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MOOSE DISEASE REPORT

BY
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Volume I
Project Progress Report
Federal Aid in Wildlife Restoration
Projects W-17-4, W-17-5 and W-17-6 (1st half), Job 1.9R

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JOB PROGRESS REPORT (RESEARCH)

State: Alaska

Cooperators: Kenneth A. Neiland

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Job No.: 1.9R Job Title: Disease and Winter Mortality of Moose

Period Covered: July 1, 1971 through December 31, 1973.

SUMMARY

The moose ranging near Fairbanks and elsewhere in Alaska are host to a number of potentially pathogenic organisms. Among these, the rumen fluke, *Paramphistomum cervi*, must remain a prime candidate until appropriate experiments can be done. On the other hand the finding of nearly 1300 cysticerci of *Taenia krabbei* in heart muscle of an animal in otherwise good condition suggests that moose are well adjusted to some of their verminous tenants.

We continue to see evidence of the irregular distribution of parasites in Alaskan moose. For example, *Setaria yehi*, the body cavity worm of moose, continues to be found only in moose in interior Alaska.

Continued serologic testing has failed to reveal any evidence of rangiferine brucellosis in moose. However, serologic evidence of infection by leptospires and encephalitis viruses has been found in a few animals.

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BACKGROUND

The present study was initiated in conjunction with a larger project dealing with the ecology of moose in interior Alaska. Of particular interest both to the present study and the larger project was the question of the causes of winter mortality. While it was suspected that a combination of severe weather and under-nutrition was most often the primary cause of winter kill of moose in interior Alaska, it was obviously essential to evaluate the possible contributions of potentially pathogenic agents.

Although there is a considerable literature on the parasites and microbes which infect moose elsewhere in Alaska, North America and

Eurasia (see Neiland and Dukeminier 1972, Neiland 1962, 1965, 1967, 1968, 1969), relatively little information is available on this host from that part of Alaska north of the Alaska Range. Accordingly, the present on-going study was considered to have this added value.

Most of the data were obtained from animals killed along the highways near Fairbanks by automobiles. Such traffic-related fatalities are numerous only during times of heavy snow pack when moose tend to congregate along the open roads where traveling and feeding is easier. These are also the times when moose are most apt to suffer from malnutrition which may be aggravated by various parasitic or infectious conditions. Because of lack of indoor facilities sufficient for handling intact, frozen carcasses of adult moose, it was seldom possible to extensively examine each road kill that came to hand.

Some full and/or partial necropsies were also performed in the field on animals collected for nutritional studies during various times of the year. In most instances, because of helicopter load limitations, only small samples of selected organs could be brought back to the laboratory for closer examination by specialists. In these instances the general field necropsies were performed by persons experienced in other aspects of moose biology.

I have also included unreported observations on specimens of particular interest brought in by hunters regardless of the area in which the animals were taken.

FINDINGS

Information on parasitic infestations will be considered first, followed by data on bacterial infections, serology, etc.

I. Parasites

Thus far we know of six species of flatworms (i.e. flukes or tapeworms) and four species of roundworms which occur in moose in central Alaska. Each of these will be discussed separately.

A. Flukes

1. *Paramphistomum cervi* Zeder, 1790. This species of "rumen fluke" is a common parasite of moose in all the major areas of moose range around the world. However, because of special life cycle requirements, this parasite may be absent or rare in specific areas. Species of *Paramphistomum* require certain kinds of aquatic snails as an intermediate host and the infective larvae eventually encyst on aquatic vegetation.

Accordingly, the parasite only occurs where aquatic habitat is available and the particular snail intermediate hosts occur. For example, moose frequenting the swampy Tanana Flats near Fairbanks are almost invariably infected, frequently with thousands of individual flukes. On the other hand, I have seen this worm only rarely in moose in certain other areas (e.g. Yakutat, Denali Highway, etc.).

It appears that this parasite sometimes might be one of the potentially, more pathogenic species of parasites occurring in moose. I believe this to be a fair statement even though pathogenic complications have only rarely been reported in moose (Seyfarth 1938) in which the parasite is otherwise commonly seen.

