THE SIGNIFICANCE OF HOOVES IN MOOSE MANAGEMENT - A PRELIMINARY STUDY

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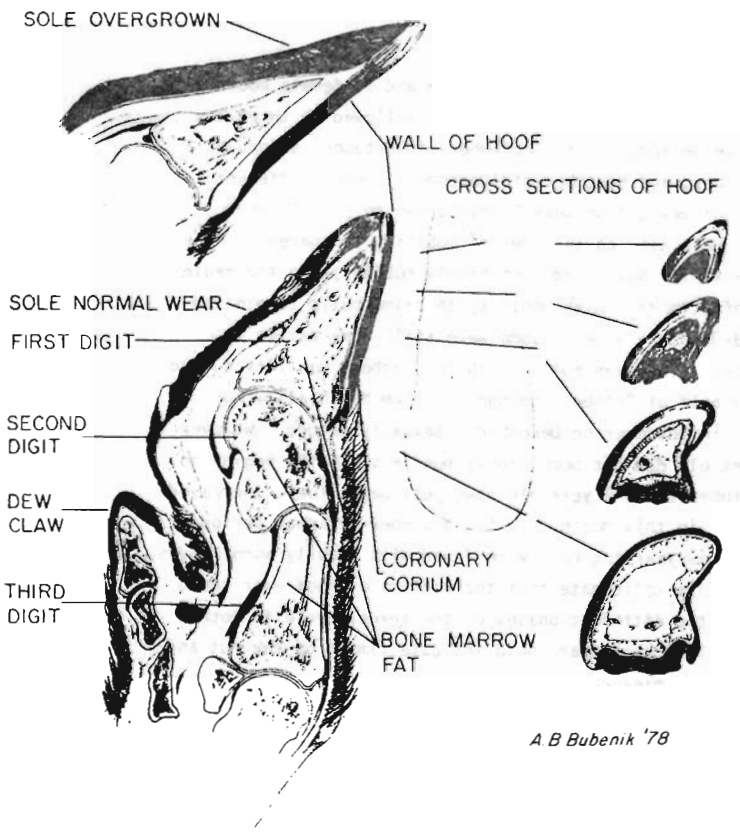
Abstract: The hoof wear of 80 male and 78 female moose of all social (maturation) classes was followed in three consecutive periods: late September-mid-October, second half of October, and November-mid-December. Seven different stages of wear, from heavily overgrown to heavily worn hooves were used as an index of mobility. Apparently none of the senior bulls had been highly mobile since the beginning of October. High mobility in prime bulls terminated by mid-October, however some were still very active in November. The teen bulls exhibited highest mobility during second half of October and none of them had heavily worn hooves in November or December. Sexually mature cows over 3 years old had not been highly mobile since the beginning of October while 2 year old cows just began their increased activity in this month. In the November-December period only a few yearling cows were found with heavily worn hooves. The authors anticipate that the pattern of hoof wear could reflect the different phases of the sexual cycle in both sexes. Thus hoof wear could indicate timing of the rut and be a useful management tool.

The anatomy of the hoof (ungula) in Artiodactyla of the suborder Ruminantia, Acopoli, 1777 (Haltenorth 1963; Simpson 1945) follows the general model of even-toed ungulata (Sisson 1938).

The hoof wall (paries ungulae) could be, for topographic purposes,

FRONT HOOF OF MOOSE Figure 1



divided into the anterior part or toe, the medial and lateral parts and the angulae or heels (Fig. 1). The relatively smooth surface is crossed by more or less visible ridges which run parallel to the coronary border. The ridges are more pronounced at the angulae where they are better protected from wear. The ridges indicate that hoof growth is a rhythmic process. Unfortunately, we have not found any papers referring to the rate of growth and wear in wild ruminants' hooves. Only Řeřábek and Bubenik (1963) mention that the turnover of labelled phosphorous, as an indicator of cell growth, is very fast in the hoof of cervids.

