The Distribution and Importance of Meningeal Worm (*Parelaphostrongylus tenuis*) in Western Canada

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(1) The distribution maps (Figs. 1-4) were prepared from information contained in *The Mammals of British Columbia* (Cowan and Guiguet, 1965), *The Atlas of Alberta* (University of Alberta Press), and *The Range of white-tailed deer in Alberta* (Webb, 1967). I am particularly grateful for the information supplied by Mr. Wayne Runge on the mammals of Saskatchewan and by Mr. Larry Bidlake for the mammals of Manitoba.

(2) Pryado and Boev (1971) have transferred meningeal worm (*Pneumostrongylus tenuis*) to the genus *Parelaphostrongylus* and the parasite should hereafter be referred to as *Parelaphostrongylus tenuis* (Anderson, 1971).

I Present Distribution of *Parelaphostrongylus tenuis* in Western Canada and Evidence of *P. odocoilei* in British Columbia

This study was carried out under contract to the Canadian Wildlife Service, Ottawa, Ontario. The author wishes to acknowledge the support of the Director, Dr. J.S. Tener and members of the Pathology Section, especially Dr. L.P.E. Choquette, Head, and Dr. G. Gibson for their assistance and encouragement.

Abstract

Larvae indistinguishable from those of *Parelaphostrongylus tenuis* were recovered from one white-tailed deer faecal pellet group in southwestern Saskatchewan. Such larvae were not recovered from 585 white-tailed deer pellet groups collected elsewhere in western Saskatchewan and Alberta, suggesting that the present western limit of *P. tenuis* distribution in Canada lies within the borders of Saskatchewan.

Larvae indistinguishable from those of *P. tenuis* which were recovered from 63 per cent of white-tailed deer pellet groups in East Kootenay District of British Columbia are, in the absence of adult nematodes in the crania of 49 deer, almost certainly those of *P. odocoilei*.

Introduction

Meningeal worm (*Parelaphostrongylus tenuis*) is a prevalent and widespread parasite of white-tailed deer (*Odocoileus virginianus*) in eastern North America. Whereas the parasite is normally non-pathogenic in this host, it is the cause of an often fatal neurologic disease (Parelaphostrongylosis) in other ungulates.

Bindernagel and Anderson (1972) showed that *P. tenuis* was present in all major white-tailed deer populations in eastern Canada as well as in Manitoba and eastern Saskatchewan. They recovered adult nematodes from deer heads as far west as southwestern Manitoba, and larvae indistinguishable from those of *P. tenuis* from white-tailed deer faeces as far west as Prince Albert National Park in central Saskatchewan. These findings whowed that *P. tenuis* is established in deer of the eastern end of the aspen parkland ecotone. The authors observed that there is no apparent barrier to the continued westward spread of the parasite and that its occurrence in western Saskatchewan and in Alberta could not be discounted on the basis of their results. They also raised the question of the parasite reaching the foothills of the Rocky Mountains.

The present study was undertaken to determine whether or not P. tenuis was present in white-tailed deer in western Saskatchewan, Alberta and British Columbia. The advances of white-tailed deer in western Canada in the past century, both in terms of numerical increase and expansion of range, have brought this adaptable ungulate into close association with moose (Alces alces), elk (Cervus canadensis), mule deer (Odocoileus hemionus), caribou (Rangifer tarandus), and occasionally bighorn sheep (Ovis canadensis) and mountain goat (Oreamnos americanus). If white-tailed deer in western Canada became infected with P. tenuis the possibility of parelaphostrongylosis in these populations would arise.

The method used in this study indicates whether animals are passing Parelaphostrongylus sp. larvae in their faeces and are therefore infected with one or more of the three species of Parelaphostrongylus. Since the first-stage larvae of P. tenuis, P. odocoilei and P. andersoni are indistinguishable, adult nematodes must be found to determine which species is present. This is easiest in the case of P. tenuis since adult nematodes occur most commonly in the subdural space in the cranium and are usually visible when the brain is removed.