There are other reports on the pathological nature of infections of *P. cervi* in wildlife. For example, Zadura (1960) has observed natural mortality in Polish stags (*Cervus elaphus* L.) caused by this parasite. Pav (1962) reported on the histopathologic consequences of infections of *P. cervi* in *C. elaphus*, *Dama dama*, *Capreolus capreolus* and *Ovis musimon* in Czechoslovakia. There is a relatively abundant literature on paramphistomiasis in domestic animals. In cattle, the gravest consequences are most commonly seen in calves. Butler and Yeoman (1962), for example, report on an epizootic in zebu cattle in Tanganyika in which 6 of 131 adults and 73 of 76 calves died within 3 months of being placed on swampy grazing. Deiana et al. (1962) have reported on mass mortality in domestic goats in Sardinia. In most instances wildlife observers only see the adult flukes in the rumen, while in actuality, if pathogenic effects occur, they most likely do so in response to immature flukes in the duodenum. It is the "grazing" of the immature flukes on the duodenal lining as they move up the digestive tract toward the rumen, their final habitat, that causes the intense, hemorrhagic enteritis and bloody diarrhea which is commonly fatal in heavy infections. Most specimens of moose that come to hand for parasitologic examination are adult animals killed by hunters in the fall. These cannot be expected to provide evidence concerning larval fluke infections which probably occur in their severest form earlier in the summer in calves. I can see little reason, at this time, to doubt that severe infections do sometimes occur in substantial frequency when conditions are propitious. On the other hand, wildlife biologists generally seem to think only of nutritional problems and predators when faced with poor summer survival of moose calves. It is indeed unfortunate that personnel assigned to pick up road-killed moose during the hard winter of 1970-71 were unable or simply failed to note whether rumen flukes were present. Most of these accidental kills were 7 to 9 month-old calves that were in rather poor condition (see Coady 1973) with little or no fat reserves. The comparatively few parasitologic observations made (considered in detail later) did not reveal any cases in which parasitism was more than a minor contributor to the poor condition of the calves.

A number of adult moose have been collected on the Tanana Flats for nutritional studies. Most of these were subjected to relatively rigorous necropsies. Seventeen of 20 (85%) harbored one or more colonies of rumen flukes. No attempt was made to count individual flukes. Instead colonies were counted and in 13 instances the approximate size of each colony (i.e. length and breadth) was measured.

These so-called colonies of rumen flukes are tightly-packed aggregations which tend to be roughly circular or broadly oval in outline. They are frequently found near the opening into the reticulum, but we have not recorded in detail the exact location of each colony encountered. These colonies range in size up to nearly a foot in diameter (23x23 cm). Considering that each fluke occupies about $16mm^2$ in a moderately packed colony, such an aggregation would include about 3300 individuals. In this particular instance there were four other colonies which probably included another 700 flukes for a maximum infestation of 4000 flukes. The other 16 animals harbored about 500-2000 flukes. None of the adult animals we have seen have shown any obvious signs of pathologic reaction to these moderate infestations. The significance of the relatively high prevalence (i.e. 85%) of moderately intense rumen fluke infections is that the exposure rate must be high. If exposure rate is high there is then more likelihood of heavy infestations being built up in young animals. Because of the absolute requirement for a snail intermediate host in the life cycle, the prevalence and intensity of rumen fluke infestations probably depend as much on the population dynamics of snails as on any other factor. Plenty of snails...plenty of flukes.

2. *Zygoctyl lunata* Diesing, 1836.

This caecal parasite which is usually seen in waterfowl and galliforms was found on two occasions in adult cows killed near Fairbanks. It has been previously reported (Yamaguti 1958). The life cycle of this worm involves generally the same kinds of snails required by rumen flukes and the infective larvae (i.e. metacercariae) are found on vegetation. Its rare occurrence in moose must be related to either 1) inability to inhabit the moose digestive tract other than as a transient passing through or 2) the rarity with which moose eat the kind of vegetation on which the snail intermediate host and larval cysts occur. This parasite has been experimentally reared in white rats.

Considering the not uncommon outcome, i.e. increased pathogenicity, of parasitic infections in abnormal or unusual hosts, it might be that *Zygoctoyl*, a bird fluke, would show hightened pathogenicity in at least some mammals, e.g. moose. Unfortunately, I have been unable to obtain the original reports on infestations in cattle and therefore have no knowledge of the pathogenicity which, in this host, is not considered in Yamaguti (1958).

B. Tapeworms

1. *Echimococcus granulosus* Batsch, 1796.

Wherever wolves or feral dogs are common, moose are quite often infected by the larval stage (hydatid cyst) of this tapeworm. The Tanana Flats and the general environs of Fairbanks are no exception. The parasite is world-wide in distribution and the "moose-wolf strain" is common to all arctic areas.

Usually hydatid cysts will be found only in the lungs, but we have previously reported the rare occurrence of cardiac and liver cysts. For the first time we saw a kidney cyst in an animal collected for other studies on the Tanana Flats in May, 1971. During the present studies we saw hydatids in 9 of 21 adult animals collected for nutritional studies. Levels of infection ranged from 1 to 20 cysts (averaging about 2.5cm in diameter) per animal. We have on a number of occasions seen relatively heavy infections involving as many as about 200 cysts, more or less, equally distributed in both lungs of otherwise apparently healthy adult moose (Neiland 1965). It is our impression that moose are rather well adapted to the presence of this parasite and we have critically commented previously on claims to the contrary (Neiland 1965).