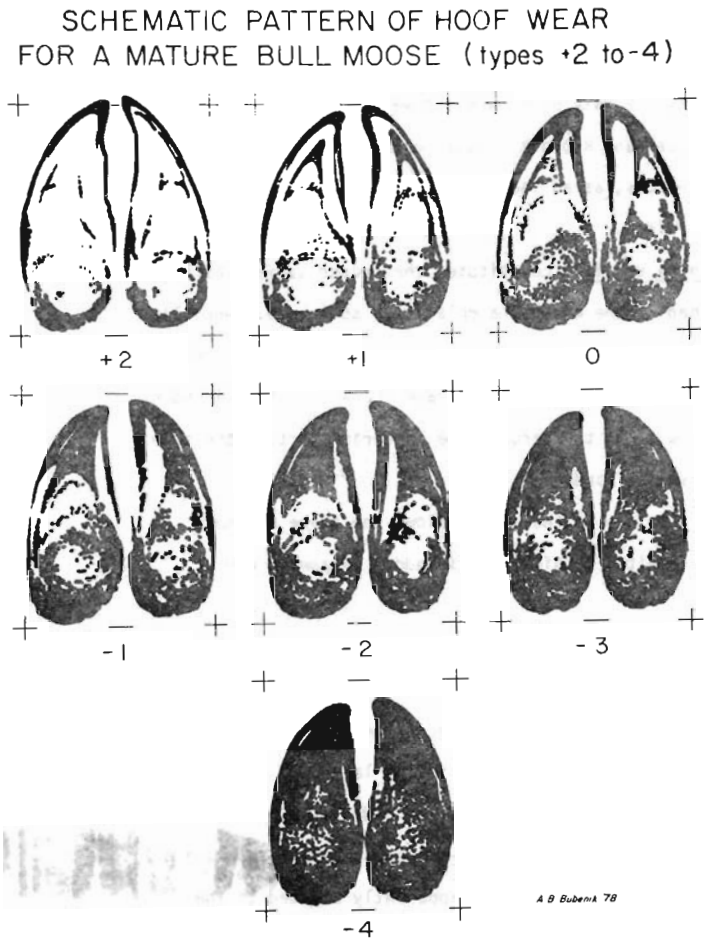
The sole (solea ungulae) constitutes the ground surface of the hoof. It is joined to the wall by a relatively soft horn, generally ivory in colour (Fig. 1). In unworn hooves, there is a deep concave border, called the bar, between the sole and the wall (Fig. 2) ending at the angle. This tends to overgrow the posterior part of the sole, building an "L" shaped border.

The internal surface of the sole follows the shape of the phalanges and the digital cushion with imbedded ligaments and tendons (Fig. 1).

Through a "folding process" occurring during growth of the sole layers, the sole tends to get a relatively rough surface, with elevated edges around the bar and the concave central part (Fig. 1). In large ungulates like moose, the keratinized layers of the sole are pressed out to the surface so that wave-like ridges run across the surface from the tip towards and around the balls of the sole (Fig. 2).

The rate of growth of the hoof is apparently adapted to the normal wear rate, e.g. ground conditions and average mobility. On soft ground, and/or with reduced mobility, the hoof of ruminants can

Figure 2



overgrow, or it can be excessively worn if the ground is too hard and mobility too high. This leads to the conclusion that the rate of growth of the hoof is a process which can hardly be controlled by homeostatic mechanisms. Under such conditions the mobility of individuals, and possibly distribution of the species, can be limited by ground conditions and hoof wear. Animals with overgrown or heavily worn hooves cannot move fast enough when necessary. Heavily worn soles can also get cracks which enable infection of the coronary corium, swollen joints and a fatal infection as we have found in red deer (Cervus elaphus) (Bubenik, unpubl.).

Since the weight on the front hooves is greater than on the hind ones, the front hoof is larger, e.g. wider and longer. In heavier individuals more weight is borne by the anterior part of the hoof. This results in the general phenomenon that in large Artiodactyls, in which the males can nearly double the weight of the females', the males' front hoof tips are more worn and therefore more rounded than the females'.

Our impression is that in moose, the wall and sole of the hoof is much softer than that of white-tailed deer, elk or domestic cattle and horses.

In some species, due to anatomical features, the males place the hooves in normal gait differently than the females (Hermansson and Boethius 1975, Raesfeld 1920, Skuncke 1949). Thus, one can distinguish between the track of a juvenile male and a prime female of similar weight.

The hind hoof is generally put directly into the track of the front one. However, variations occur related to the age and physiological status of the individual (Raesfeld 1920). Thus tracking

of wild ruminants is an important hunting technique throughout the world. To our knowledge it has never been used as a managerial tool, other than as a crude census technique.