Adults of P. odocoelei are presently known only from Columbian black-tailed deer (Odocoileus hemionus columbianus) (Hobmaier and Hobmaier, 1934; Brunetti, 1969) and mule deer (Brunetti, 1969) in California. They are reported to occur in the musculature and in the large blood vessels of the lung. P. andersoni also occurs in the musculature and is known only from white-tailed deer in southeastern U.S.A. (Prestwood, 1972).

Methods

White-tailed deer faeces pellet groups were collected in western Saskatchewan, eastern Alberta and south-eastern British Columbia in the fall and early winter of 1972. The Baermann technique was used to recover larvae from the faeces.

White-tailed deer heads from southeastern British Columbia were examined for adult nematodes. Heads were bisected by hand using a hack saw. The brain was removed and the surface of the brain and cranium was examined.

The blood vessels of the lungs of five white-tailed deer in British Columbia were dissected and examined for nematodes.

Results

Of 403 white-tailed deer pellet groups from western Saskatchewan examined with the Baermann technique, larvae indistinguishable from those of P. tenuis were recovered from only one (Table 1). This pellet group, from which numerous larvae were recovered, was collected in southwestern Saskatchewan near the Cypress Hills (Fig. 1).

None of 182 pellet groups collected from white-tailed deer range in Alberta yielded larvae indistinguishable from those of P. tenuis (Table 2) (Fig. 1).

In British Columbia larvae indistinguishable from those of P. tenuis were recovered from 45 (63 per cent) of 71 white-tailed deer pellet groups on two East Kootenay ranches (Fig. 1). Nematodes were not observed in the cranium of 49 heads from one of the ranches and the surrounding area.

The head, lungs and faecal pellets of two deer from this area were available for examination. Larvae indistinguishable from those of P. tenuis were recovered from the faecal pellets of both but no nematodes were observed in the cranium. Only a single Dictyocaulus sp. was found in the lungs although larvae indistinguishable from those of P. tenuis were recovered from lung washings following dissection. No nematodes were found in three additional sets of lungs from one of the ranches.

Discussion

The recovery of larvae indistinguishable from those of P. tenuis from one white-tailed deer faecal pellet group in southwestern Saskatchewan almost certainly represents an animal infected with P. tenuis. The finding is approximately 330 miles due west of the most westerly previous finding of larvae in southern Saskatchewan by Bindernagel and Anderson (1972). It is within 15 miles of the Alberta border and 65 miles of the northern border of Montana.

The recovery of larvae so far west of the nearest previous recovery may be a result of a high degree of mobility of prairie white-tailed deer. Runge (unpublished data) has shown that white-tailed deer tagged in wintering areas in woutheastern Saskatchewan may travel up to 200 miles from the tagging site within one year. His data suggest that prairie white-tailed deer may move considerably longer distances than do deer in forested areas. More restricted white-tailed deer movements in forested areas may explain the apparent absence of P. tenuis in the forest fringe area west of Prince Albert National Park.

The failure to recover larvae indistinguishable from those of P. tenuis elsewhere in western Saskatchewan and in Alberta suggests that the parasite is absent or very rare in these areas.

The recovery of larvae indistinguishable from those of P. tenuis from 63 per cent of the white-tailed deer pellets collected in southeastern British Columbia is indicative of P. odocoilei. The failure to recover adult nematodes in the cranium of 49 deer from this area argues strongly against the possibility of P. tenuis. In Quebec where larvae were recovered from 63 per cent of pellet groups, adult P. tenuis were observed in six (30 per cent) of 20 heads and even in southwestern Manitoba where larvae were recovered from only 31 per cent of pellet groups, adult nematodes were recovered from six (10 per cent) of 59 heads (Bindernagel and Anderson, 1972).

Although mule deer were not present in the area when these white-tailed deer pellets and organs were examined, they are abundant later in the winter when deeper snow depth drives them down to the ranches in the valley bottoms. Their return to higher elevation in the spring is relatively late and it appears that they coexist with white-tails, especially in alfalfa fields, during a period when parasite transmission could readily occur. Although mule deer faecal pellets were not examined in this study, Russel (1967) reported "protostrongylid larvae" from pieces of lung from both white-tailed deer and mule deer in this area.