It is perhaps again worth noting that the principal concern over hydatids in moose (or other game) involves their zoonotic potential. If infected moose lungs are fed to a dog or the dog is allowed to run loose in an area where it can find such a meal for itself, then the hunter and his family, particularly young children, run the risk of eventually growing hydatid cysts in their lungs. That is, larval hydatids grow into thousands of mature tapeworms in the dog and produce tapeworm eggs which can, when accidentally swallowed, infect humans. It is now known that this is a hazard of only somewhat less degree than surgical removal of such cysts.

2. *Taenia hydatigena* Pallas, 1766.

The larval stage (cysticercus) of this close relative of *Echinococcus* also utilizes various big game ruminants as an intermediate host, but unlike the hydatid larvae of *Echinococcus*, *Taenia* cysticerci will not develop in humans. The adult tapeworms also develop in canids. The cysticerci of this particular species of *Taenia* are usually found growing in or on certain abdominal organs, principally the liver and omentum. We have no reason to conclude that it is a serious parasite of moose, and in the case of its congener discussed in the next section, we have evidence suggesting that even relatively heavy infections of vital organs are well tolerated.

Taenia cysticerci are only common in moose wherever wolves, coyotes, dogs, etc. occur on moose range. Barrett's (1972) observations on this and other parasites of moose on and off the Cypress Hills Range in Alberta, Canada clearly illustrate this point. I have reported similar findings on Kenai versus Matanuska Valley moose (Neiland 1962). Kadenatsii and Zinoviev (1973) have recently reported on this and other parasites of Russian moose on a number of different game ranges in central Russia.

Twelve of 24 adult moose livers available for examination during the study period harbored up to 24 cysticerci per liver. No doubt substantial amounts of moose liver is discarded by hunters who find such worms unappetizing.

3. *Taenia krabbei* Moniez, 1879.

This species of tapeworm is another of those which has evolved in the context of a predator-prey relationship. Like *T. hydatigena*, discussed in the preceding section, the adult tapeworm matures and produces eggs in wolves, coyotes and dogs after these predators have eaten skeletal or cardiac muscles of various wild ruminants (cervids or gazelles) in which the cysticercus (i.e. larva) develops. This tapeworm is known throughout the northern hemisphere and is morphologically identical to another species in the genus, i.e. *T. ovis* (Cobbold 1869) in which the larva occurs in domestic sheep. Because on the one hand the adults are identical, while on the other, the larvae require either ovids (*T. ovis*) or cervids and gazelles (*T. krabbei*), it was proposed by Verster (1969) that the latter should be recognized only as a subspecies of the former (i.e. *T. ovis krabbei*). This proposal is based on the classic principal of helminth taxonomy that species are defined only on morphologic grounds. I do not at this late and more enlightened time accept this principal and therefore recognize *T. krabbei* as a full and valid species whose larva stage is physiologically distinct from its otherwise identical congener.

Taenia krabbei cysticerci occur with great frequency in wild cervids throughout Alaska wherever wolves or feral dogs are common. Considering both the prevalence and intensity of infections we have seen in moose, one can only conclude that moose and worm enjoy one another's company normally without any obvious detriment to either. We have never had the opportunity to do a total dissection of all the muscle tissue of a heavily infected animal. However, Samuel (1972) reported recovering 9531 cysticerci from a moose taken in Alberta. Most of these larvae were found in the more active skeletal muscles with only 608 taken from cardiac muscle. We have had occasion during this study period to quantitatively dissect two heavily infected moose hearts from adult bulls taken by hunters in interior Alaska. One carried a minimum of 750 cysticerci while the other was literally riddled by at least 1280 cysts. Both were vigorous animals in normal, good pre-rut condition and apparently not suffering any severe effects. If the ratio of cardiac to skeletal cysts observed by Samuel (1972), i.e. 608:8223, is typical, then one can calculate that about 19,000 skeletal muscle cysts accompanied the 1280 we found in one moose heart. Needless to say, any one eating meat from such an animal is either blissfully ignorant or on adequately good terms with the idea of worms as an item of diet.

Twenty of 27 adult moose that were available for inspection harbored *T. krabbei* cysticerci in cardiac and/or skeletal muscle. As already noted, some of the infections were relatively intense, but I feel it is again worthwhile to note that we have little or no reason to suppose that under normal "day-to-day circumstances" these infections were much of a burden to the hosts. However, there are two sets of circumstances which are occasionally normal to the lives of moose, during which intense infections (i.e. 1000 per heart; 10,000 per carcass) might be a problem. Both of course, involve vigorous muscular activity: evading predators and fighting during the rut. While it is true as Samuel (1972) states that, "We have no exact knowledge whether heavy infections are harmful," I cannot believe other than that the capacity for performing vigorous activity for extended periods is reduced. A knowledge of the significance of this reduction awaits either suitable experimentation or careful comparison of cysticerci number in predator-killed and surviving host-animals in several populations.

