair loss pattern diagrammed from a helicopter at EINP (n=44), April 21, 1978, northeast of Rochester, Alberta (n=28), April 26, 1978, and east of Swan Hills, Alberta (n=25), May 12, 1978. Many diagrams were refined after comparison with aerial photos (Figs. 9,10). The prevalences of moose with hair loss were 91%, 100%, and 68% for EINP, Rochester and Swan Hills, respecitvely (Table 6). Sixty-one percent of the 28 moose from Rochester had patterns of loss termed "severe" (Figs. 8,9) or "very severe" (Figs. 8,10). Only 12 had no observable hair loss (Table 6). Unlike other age classes (Table 7) calves either had little or severe hair loss.

Ground Observations in Winter-Spring 1977-78

Park Naturalist, Steve Schwartz, observed a bull in EINP on March 20 with "slight" hair loss and a large clump of ticks on the sternum (Fig. 11). An adult female with severe hair loss and in emaciated condition and her calf (moderate to severe loss, Fig. 12) were seen together in EINP on March 31

FIGURE 8. Categories of hair-loss patterns assigned to moose observed in central Alberta in April-May 1978.

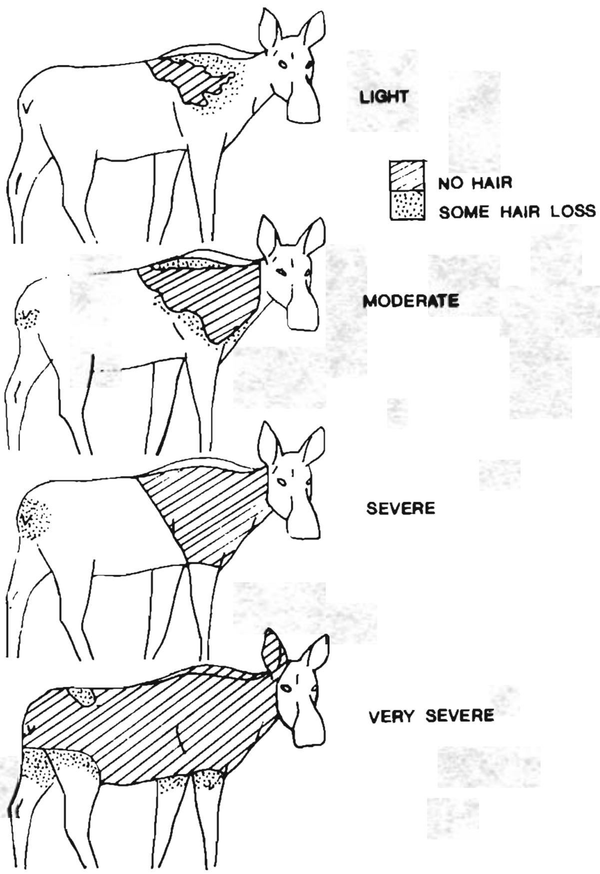


FIGURE 9-10. Aerial photographs of 2 adult moose (both collared) from near Rochester, Alberta with "severe" and "very severe" loss of hair presumably induced by D. albipictus, late April 1978.