Hoof Wear and Sexual Activity

We have found considerable differences in the wear of hooves in moose. Assuming average ground conditions throughout most of the North Central Region (north and west of Lake Superior), and that the growth is adapted to the average wear rate, then hoof wear should reflect the degree of individual mobility in time.

From the knowledge of sex dimorphic behaviour and mobility of moose during the seasons (Bubenik, unpubl., Lent 1975, Peek 1962, Thompson 1949, Van Ballenberghe and Peek 1971) there should exist differences in wear at given times between the social classes in both sexes, especially during the rut. This is expected since the bull's sexual readiness and responsiveness lasts at least some weeks or months as he travels to find receptive females (Markgren 1952, 1969, 1971, 1974). According to studies in other cervids, the timing of the onset and termination of the male's sexual activity is dependent on its maturation status, or on sexual stimulation caused by social disorder; e.g. too many females and/or too few prime males (Bubenik et al 1978). The hoof wear of the cow should increase only during estrus as she walks more extensively to advertise her estrus by patrolling the mating area, transmitting scent, calling or occasionally digging pitholes (Thompson 1949).

We assume estrus repeats in approximately 20 to 30 day intervals (Edwards and Ritcey 1958, Hagenrud and Markgren 1974, Markgren 1952,

1969), similar to other large ruminants (Morrison 1960, Thomas and Cowan 1975). In the Thunder Bay area we have observed at least three peaks of rutting activity (around September 10 and 26, and October 10). During the second peak the highest mobility and other sexual activity in both sexes has been recorded. We do not know yet if the first peak is elicited only by a silent heat (Markgren 1952, 1969, Morrison 1960, Thomas and Cowan 1975) or just the first overt estrus. We anticipate that the majority of cows over 3 years old will come into estrus in September. Those not bred at this time will repeat estrus cycles in the following months. During these later periods, the younger primiparous cows (an unknown percentage of yearlings and 2 year olds) will experience their first overt estrus, similar to other cervids, as mentioned above.

It is not yet known how many estrus cycles a primiparous or multiparous moose cow can have or how many cycles produce enough estrogen to promote sex pheromones secretion necessary to stimulate the bulls. From the sexual behaviour of moose and other cervids we hypothesize that estrus cycles could continue up to the end of December or (exceptionally) to mid-February.

Again from the behaviour of other cervids (i.e. in red deer, Bubenik, unpubl.), we believe that the high prime and senior bulls are the first in the rut and ready to service the cows in August or the beginning of September. We do not know which maturation classes of bulls respond to the later season estrus cycles.

We have assumed that the hoof growth from one estrus to the next estrus will not fully replace the wear from the 3 to 5 days of high mobility. Thus we expect that the hooves of cows having only one "overt" estrus will be less worn than those having two or

more. Cows in silent heat (Markgren 1952) are probably not too mobile and are unlikely to show much hoof wear.