The importance of P. odocoilei as a pathogen of western ungulates remains to be determined. Brunetti (1969) reported that the primary cause of death of the twelve-month-old black-tailed deer in which he rediscovered P. odocoilei was "an overwhelming parasitemia of the lungs with ova and larvae indistinguishable from those described for P. odocoilei."

"Fig. 1. Distribution of white-tailed deer" and *Parelaphostrongylus tenuis* in western Canada

Distribution of white-tailed deer
/// low density
XXX high density
---- Present western limit of *P. tenuis* distribution

● Location where larvae indistinguishalle from *P. tenuis* recovered from white-tailed deer faecal pellets (Data east of Saskatoon is from Bindernagel and Anderson, 1972)

◎ Location where larvae not recovered from white-tailed deer faecal pellets

Table 1. Results of examination of white-tailed deer faecal pellets in western Saskatchewan (Part I).

Area	No. Pellet Groups Examined	No. Pellet Groups Positive
NW Saskatchewan-Forest Fringe West of Prince Albert Park		
16 miles S of Shell Lake	14	0
ca 7 miles NE of Spiritwood	10	0
ca 7 miles SW of Spiritwood	4	0
2 miles W of Belbutte	44	0
2 miles E of Fairholme	26	0
5 miles SW of St. Walburg	8	0
	106	0
NW Saskatchewan-South of Forest Fringe		
2 miles S of Borden, 1 mile N of N Saskatchewan River	24	0
5 miles SW of Hafford (Hafford Community Pasture)	11	0
ca 5 miles NW of Sonningdale	20	0
9-12 miles S of Nielburg	23	0
	78	0
SW Saskatchewan-Qu'Appelle-S Saskatchewan River drainage		
ca 5 miles E of Lumsden	10	0
ca 8 miles N of Eyebrow	8	0
5-10 miles SE of Elbow (Elbow Wildlife Management Area)	22	0
ca15 miles N of Cabri along S Saskatchewan River	23	0
	63	0
SW Saskatchewan		
1-4 miles W of Willow Bunch	32	0
1-4 miles E of Val Marie along Frenchman River	31	0
2-7 miles S of Piapot along Bear Creek	24	0
15-17 miles S of Piapot along Bear Creek	14	0
10 miles SW of Maple Creek on Gap Creek	15	0
15 miles SW of Maple Creek on Gap Creek (R.Small Ranch)	21	1
ca 5 miles S of Cypress Hills (W.Block) on Battle Creek	19	0
	156	1
Western Saskatchewan Total	403	1

Table 2. Results of examination of white-tailed deer faecal pellets in Alberta (Part I).

Area	No. Pellet Groups Examined	No. Pellet Groups Positive
Eastern Alberta along Forest Fringe		
ca 7 miles N of Marwayne, 2 miles S of Lea Park	2	0
1 mile SE of Lac Bellevue	28	0
Elk Island National Park (Isolation area S of Hwy 16)	66	0
	96	0
Southcentral Alberta		
ca 5 miles S of Cadogan	15	0
2 miles SE of Dowling Lake, 3 miles N of Hanna	11	0
East shore of Little Fish Lake	2	0
Clearwater River S of Rocky Mountain House	3	0
	31	0
Southern Alberta		
3 miles N of Walsh on Boxelder Creek	14	0
Q Ranch ca 5 miles N of Wild Horse	8	0
Kerr Ranch ca 4 miles W of Coleman in Crowsnest Pass	33	0
	55	0
Alberta Total	182	0

II The Importance of *Parelaphostrongylus tenuis* in Western Canada

- White-tailed Deer
- Moose
- Elk
- Caribou
- Mule Deer
- Other Susceptible Hosts
  - Pronghorn
  - Bighorn Sheep
  - Mountain Goat

White-tailed Deer
(*Odocoileus virginianus*)

Because white-tailed deer can harbour and transmit *P. tenuis* without suffering ill efects, the importance of this host in the epizootiology of *P. tenuis* is as a disseminator of the parasite. This role has been most significant where white-tailed deer have come into contact with other cervids such as moose and caribou in which *P. tenuis* causes an often-fatal neurologic disease.