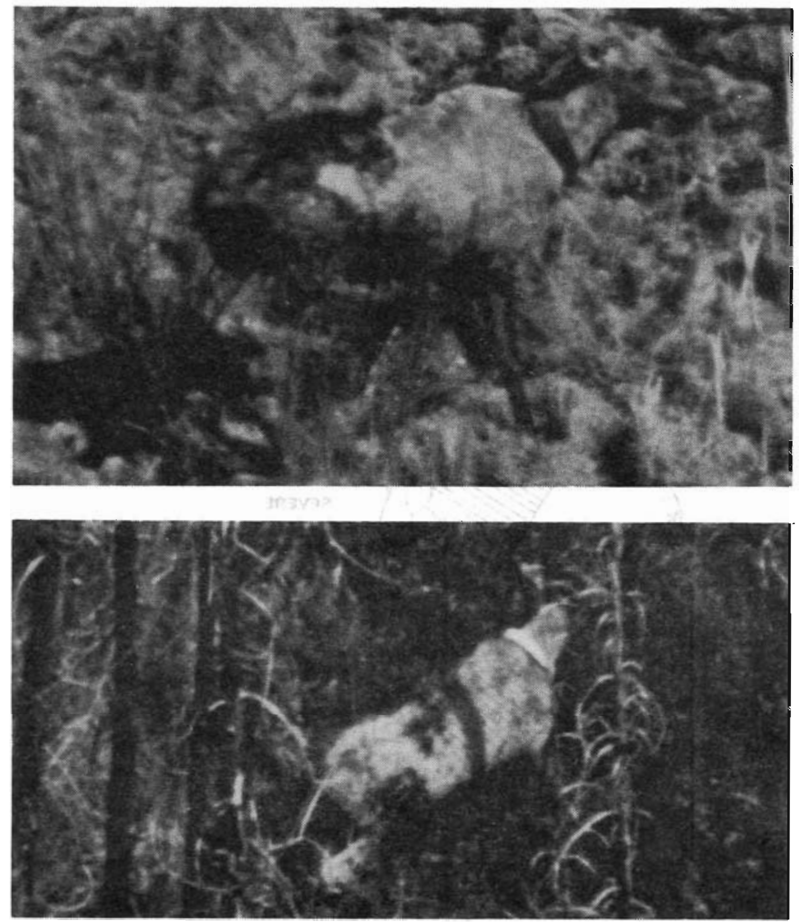
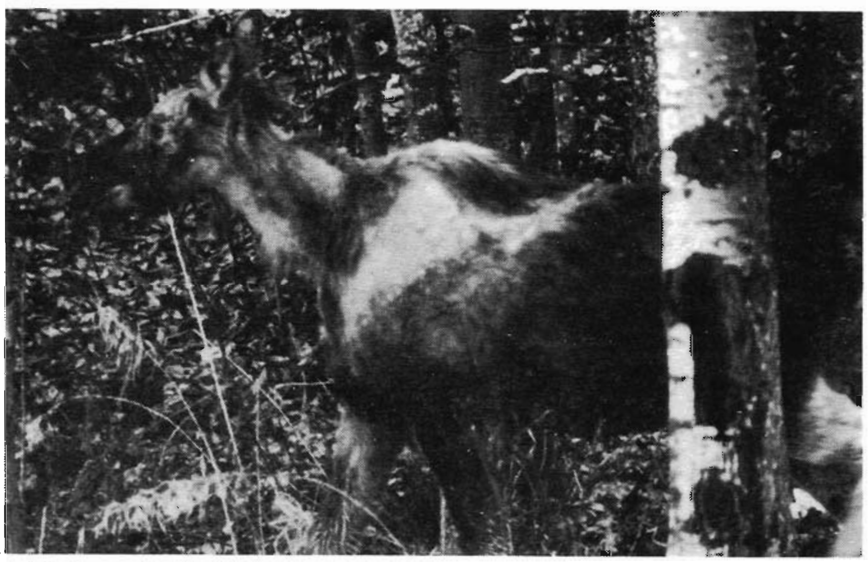


FIGURE 11. Adult male moose observed in EINP, March 20, 1978. Note large "clump" of ticks at base of neck (arrow).



. Calf moose observed in EINP, March 31, 1978.

Table 6. Subjective assessment of hair-loss patterns on moose presumably induced by ticks, central Alberta, April-May 1978.

AREAS FLOWN	ESTIMATED HAIR LOSS				
	NONE	LITTLE	MODERATE	SEVERE	VERY SEVERE
EINP (n=44)	4	24	10	3 (7)*	3 (7)*
ROCHESTER (28)	0	8	3	12 (43)	5 (18)
SWAN HILLS (25)	8	7	5	2 (8)	3 (12)
TOTALS	12 (12.4)	39 (40.2)	18 (18.6)	17 (17.5)	11 (11.3)

*Number (%)

Table 7. Subjective assessment of hair loss patterns on aged and sexed moose presumably induced by ticks, central Alberta, April-May, 1978.

Age Group	Sex Group	Estimated hair loss				
		None	Little	Moderate	Severe	Very Severe
Calf (n=26)		4(15)*	12(50)	1(4)	7(27)	1(4)
Ad.	Cow (n=34)	2(6)	14(41)	8(24)	7(20)	3(9)
Ad.	Bull (n=16)	3(19)	7(44)	3(19)	0(0)	3(19)
Ad.	? (n=21)	3(14)	5(24)	6(29)	3(14)	4(19)

* Number (%).