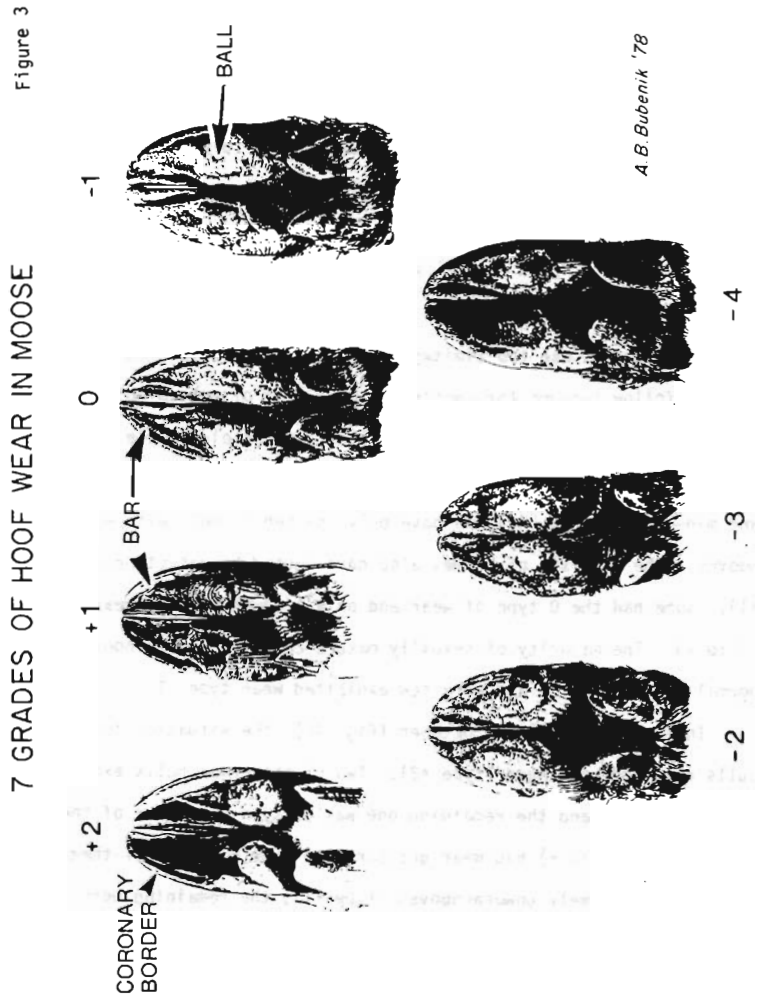
METHOD

Hunters and conservation officers in the Thunder Bay Region collected 80 male and 78 female front hooves, from moose harvested during the 1976 and 1977 season (last three weeks of October to mid-December) plus a few road kills found prior to that date. We studied the wear of the sole of the front hoof and made photographs using 35mm Kodachrome 64 ASA film. The animals, aged by the cementum layer technique (Sergeant and Pimlott 1959), fell between the ages of calves and 13 years.

The dynamics of wear were studied from sagittal and transverse sections as well as the photographs. For evaluating the hoof wear, we designed a scale of different degrees of hoof wear ranging from nearly unused, type ±2 (overgrown), up to extremely used ones, type -4 (see Fig. 3). Bubenik and Williams independently estimated the degrees of wear. In about 10 percent of the cases we had difficulty categorizing a hoof. This was because the wear pattern was intermediate between two classes or because the hoof of one toe was used more than the other, a behaviour for which we have no explanation. In those cases we used other criteria such as the shape and wear of the dew claws and the degree of wear of the hoof ball (Fig. 3) and hoof tips.

It must be stressed that due to the different method of hoof use by bulls and cows, the wear of the hoof in bulls is more concentrated to the anterior part and in cows more or less the whole sole is worn.

Figure 3



Since the opening days of the hunt were October 6 and 11, we were unable to collect enough hooves from September. As is shown later, this leaves some important questions unanswered. For sociobiological and physiological reasons alone, we clumped the age classes into maturation (or social) classes as follows:

Males: calves, yearlings, older teens (2 to 3), primes (4 to 10), seniors (in our collection bulls aged 11 to 13 years)*.

Females: calves, yearlings, 2 years old, 3 years and older.

RESULTS

The material was too limited for statistical evaluation. First we will follow through the season the hoof wear of mature animals, e.g. senior and prime bulls and cows over 3 years old (Table I). Our data is presented graphically in Figure 4. In late September and mid-October (Fig. 4a), we have only one senior bull with worn hooves. The majority of primes also have unused hooves (type +2 or +1). Some had the 0 type of wear and only a few exhibited wear type -1 to -3. The majority of sexually mature cows had unused hooves or normal wear (+2 to 0) and very few exhibited wear type -1.

In the second half of October (Fig. 4b), the situation in senior bulls remained unchanged (type +2). Two of the prime bulls exhibited normal wear (0) and the remaining one was of type -1. None of the mature cows (3 1/2 +) had wear greater than type 0. Most of them displayed relatively unworn hooves (type +1), the remaining were of type +2.

*We have no proof of reduced testicular activity. Only the peculiarity of hoof wear in these older bulls leads us to consider them as seniors.