On rare occasions intense infections of larval taeniids no doubt cause the death of moose (especially calves) or other wild ruminants. While I am unaware that such cysticercus-caused deaths of wild ruminants have been reported, deaths of domestic animals by this means are not uncommon. Schiefer (1966) reports on the sudden deaths of pigs due to acute traumatic hepatitis caused by the massive attack on the liver by the larvae (i.e. *Cysticercus tenuicollis*) of *Taenia hydatigena*. I have seen reports of similar consequences of experimental infections in domestic cattle of *Taenia krabbei*.

4. *Moniezia*

Two species of this genus of tapeworms occur as adult parasites in the small intestines of moose and most other wild or domestic ruminants. Unlike caribou, in which *Moniezia* evidently occurs only in calves, moose of all ages may harbor this parasite. *Moniezia expansa* (Rudolphi 1805) can be distinguished from its congener *M. benedeni* (Moniez 1879) by the relatively lesser breadth (up to about 1.6 cm) of the mature segments of the former as compared to the broader (2.5 cm) *M. benedeni* and certain aspects of their respective internal anatomies. The intermediate hosts for species of *Moniezia* are various tiny, free-living, oribatid mites. Ruminants become infected by *Moniezia* and other anoplocephalid tapeworms when they inadvertently swallow mites carrying the tapeworm larvae.

We have as yet seen only one *Moniezia* infection in moose from north of the Alaska Range. Only one other infection turned up elsewhere during the study period. A male calf found dead along the Slana-Tok Highway in February, 1972, was considered to have died of malnutrition by the local field biologist. He reported that the calf was infected by both *Moniezia* sp. (?) and *Nematodirella*, a trichostrongylid roundworm widely found in moose in Alaska and elsewhere.

We have seen and reported on infections of *Moniezia* (predominantly *M. benedeni*) in moose in southcentral Alaska and the Kenai Peninsula (Neiland 1962 and later). Barrett (1972) found 6 of 24 Alberta moose carrying *Moniezia* and 11 of 35 moose on range frequented also by wapiti (i.e. *Cervus elaphus canadensis*) carrying *Thysanosoma actinoides* Diesing, 1835. It appears from other work (Jacobson and Worley 1969) that wapiti may in some areas at least serve as a wild reservoir of this parasite. For other more recent observations on anoplocephalid parasites in moose see Kadenatsii and Zimoviev (1973) and Neiland and Dukeminier (1972).

Species of *Moniezia* are claimed to be serious parasites of reindeer calves in Siberia (Polyanskaya 1961), but the only information we have in this regard involving moose is that cited above. Either suitable experimentation or comparative field observations are needed to resolve this question in respect to moose, particularly young animals.

C. Roundworms

1. Trichostrongylids

The nematode family Trichostrongylidae Leiper, 1912, includes a considerable number ot common parasites of the digestive tracts of wild and domestic ruminants. Thus far only one species, i.e. *Nematodirella longispiculata* Yorke and Maplestone, 1926, has been identified with certainty among those known from Alaskan moose. We have not yet worked over the other species that have been collected, reserving these for a larger project underway dealing with parasites of this family in other Alaskan hosts (e.g. sheep, caribou, deer). This latter study is being carried on by Mrs. Carol Nielsen of our staff and has been principally concerned to this date with the very abundant trichostrongylid fauna of Dall sheep. In any event we expect to see representatives of several genera, particularly *Ostertagia* Ransom, 1907, and also *Nematodirella* Yorke and Maplestone, 1926.

Comparatively little effort has been made to characterize the trichostrongylid fauna of moose. Considering the size of the "digestive tract" (i.e. abomasum and intestine) of moose, it can readily be appreciated that doing so can be a formidable task. Barrett (1972) has found 18 of 34 moose in Alberta carrying *Nematodirella* and reports one of 30 harboring *Ostertagia* sp. (?). In central Russia Kadenatsii and Zinoviev (1973) have recently reported species of *Ostertagia*, *Nematodirella*, *Trichostrongylus* Looss, 1905, and *Spiculopteragia* Orloff, 1933, all more or less common trichostrongylids in moose, from seven different regions. We expect that we will eventually see the greatest variety of these parasites in moose in areas in Alaska where other wild or domestic species jointly share range with moose. The Matanuska Valley where domestic cattle are abundant or Big Delta where bison are common are two such areas. Unfortunately, only a few of the 37 calves that died in the vicinity of

Fairbanks as road-kills or otherwise during the hard winter of 1970-71 were unfrozen and therefore suitable for an examination of parts of the digestive tract when they came to hand. Without facilities where these could be thawed as they were brought in (e.g. 11 animals in 5 days during one period), it was impossible to quantitatively examine them as they became available or even remove suitable pieces of gut for later examination. As it was 10 of 37 calves were found infected with what appeared to be moderate number of *Nematodirella*.