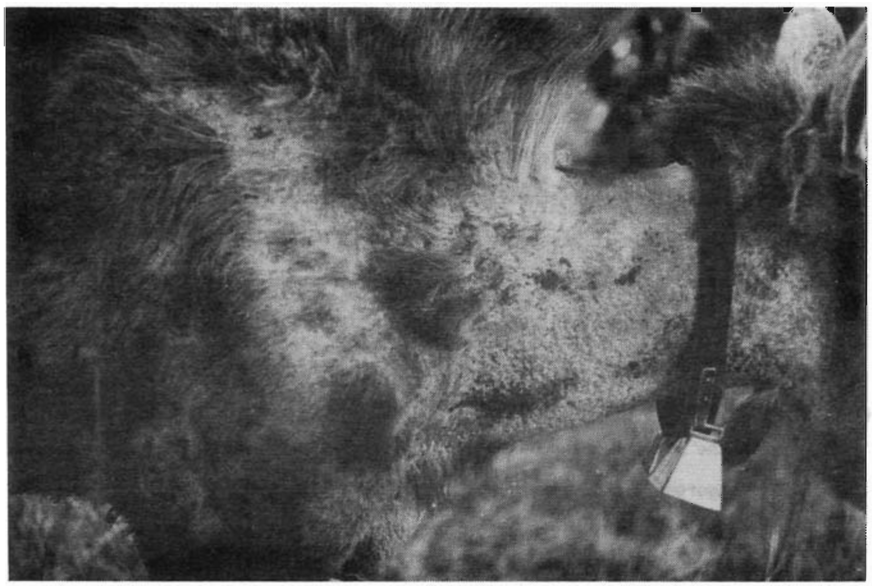
by the author. Only the calf was seen on April 17 and it is assumed the cow died. The author observed an adult moose with very little hair loss on April 5 at EINP. When it was "back-tracked" in the snow, flecks of blood and ticks were observed wherever the moose had touched brush. The author observed single adult moose with "slight" hair losses in EINP on April 15 and 17.

On April 9, the author visited an enclosure housing 9 wapiti and 2 yearling moose at Ministik Lake immediately south of EINP. Both moose (Fig. 13) and several wapiti had been bothered by ticks since November (Gates, pers. comm.). All animals had been on treatment for ticks, but on April 9, both moose still had clumps of ticks around the anus and along the edge of hairless parts of the shoulders (not visible on Fig. 13). The smaller animal appeared to have the worst of the two infestations. She was found dead on April 21 by the author; she had been dead for several days. Nothing other than many ticks was found during post-mortem examination (Gates, pers. comm.).

A moose was found dead on the road near Edson on April 31, 1978. It was "crawling" with ticks and had lost much hair (Gaboury, pers. comm.).

Many of the moose at Rochester were collared by researchers from the University of Wisconsin prior to 1977. The population was not studied from the air in late winter-spring 1977, but was checked on April 5, 1978 (Frokjer, pers. comm.). Apparently 4 of 24 moose (all calves) with radio-collars died

FIGURE 13. Hair loss on a tame yearling moose held at Ministik Lake, just south of EINP, April 9, 1978.



between February and May 1978 (Frokjer, pers. comm.). All of 12 moose with radio-collars in the Swan Hills survived winter (Lajeunesse, pers. comm.).

Bob Stewart, moose biologist, and Gary Wobeser, University of Saskatoon, heard of or saw many hairless moose in winter, 1978 in Saskatchewan and necropsied 2 moose with "many" ticks, respectively. Prevalence of hairless moose was particularly high in the Primrose Lake region of western Saskatchewan in April (Stewart, pers. comm.). Blair Rippin of the Alberta Fish and Wildlife reported the death of an adult bull in the same region (but in Alberta) on May 8, 1978. It was "probably killed by wolves (3 had been observed in the vicinity), but signs of struggle were very few". The moose had been observed in a weakened condition for about 1 week. There were wolf tracks at the site. There was moose hair in the rumen and a small amount of fat on the omentum. The animal was covered with engorged and unengorged ticks. There was an old puncture hole in the area of the genitals suggesting secondary infection. The pattern of hair loss was mapped and virtually identical to the "very severe" category (Fig. 8).

Moose with bare patches on the neck, shoulders and around the anus were observed in Jasper National Park in late February, 1978 (Samuel, pers. observ.); blood-stained snow in moose beds was also observed there in early March (Holmes, pers. comm.).

DISCUSSION

Peterson (1955) asserted that D. albipictus is the only ectoparasite of serious importance on moose of North America. We concur given the subjective assessment of high losses of moose (∿ 100) in 1976-77 by personnel of the 186 km^2 EINP, the high moose population (Table 8) particularly in relation to the percent of browse utilized (Telfer, pers. comm.), and the high percentage of moose with varying degrees of hair loss seen in late April-early May, 1978. All suggest that D. albipictus was a serious pest on moose of EINP and elsewhere in Alberta in the winters of 1976-77 and 1977-78. The huge numbers of ticks collected from moose shot or found dead in December, March or April and their location on parts of the body suffering hair losses in April-May reinforce this belief.