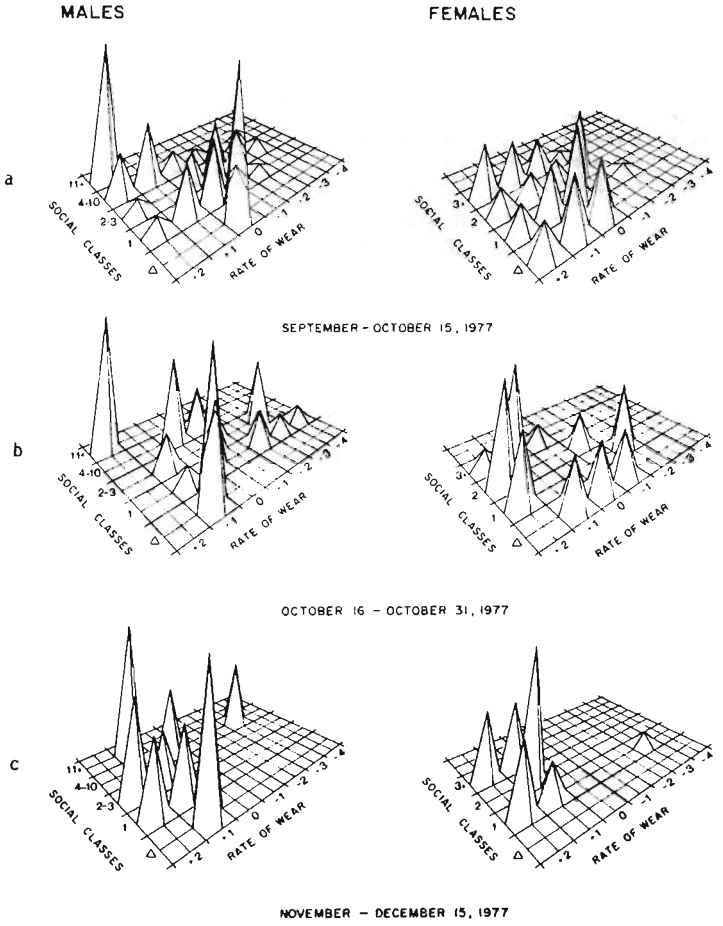
HOOF WEAR IN MOOSE 1976-77

Table I

Males (N=80)	N*	September - October 15 Wear Type (%) +2	+1	0	-1	-2	-3	-4
Calves	1	-	-	100	-	-	-	-
Yearlings	22	9	32	41	14	5	-	-
Teens (2-3 years)	13	8	-	23	38	23	8	-
Primes (5-10 years)	14	29	43	14	7	-	7	-
Seniors (11+ years)	1	100	-	-	-	-	-	-
		October 16-31 +2	+1	0	-1	-2	-3	-4
Calves	1	-	100	-	-	-	-	-
Yearlings	8	-	13	38	-	25	13	13
Teens (2-3 years)	4	-	25	-	25	-	50	-
Primes (5-10 years)	3	-	-	66	34	-	-	-
Seniors (11+ years)	1	100	-	-	-	-	-	-
		November - December 15 +2	+1	0	-1	-2	-3	-4
Calves	2	-	100	-	-	-	-	-
Yearlings	4	50	50	-	-	-	-	-
Teens (2-3 years)	3	66	-	34	-	-	-	-
Primes (5-10 years)	2	-	-	50	-	-	50	-
Seniors (11+ years)	1	-	100	-	-	-	-	-
Females (N=78)		September - October 15 +2	+1	0	-1	-2	-3	-4
Calves	5	20	40	40	-	-	-	-
Yearlings	17	18	24	53	-	6	-	-
2 years old	6	17	17	17	50	-	-	-
Primes (3+ years)	16	31	38	6	25	-	-	-
		October 16-31 +2	+1	0	-1	-2	-3	-4
Calves	3	-	33	33	33	-	-	-
Yearlings	2	50	-	-	-	50	-	-
2 years old	4	75	-	-	25	-	-	-
Primes (3+ years)	7	14	71	-	14	-	-	-
		November - December 15 +2	+1	0	-1	-2	-3	-4
Calves	0	-	-	-	-	-	-	-
Yearlings	8	50	25	-	-	-	25	-
2 years old	1	-	100	-	-	-	-	-
Primes (3+ years)	6	50	50	-	-	-	-	-
	158							

*N = sample size in each age class

HOOF WEAR IN MOOSE Figure 4



The senior bull harvested in November-December (Fig. 4c) showed hoof wear of type +1. Of the two prime bulls, one had wear type 0 and the other -3. The two sexually mature cows of this period had hooves of wear type 0 and +2 (Fig. 4c).