The spread of *P. tenuis* is closely tied to the spread of white-tailed deer. In the past 100 years the white-tailed deer has extended its range into parts of Nova Scotia, New Brunswick, northern Ontario and Manitoba. Most of these northern movements have been facilitated by logging and agricultural practises which created suitable habitat in the form of forest edges and clearings. This northern expansion of deer range since the late 1800's was probably responsible for the introduction of *P. tenuis* to moose and possibly to caribou in eastern North America. Such range expansion may also have introduced the parasite to white-tailed deer in the aspen parkland of Manitoba and eastern Saskatchewan.

White-tailed deer in Alberta appear to have their origins largely within the borders of that province. There are records of white-tailed deer in northern Alberta before 1800 and in the Rocky Mountain foothills as early as 1863 (Webb, 1967). Whereas there is no indication of an influx of deer from the east, there apparently were increases in local populations along the southern foothills and throughout the parkland in the late 1930's (Webb, 1967). There was also northward expansion in response to deforestation and settlement during this period. Slight range expansion is apparently still occurring in western and northern Alberta (Kyut, 1966).

Although white-tailed deer are widespread in the prairie provinces, they appear to be concentrated in a few well-recognized zones. The detailed distribution of white-tailed deer on the prairies is particularly important since the areas of highest density may provide avenues for the westward movement of *P. tenuis* (Fig. 1).

The three principal areas of high deer density in Saskatchewan are as follows:

(1) The forest fringe, which is the transition from cultivated land to commercial forest, is a relatively

high density white-tailed deer area across northern Saskatchewan. In Alberta the forest fringe is further north and deer density is somewhat lower.

(2) Major river valleys, especially the North Saskatchewan and the Qu'Appelle-South Saskatchewan chain of southern Saskatchewan, constitute ribbons of continuous deer habitat through what is otherwise less desirable range.

(3) The creek bottoms of the southern Saskatchewan prairies constitute small but important bedding and wintering areas for large numbers of white-tailed deer which have adapted to intensively cultivated land.

Bindernagel and Anderson's (1972) westernmost recovery of larvae indistinguishable from those of P. tenuis was in the southern end of Prince Albert National Park and near Duck Lake in the forest fringe. They suggested that the parasite might occur even further west in this apparent "corridor" of continuous high deer density. This hypothesis was not confirmed in the present study dispite intensive sampling along the entire forest fringe in western Saskatchewan and well into Alberta. Similarly no larvae were recovered from samples along the North Saskatchewan River or along the Qu'Appelle-South Saskatchewan River chain (Fig. 1).

In a creek bottom of southwestern Saskatchewan, however, larvae indistinguishable from those of P. tenuis were recovered from one white-tailed deer pellet group. This record is approximately 330 miles due west of the westernmost record of such larvae in southern Saskatchewan (Bindernagel and Anderson, 1972). The sample from which the larvae were recovered was one of 21 samples collected from a ranch where up to 11 white-tailed deer were seen feeding on the two occasions when the samples were collected. The ranch is situated in the grassland biome about eight miles north of the Cypress Hills.

This record of a white-tailed deer apparently infected with P. tenuis so far west of the nearest previous records (Moose Mountain Provincial Park) is most easily understood in the light of the studies of Runge (unpublished data). Of numerous deer trapped and tagged near Moose Mountain Provincial Park one was recovered a year later in Montana over 200 miles southwest of the tagging site. This and similar but less spectacular tag returns indicate that prairie white-tailed deer may move considerably longer distances than do deer in forested areas. These movements may be related to the distribution of wintering areas in the southern aspen parkland and grassland areas as compared with the forest fringe where wintering areas are more or less continuous.

There is clearly a gradient in the prevalence of larvae indistinguishable from those of P. tenuis across southern Manitoba and Saskatchewan. From a high of 81 per cent in southeastern Manitoba (where moose neurologic desease is known (Lankester, 1972) it declines to 31 per cent in southwestern Manitoba and to 8 per cent in southeastern Saskatchewan (Bindernagel and Anderson, 1972). This study indicates that in southwestern Saskatchewan the prevalence is even lower.