Anderson and Lankester (1974) reviewed reports dealing with the effects of moose ticks on moose. Reports of dead or dying moose with many ticks and many heavily infested cattle and horses were common in Saskatchewan (Cameron and Fulton 1926-27). Cowan (1944) reported serious infestations on moose carcasses in British Columbia during the spring of 1943. His wording suggests that all were heavily infested with ticks. Cowan (1951) suggested that moose ticks were important because they tended to attack young animals during periods of food shortage and severe weather. Results of the present study suggest that epizootics may be more complex than thought pre-

Table 8. Estimate of numbers of large ungulates in EINP (from B. Jones, per. comm.).

Year	Moose	Bison	Wapiti	W.T. Deer
1968	850	-*	440	214
1969	477	-	437	250
1970	228	-	249	204
1971	365	-	217	88
1972	307	-	516	122
1973	417	-	554	331
1974	287	-	332	151
1975	402	-	273	49
1976	436	-	448	76
1977	674	596	567	170
1978 (Jan. 24)	454	-	435	-

* No data provided

viously. Although the winter of 1977-78 was more typical of the long-term, it was not severe. The winter of 1976-77 was very mild with little cold and/or snow. Although only a few dead moose were found in 1978 in EINP and all were calves, such was not the case in 1977 when at least 20 moose carcasses were found in the Park.

Ritcey and Edwards (1958) observed moose of Wells Gray Park, British Columbia, attempting to dislodge ticks from their heads. They found blood stains and ticks in moose beds, but concluded that heavy infestations along with other factors (but not alone) might lead to mortality. Webb (1959) and Berg (1975) agreed that heavy infestations were probably contributing (but not sole) causes of moose mortality. Mech (1966) noted that heavy infestations of ticks occurred mostly on moose of Isle Royale that were in poor physical condition. He thought ticks could be an important and direct cause of mortality for some populations.

Although we have much work to do yet, our preliminary results may not agree completely with all the above observations. Moose populations were high in 1976-77 at EINP (Table 8), but there was little evidence of food shortage. Utilization of the browse available was high when compared with most other moose populations (Telfer, pers. comm.). We suggest that, although host density would appear to play a major role in transmission of D. albipictus, little is known about what causes the irregular peaks in "ticky moose" that occur in many areas. For example, the 9 wapiti and 2 moose in an enclosure

near Ministik Lake were tick-free when moved to the site in September 1977. This enclosed area was not known to have high densities of ungulates prior to the building of the enclosure, hence one would have assumed that the vegetation held few larval ticks. Nonetheless, the few white-tailed deer and/or moose there before the fence was built provided sufficient ticks to cause serious problems after the fence was built. Moose are the likely contributers since we found relatively few ticks on the 3 white-tails examined (also, see Samuel et al. 1979).

The exact mechanism or sequence of events in tick harassment of moose remains unknown, but literature for other ticks is useful. Members of the genus Dermacentor have short mouthparts which penetrate skin only superficially (Moorhouse 1969). Such genera secrete cement in order to attach mouthparts to the host at the same time the chelicerae are cutting host tissue. There is much tissue destruction at the feeding site of D. albipictus (pers. observ.) which, as has been reported for other ticks, may be due to host reaction to pharmacologically active materials in tick saliva. This "results in trauma to the host vascular system near the feeding lesion" (Sauer 1977). Seebeck et al. (1971), in a well-designed study of growth of cattle with Boophilus microplus (like D. albipictus, a one-host tick), suggested that a tick toxin disturbed appetite and metabolism in infested animals. Once their experiments ended and ticks eradicated, the cattle were put on pasture. Those infested regained weight much slower (0.56 kg/day) than tick-free cattle (0.78 kg/day).

The effect of ticks on the hair coat hasn't been studied although hair loss due to other parasitic arthropods is known (Nelson et al. 1977). Alopecia on cattle heavily infested with lice was once attributed to rubbing by the host, but is "now believed to be due primarily to weakening of hair fibers by ischemia resulting from allergic responses to the lice" (Nelson et al. 1977). Results of the present study and observations of others (Mech 1966, and Nowlin pers. comm.) indicate that, unknown mechanisms aside, infestation with D. albipictus results in premature loss of the winter hair coat and general behavior alteration of moose (i.e., they spend long periods scratching and rubbing against trees).