For a relatively complete list of titles dealing with trichostrongylids of moose around the world see Neiland and Dukeminier (1972). One can only conclude that these parasites which are so important in domestic animals, also play an important, though less frequent role in unthriftiness and more severe complications in moose. In this regard it would probably be instructive to compare detailed autopsy results on a sizable number of calves which failed to survive through to one year of age with similar autopsies on those that reach yearlinghood. Considering that it is exactly this period of survival that moose biologists find lacking in certain critical Alaskan herds (McIlroy et al., personal communication), it seems particularly important to make such observations if the opportunity should ever arise. We can now successfully handle frozen large animals in our new facilities at Fairbanks.

2. Caecal Roundworms

Although we know of several genera of roundworms which inhabit the caeca of other Alaskan wild ruminants (i.e. sheep, caribou, black-tailed deer) we have not seen more than a few transient roundworms from the upper digestive tract passing down the gut on their way out of their moose hosts. To the present date we have examined more than 100 animals. Elsewhere caecal worms like *Trichuris* (whipworm) are occasionally present in moose (e.g. Alberta, Canada, 1 of 19 animals, Barrett 1972; Central Russia, 3 of 7 herds, Kadenatsii and Zimoviev 1973). Trichurids are not commonly considered to be an important parasite of domestic animals (Levine 1968) and because of their apparent scarcity in Alaskan moose need not be further considered in this regard.

3. *Diclyocaulus viviparus* Bloch, 1782.

Roundworms of this genus inhabit the bronchioles of ruminants and are not uncommon in some Alaskan wild ruminants, especially bison. Olsen and Fenstermacher (1942) found the above species relatively commonly in moose in Minnesota (i.e. 14 of 33) and more recently Kadenatsii and Zimoviev (1973) have reported prevalence rates of 18-40 percent in moose on several ranges in central Russia. On the other hand, our own experience is that *Dictyocaulus* is comparatively less common in Alaskan moose in which we only saw 2 infections in 14 animals in which careful dissections of the lungs were made. Barrett (1972) reported that 4 of 40 moose from two areas in Alberta harbored lungworms.

Heavy infections of *Dictyocaulus* cause a relatively serious condition in cattle known as "husk" or more properly parasitic bronchitis. We have never seen any indications of inflammation, i.e. bronchitis, in the few infected moose we have encountered among hundreds of animals examined over the past 14 years. However, we have seen several mild cases of early bronchitis in bison and black-tailed deer which are more commonly and heavily infected.

I know of no reason to rule out the possibility of lungworm bronchitis occurring in Alaskan moose, other than the apparent normally low prevalence and intensity of the infections. Otherwise, Cowan (1951) has reported that *Dictyocaulus* causes severe infections in black-tail deer of coastal and insular British Columbia in which epidemic die-offs occur.

4. *Setaria yehi* Desset, 1966.

This roundworm normally inhabits the body cavity of moose and is transmitted by various species of mosquitoes. We have never seen it in Alaskan moose other than in animals taken in the general vicinity of Fairbanks where it is relatively common. Seven of 37 calves examined during the hard winter of 1970-71 and 8 of 21 adult moose examined more recently carried body cavity worms. Barrett (1972) reported only 1 of 39 Alberta moose carrying *Setaria* while in central Russia body cavity worms were observed to occur in unstated frequencies in 2 of 7 moose herds (Kadenatsii and Zimoviev 1973). Evidently this parasite is rare in the moose of eastern Canada (Peterson 1955).

I am unaware of any reports claiming that setarial signs of fibro-inflammatory responses to *Setaria* in some of the infections that we have observed. These involved encapsulation of worms on the surface of the liver in apparently harmless fibrous capsules.

Not all infections by *Setaria* are harmless, however. *Setaria digitata* (Linstow 1906), which normally parasitizes Eurasian bovids, is a well known cause of severe cerebrospinal nematodiasis in non-bovid hosts (Innes 1951). Accordingly, one might speculate that there could be some degree of risk in the association of non-cervids (e.g. Dall sheep, bison, cattle) with infected moose. Such associations (risk?) do occur in central Alaska. Perhaps *Setaria yehi* is unable to survive at all in non-cervids. Dieterich and Luick (1971) have reported finding harmless infections of this parasite in reindeer held for experimental purposes near both Fairbanks and Cantwell. We noted our failure to find *Setaria* in hundreds of free-ranging caribou and offered an explanation of Dieterich and Luick's (1971) surprising observation of this parasite in reindeer (i.e. *Rangifer* sp.) in Alaska (Neiland 1972).

5. *Wehrdiksmansia cervipedis* Wehr and Dikmans, 1935.

This parasite is more commonly known as the "foot-worm of deer" (i.e. cervids). However, it is found subcutaneously not only in the feet and lower legs, but also under the skin of the torso and even the head and ears. Indeed, it appears there is some reason to conclude that the area of the lower leg and foot are abnormal places for this parasite to locate. None of 76 specimens from 9 moose taken near Fairbanks were males, and Herman and Bischoff (1946) concluded that those that locate in the extremities are likely to die virgins. Therefore, using reproductive success as an index of normality of habitat, one must conclude that the extremities are an abnormal habitat, at least in deer and moose.