This situation contrasts with that in the forest fringe where the prevalence of larvae in both eastern and central Saskatchewan was approximately 25 per cent but where no additional recoveries of larvae occurred west of Prince Albert Park.

The recovery of larvae indistinguishable from those of P. tenuis in southwestern Saskatchewan may indicate the route that the parasite is most likely to take in any future westward spread. It is perhaps significant that the parasite could reach the Rocky Mountains sooner by this southern route than by a northern route. Waterton Lakes National Park is less than 200 miles from the present positive sample and there are areas of relatively high white-tailed deer density in southern Alberta which extend well into the foothills. Wishart (personal communication) suggested that white-tailed deer are present in much of the foothill area south of Calgary but that only isolated populations occur in the foothills further north. There is a considerable gap between the western limit of white-tailed deer distribution in Alberta and the Rocky Mountain National Parks north of Banff. The relatively small numbers of white-tailed deer in Banff and Jasper National Parks are thought to have originated west of the Rocky Mountains (Banfield, 1958; Webb, 1967).

Moose
(*Alces alces*)

Moose occur in the boreal forest across Canada and also in forested areas of the Rocky Mountains. There are isolated populations in Manitoba (Spruce Woods Provincial Forest, Riding Mountain National Park, Duck Mountain Provincial Park), Saskatchewan (Moose Mountain Provincial Park, Duck Mountain Provincial Park, Cypress Hills), and Alberta (Elk Island National Park, Cypress Hills) (Fig. 2).

That moose neurologic desease is caused by *P. tenuis* was demonstrated by Anderson (1964). The parasite has since been recovered from sick wild moose in Ontario (Anderson, 1965), Nova Scotia and New Brunswick (Smith *et al*., 1964; Smith and Archibald, 1967) and Manitoba (Anderson, personal communication; Lankester, 1972).

In the U.S.A., *P. tenuis* has been recovered from wild sick moose in Maine (Behrend and Witter, 1968; Gilbert, 1973), and Minnesota (Kurtz *et al*., 1966; Karns, 1967).

Kelsall and Prescott (1971) showed that moose in Fundy National Park contracted neurologic disease only when they descended to elevations occupied by white-tailed deer.