A quite different wear pattern was found in the older teens, e.g. 2 1/2 to 3 1/2 year old bulls. In the first time interval (Fig. 4a) a few had unworn hooves, a few more exhibited normal wear and the majority (69 percent) had hooves in wear type -1 to -3. Most of the 2 1/2 year old cows displayed wear type -1, while the others were equally distributed in the 0 and +2 types.

The wear pattern in the second half of October (Fig. 4b) changed dramatically. Two of the 2 1/2 and 3 1/2 year old bulls were of wear type -3, one of -1, while one exhibited +1. Three 2 1/2 year old cows exhibited a majority in wear type +2, very few were of type -1.

In the third period (Fig. 4c) the older teen bulls had equally unworn hooves in type +2 and 0. The 2 1/2 year old cow showed wear type +1.

The wear pattern of yearling bulls in the first half of October showed a slight tendency to wear but not as much as in the older teen bulls. The majority of yearlings have unworn hooves (Fig. 4a). A similar wear pattern was found in yearling cows but more cows had unworn hooves than did bulls of the same age.

In the second half of October the picture changed considerably. Four of eight yearling bulls were highly mobile (type -2 to -4), while three showed normal wear and only one was worn. The yearling cows were equally divided between those with moderate wear (type -2) and those without wear (type +2).

In November and December (Fig. 4c) all yearling bulls were without

worn hooves. Most of the yearling cows exhibited a similar pattern, except for two with wear type -2, which is relatively high for cows.

The hooves of calves for the entire collection period were either unworn or showed normal wear. Only in the second half of October was a slightly higher rate of wear noticed (Fig. 4b). We assume that the wear degree of the calves would follow that of their mothers, but due to the lower weight, the calves' wear could possibly be less.

CONCLUSIONS

Summarizing our findings, we conclude that the hoof wear in both sexes and maturation classes agrees with our observations of rutting activity as well as the expected course of sexual activity and estrus cycles.

The senior bull examined was evidently out of rutting activity by the beginning of October. As time progress, only the prime bulls, and later on only the teenagers, were highly mobile, e.g. searching for and courting cows in heat. The yearling bulls represent a class which is apparently the last to be in a rutting mood.

From the hoof wear of sexually mature cows, we conclude that they conceived during September. The 2 1/2 and 1 1/2 year old cows either experienced the first estrus in October or did not conceive in September and repeatedly had a second or third estrus. It could be that those yearling cows which go into heat do it very late, e.g. in November or December.

It would be necessary to have the sex glands of these animals to know exactly in which phase of the sexual cycle they were and

thus be able to verify our conclusions. This we hope to realize in the next season.

If the hoof wear does reflect the sexual activity of both sexes (e.g. the degree of mobility associated with redirected activity [Eibel-Eibesfeldt 1970], as digging and scratching the ground) these findings did not correspond with the ovarial activity of Swedish moose (Haagenrud and Markgren 1974, Markgren 1969, 1974) or with the statistics on harvest structure for yearling moose (Bubenik et al 1977, Mercer 1974, Simkin 1974). We have no explanation for this discrepancy.

We were worried about the influence of the ground surface on the individual rate of wear. The results suggest that in our area ground surface differences are unimportant since the wear rate in both sexes seems to follow the expected course of sexual maturation and cycles, rather than that of the ground conditions.

We hope that our further study of hooves will clarify the extent to which hoof wear might be used as a simple and reliable tool for estimation of rutting activity and duration of rut. Results to date suggest at least a 2 1/2 month long rutting period, which is in accordance with the estimated calving time in our study area (Timmerman 1978). Such a long rutting period must be dangerous for the population. It probably does not influence reproductive rate, but could reduce reproductive success (cow/calf ratio after the summer) which is dependent on a short calving time and the number of experienced (e.g. multiparous) cows in the population.

ACKNOWLEDGEMENTS

This type of study would be impossible without the physical effort of the hunters to provide us with data. Our appreciation is extended to the North Central Region's biologist, Al Elsey, and the staff of the check stations. Also invaluable was the help of Tim Bellhouse for data compilation and Jim Hall for the graphics.

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