Peterson (1977) suggested that "since the bare areas on the upper back and neck correspond to those where winter hair is first shed, this loss of hair in spring is more likely a molt pattern". Although molting could be involved in the moose—D. albipictus association, we would not expect molt up to 90%+ of the winter hair in April. Data on the timing and sequence of molting on moose from areas with and without ticks are needed.

Anemia may also play a role in host death and has been reported for moose with D. albipictus (Jellison and Kohls, 1938). Barker et al.(1973)found that severity of anemia was proportional to numbers of lone star ticks on white-tailed deer fawns of Oklahoma. Similar results were provided by Riek (1957) for cattle with B. microplus, but anemia was most

severe in hosts in poor condition. Based on numbers of ticks recovered from moose of Alberta, a high (but as yet unmeasured) volume of blood must be lost. Whether or not toxins in oral secretions of D. albipictus cause anorexia in moose severe enough to offset food intake needed to compensate for blood loss has yet to be studied (but see O'Kelly and Seifert 1970 and O'Kelly et al. 1971).

Ticks were localized on major areas of the body and, also, clumped within those regions. For example, we saw clumps of ticks on one ear of an adult female collected on March 28 and localized but more generally distributed ticks on the other ear. Clumping possibly facilitates engorging. Thickness of the skin apparently does not influence localization or clumping. This is because the thickness of the epidermis varies very little between regions and the blood vessels are closely apposed to the epidermis.

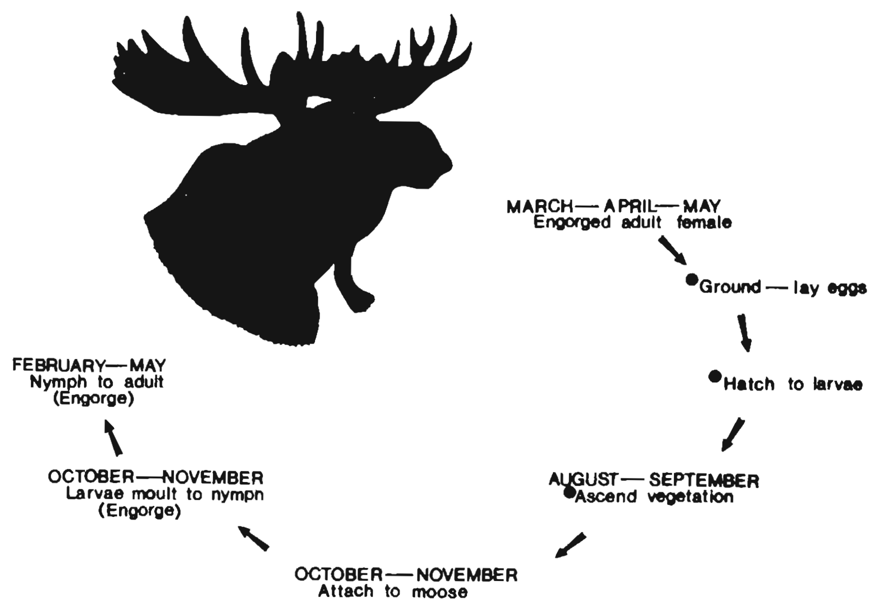
Localization and/or clumping of ticks appear to occur mainly in the longer, coarse, less dense hair of the neck, shoulders, whithers, and near the anus, with a decreased preference for fine, short hair on the lower legs. However, it is unknown why relatively few ticks were found high on the back mid-distant between the shoulders and anus (an area with long coarse hair). Addison et al. (1979) reported similar findings for D. albipictus on moose of Ontario.

The adult male to female sex ratios (1.3 male: 1 female) differed markedly from the only report on the subject in the literature (3 females: 1 male- Bishopp and Wood 1913). The fact that males usually reach the adult stage shortly (several hours to a day) before the female (Bishopp and Wood 1913) should be of no consequence in accounting for our different results.

This study is timely given that moose of central Alberta are going through a period of severe tick harrassment. The completed study has provided suitable methods for determining total tick populations, some indication of nymphal-to-adult survival of ticks on moose from December to March-April, localization of ticks on moose, correlation of this localization with patterns of late winter-spring hair loss, and data on the geographic range of this epizootic. It has also pointed out that tick survival during the period off the host is perhaps the most critical feature in analyzing epizootics. Host density and age may be less important, but are probably involved.

As a result of data acquired in this and other northern studies on Dermacentor albipictus (Wilkinson 1970, Addison et al. 1979) a generalized probable life cycle is presented.

FIGURE 14. Generalized life cycle of Dermacentor albipictus on moose of Canada. Dots indicate activities on ground.



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