Wehrdiksmansia is a relatively common parasite of moose. We have had many verbal reports of it and have seen the nine cases mentioned above in the comparatively few animals (about 20) in which we made a special effort to find it. It is worthwhile noting that again, like *Setaria*, there seems to be some suggestion that this parasite is most common in moose from interior Alaska. We have not heard of or seen specimens from moose from the Kenai Peninsula, Matanuska Valley, Alaska Peninsula, Copper River Flats or from a bull taken at Berner's Bay in 1969. Also, Williams and Babero (1958) have reported what they "tentatively" identified as *Onchocerca* sp. from the lower hind legs of a bull killed in the Taku River Valley near Juneau. In view of our own findings and other considerations, I am highly skeptical about the accuracy of Williams and Babero's "tentative conclusions."

There appears to be little reason to suppose that this parasite causes much difficulty for its host. We have not seen or heard of any obvious complications directly attributable to foot worms in Alaskan moose and have never seen this parasite in other Alaskan ruminants. Williams and Babero (1958) also failed to note clearcut pathologic changes in their specimen. However, Rush (1935) reported evidence of comparatively severe foot lesions in mule deer and DeNio and West (1942) reported similar findings. By way of contrast, Herman and Bischoff (1946) reported, "No visible evidence of harmful effect to the deer was observed." There appears to be little more to consider at this time regarding the pathogenic potential of *Wehrdiksmansia* in moose.

This worm is a widespread parasite of moose. It has also been seen in western British Columbia (Peterson 1955), 33 of 72 animals from Alberta were infected (Barrett 1972) and it is known in 3 of 7 moose herds in central Russia (Kandenatsii and Zimoviev 1973). It is worth noting that most Russian authors incorrectly place this worm in the genus *Acanthospiculum* Skrjabin and Shikhobalova, 1948, which is clearly a taxonomic synonym of *Wehrdiksmansia* Caballero, 1945, described three years earlier to receive *Onchocerca cervipedis* originally described in 1935.

D. Miscellaneous Parasites and Pathology

1. *Sarcocystis*

This is a world-wide, protozoan parasite of a wide variety of mammals and birds. The organism occurs in large numbers in individual cysts which occur inside cardiac and skeletal muscle cells. Some species, e.g. *Sarcocystis rileyi* (Stiles 1893) are easily seen with the naked eye, but those in moose are quite small and not readily visible except in thin sections for microscopic study. Because of this special effort required to see them and because *Sarcocystis* spp. in general are not considered very pathogenic (Levine 1961) we have not made any special effort in the past to look for them. However, recently Dr. Rollo van Pelt, Animal Pathologist, Institute of Arctic Biology, University of Alaska, told me that he had seen them commonly in various tissue samples of wildlife that are referred to him. Accordingly, we sent to him for study samples of cardiac and skeletal muscle tissue from six moose collected in October 1972 on the Tanana Flats near Fairbanks. In three moose these cysts were seen in both kinds of muscle, while the remaining three showed only myocardial cysts. Evidently this parasite is also common in Alaskan moose. Barrett (1972) reported it in 13 of 19 moose collected in Alberta. I have no knowledge of reports of it in moose in Eurasia, but it is known there in other cervids (see Neiland 1972).

According to Levine (1961) the species that most likely occurs in cervids is *Sarcocystis tenella* Railiet, 1886, which is also known to infect wild and domestic sheep.

2. The Long-toed Syndrome

This condition involves excessive growth of the hooves resulting in great elongation producing a "slipper-foot" appearance. It seems likely that pronounced elongation as sometimes seen should interfere with the normal function of the afflicted feet resulting in some degree of lameness. While we have seen numerous examples in moose from the Kenai Peninsula or the vicinity of Anchorage, we do not know of the condition occurring in central Alaska (Bishop, ADF&G, personal communication) or elsewhere in Alaska.

Honess and Winter (1956) described a case of "long-toe" in a moose from Jackson Hole, Wyoming, and attributed the problem to "alkali or selenium" poisoning resulting from consumption of seleniferous plants. They also reported a similar case in a mule deer.

Several years ago we had a number of selenium analyses done on appropriate tissue samples from long-toed moose, but failed to demonstrate amounts harmful in domestic animals. Its toxicity in moose is unknown. As far as Interior moose are concerned, the long-toed syndrome is conspicuous by its apparent absence.

3. Fibroma

So-called infectious warts, a kind of tumor composed essentially of fibrous connective tissue, are more or less common on moose throughout Alaska. Nearly every moose season, we see examples brought in by moose hunters.

Infectious warts, more specifically papillomas, may occur nearly anywhere on the surface of the torso. Usually they take the form of swellings, but on occasion may be pedunculate (i.e. stalked) growths which hang on the animal like "apples on a tree." Our most recent local example was found on the side of the udder of a 16-year-old moose which attacked a truck and had to be dispatched.

We know of no pathogenic effects of papillomas, but in extreme cases seen elsewhere in deer, growths about the head obviously interfered with vision. We have seen one example of a pedunculate wart about 8.0 cm in diameter on a moose from the Stikine River Valley in southeastern Alaska to which some liability might be charged. The wart had frozen during a period of extreme cold and as it thawed during warmer weather, when the animal was killed by a hunter, it began to rot and give off a fearsome stink. One can only suppose that this smell would have been particularly attractive to brown bear (*Ursus arctor*) which are common along the Stikine River.

4. Hematoma

As the name indicates, this condition is a "blood tumor" (blister if you will) which, in the example that came to hand, affected the spleen of a cow moose taken by a hunter on the Kenai Peninsula. The specimen was diagonosed by Dr. Rollo van Pelt (identified earlier) as an example of "...chronic hematoma of the spleen probably resulting from trauma." The tumor was quite large, about 15 x 20 cm, and only the comparatively tough capsule of the spleen resisted full rupture which would have resulted in massive hemorrhage and rapid death.

5. Porcupine Quill-Joint Abscess

In December 1970, we had a report of a calf moose which apparently had become crippled. When we investigated it was obvious that the animal had a serious problem with its right front leg and most likely would not long survive. It was shot with an overdose of drug and taken into the laboratory for examination. We soon found a severe abscess of the carpal joint within which we discovered pieces of several porcupine quills. We can only surmise that the calf blundered into a porcupine using a moose trail and got quilled. Such quills are notorious for working their way into the hapless victim, in this case into the carpal joint, a good place for contaminating bacteria to grow and form an abscess. If the animal had survived the remainder of the winter it probably would have been afflicted with a chronic, arthritic joint for life.

We have previously reported on the untimely, fatal encounter of two mountain goat kids with a porcupine.

II. Microbial Infections

In this section we will consider data on so-called "micro-parasites" or microbes, i.e. bacteria and viruses, as potential causes of disease in moose. Most of the work that has been done with these pathogens involves immunologic studies on moose serum to detect evidence of past or present infections. Each disease agent of interest will be considered separately below.

A. Bacteria

1. *Brucella suis* type 4.

This organism is the causative agent of rangiferine brucellosis which is enzootic in several Alaskan caribou herds (Neiland et al. 1968). Among these herds is that (i.e. Delta caribou herd) which ranges along the northern foothills of the Alaska Range across the Tanana Flats from Fairbanks. In this and other areas the range of infected caribou overlaps that of moose providing for the possibility of transmission of the disease from its reservoir host species, i.e. caribou, to an alternate host, i.e. moose. Accordingly, in this case, as well as in regard to other moose herds, we have thought that it was worthwhile and important to serologically test moose for evidence of brucellosis. During this reporting period results have come to hand on 140 moose from three major moose ranges. All tests were negative. The number of animals tested from each area is shown in parentheses: Tanana Flats (27), Kenai Peninsula (60, including 8 from the Moose Research Center) and Anchorage - Matanuska Area (53).

Over the years we have tested hundreds of moose for *Brucella* antibodies and have only found one clear-cut reactor. As explained elsewhere (Neiland et al. 1968) this infection was most likely accidentally acquired through association of the victim with a bacteriologically insecure installation where experimental infections in reindeer were being studied. It, therefore, cannot be regarded as evidence for other than the susceptibility of moose to *B. suis* 4. Otherwise, we have no reason to suppose that brucellosis is at present a problem in moose.

Very little appears to be known about infections of *Brucella* in moose. The only report that I know of that described an unequivocal case of brucellosis in moose is that of

Jellison et al. (1953). They observed a fatal case of brucellosis in a moose in Montana caused by *Brucella abortus* type (?) which is found in cattle, the normal reservoir. Since brucellosis is seldom fatal in adult, large domestic animals, one must suppose that moose are no exception.

Brucella abortus infections are now enzootic in free ranging elk and bison in Wyoming and in bison in Wood Buffalo Park in Canada. However, in these species the most serious result of infection is abortion (personal communication, Dr. Thomas Thorne, Wyoming Game and Fish Department).

2. *Spherophorus necrophorus*

This bacterium is the usual causative agent of so-called "foot-rot" (necrobacillosis) which occurs throughout the world in wild and domestic ruminants. It is more or less commonly seen in Alaskan caribou (Neiland 1972) but is conspicuous by its apparent absence in moose. I have not found reference to infection of moose by this organism anywhere. However, Barrett (1972) mentioned a case of "foot-rot" in moose in Alberta from which *Corynebacterium pyrogenes* was isolated. This bacterium also is world-wide and causes various infections in birds and mammals.

We have only once seen a presumed case of necrobacillary foot-rot, but no isolation of viable organisms was made. The specimen was taken from a bull moose killed near Bettles on the south slope of the Brooks Range. The infection, whatever the cause, had severely eroded some of the articular surfaces on some of the foot bones (personal communication, Dr. R. L. Rausch, Arctic Health Research Center).

3. Leptospirosis

This infection is caused by one or another of the members of the bacterial genus *Leptospira*. The infection almost invariably lodges in the kidneys, as well as other organs, and the primary route of transmission is via consumption of materials contaminated by infected urine.

Several years ago we had the opportunity to serologically test a batch of sera taken from moose killed in a special hunt on Fort Richardson in 1969. Fifty serum samples were tested for the following serotypes of *Leptospira* (positives at 1:100 screen titre shown in parentheses): *L. pomona* (1), *L. icterohaemorrhagiae* (6), *L. hardjo* (1), *L. autumnalis* (1), *L. hebdomadis* (neg.), *L. grypotyphosa* (neg.), and *L. pyrogenes* neg.). It should be noted tnat screen titres of 1:100 are only indicative of exposure to organisms stimulating antibodies giving the above agglutination reaction and not necessarily concurrent disease.

Barrett (1972) tested 23 serum samples taken from moose in Alberta for 10 leptospiral serotypes all with negative results. However, McGowan et al. (1963) working in Ontario found 4 *L. pomona* serotype reactors in 90 moose sera. They failed to see either kidney lesions or make isolations of the organism from moose, but in the same area they reported commonly finding titres and lesions and making occasional isolations of *L. pomona* from white-tailed deer. They also noted the, "antibody in animals in areas devoid of farm livestock point to a source of infection in nature." McGowan et al. (1963) also noted evidence suggesting that leptospirosis may lead to abortion in free ranging cervids, and Trainer et. al. (1961) experimentally demonstrated its abortifacient character in white-tailed deer.

While we have no reason to think at the present time that leptospirosis is a problem in Alaskan game, further work must be done before it can be ruled out.

B. Viruses

Other than infectious warts, which in deer are known to be caused by a host-specific virus, very little is known regarding the prevalence of viruses in moose. Only recently have preliminary serologic studies on the occurrence of several viruses of veterinary and/or public health significance been reported. Trainer and Hoff (1971) presented data on the prevalence of certain encephalitides, namely western (WE), St. Louis (SLE) and California-snowshoe hare (CE) encephalitis. They found the following percentages of antibodies in sera of 23 moose: WE(8), SLE(4), and CE(70). These animals were all part of those studied by Barrett (1972) in Alberta. Thorsen and Henderson (1971) also received aliquots of serum from Barrett's study. They found antibodies against bovine virus diarrhea and parainfluenza in 4 and 3, respectivly, of 22 serum samples. None of the above workers, including Barrett, noted any signs of disease associated with the antibody titres they observed.

We submitted 52 serum samples taken from moose killed on Ft. Richardson in 1969 to Dr. Daniel O. Trainer's laboratory for virus serology. Neutralizing antibodies against only two encephalitis viruses were detected. These included: CE (21 animals) and SLE (6 animals). Again, we do not know of any signs that suggest that either viruses cause disease in Alaskan moose. However, I do not consider that our knowledge in this regard is at all adequate.

CONCLUSIONS

Moose are afflicted by a wide variety of potentially pathogenic organisms. In this regard, however, one can surmise that the list will be greatly expanded when as much effort has been expended on moose as on other cervids, e.g. reindeer or white-tailed and mule deer.

The present study was originally initiated primarily to complement a newly-started moose study principally oriented toward nutrition and winter mortality of moose near Fairbanks. However, as the project developed during the first winter it became evident that we would be unable, with the facilities and manpower then at hand, to adequately necropsy the relatively large number of moose (mostly calves) that were dying along the local roads. The majority of these, of course, were killed when struck by cars. But, as the winter progressed and the snows became deeper, the animals' condition worsened and undernutrition and starvation was the ultimate fate of those surviving the hazards of traffic. While we were unable to accurately document the total load of parasites carried by these animals, we knew from our other work with moose ranging near Fairbanks that exposure to parasitism is common and potentially heavy. Accordingly, we conclude that under the stresses of severe weather and reduced nutrition, parasitism could well have played a secondary, though influential, role in the death of those that died later in the winter. For that matter, it may well be that some of those that died in encounters with automobiles did so because of lessened ability to avoid vehicles resulting from starvation aggravated by parasitism. Sometimes, the "straw does indeed break the camel's back."

A less speculative result of the study reported above is the considerable amount of new information we gained about the potential causes of disease in moose in interior Alaska. However, in order to adequately evaluate these possibilities, two kinds of studies are needed. First, now that we have reasonably good facilities and are better staffed, we should again make an effort, the next time we have a severe winter, to measure the parasite burdens carried by dying and surviving animals. Another field study that should be done involves the post-natal survival of calves over the summer. Losses during the period can substantially minimize yearly reproductive gains. Secondly, we must eventually do studies on experimental infections, if we are to gain unequivocal information on the pathogenicity of at least some of the potential disease agents that we now recognize. No doubt, the future will reveal other pathogens as yet "undreamt of."

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