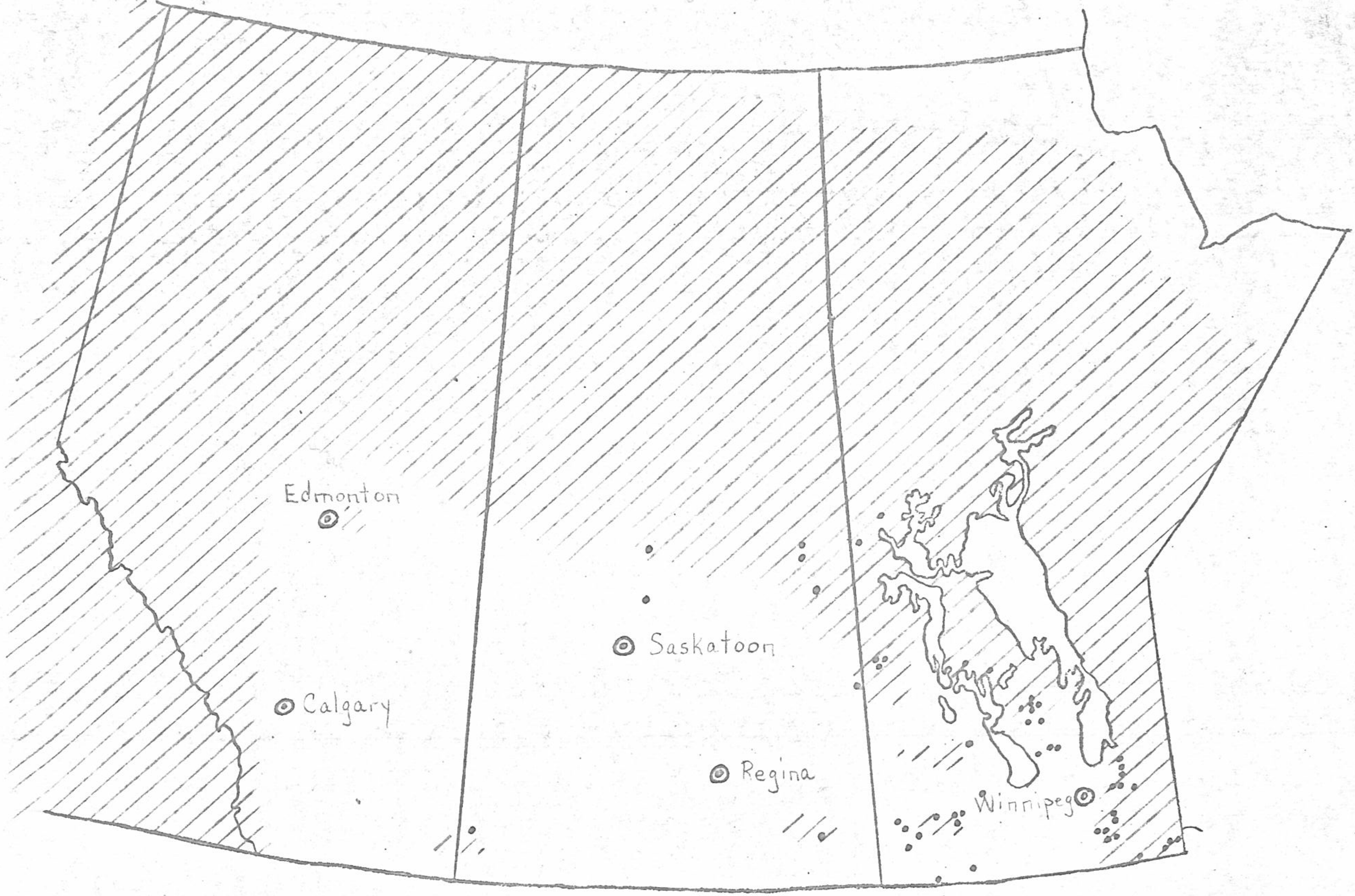
Gilbert (1973) found that almost 30 per cent of the moose examined in Maine were infected with *P. tenuis*, and was able to recover the parasite from 80 per cent of the animals showing abnormal behaviour or physical attributes which suggested "sickness". He found an apparent direct relationship between deer density and the prevalence of *P. tenuis* in moose and felt that *P. tenuis* constitutes a limiting factor in moose populations.

Although there were several confirmed cases of moose neurologic disease in northwestern Ontario (Anderson, 1965; Saunders, personal communication) there was no estimate of how widespread mortality was. Saunders (1973) compares the prevalence of *P. tenuis* in white-tailed deer with moose density in several areas. He found an inverse relationship between moose density and the prevalence of *P. tenuis* in white-tailed deer while deer density remained more or less constant. This suggests that *P. tenuis* may be an important but inapparent mortality factor in moose in areas where the prevalence in deer is high.

These three studies represent major advances in the understanding of the ecological relationships of deer, moose and P. tenuis. Indeed the principles involved may assist in the understanding of deer and P. tenuis relationships with other susceptible hosts.

Whereas moose neurologic disease is not known west of southeastern Manitoba, infected deer and moose occur together as far west as Prince Albert National Park (Bindernagel and Anderson, 1972). The prevalence of P. tenuis in deer, however, is only about 30 per cent in southwestern Manitoba and even lower in eastern Saskatchewan. It is approximately 80 per cent in southeastern Manitoba where Lankester (1972) reported moose neurologic disease.

Fig. 2. Distribution of moose in Western Canada



Shaded area represents approximate range of moose
Solid dots indicate locations where larvae indistinguishable from those of P. tenuis were recovered from white-tailed deer faecal pellets

Elk (Wapiti)
(*Cervus canadensis*)

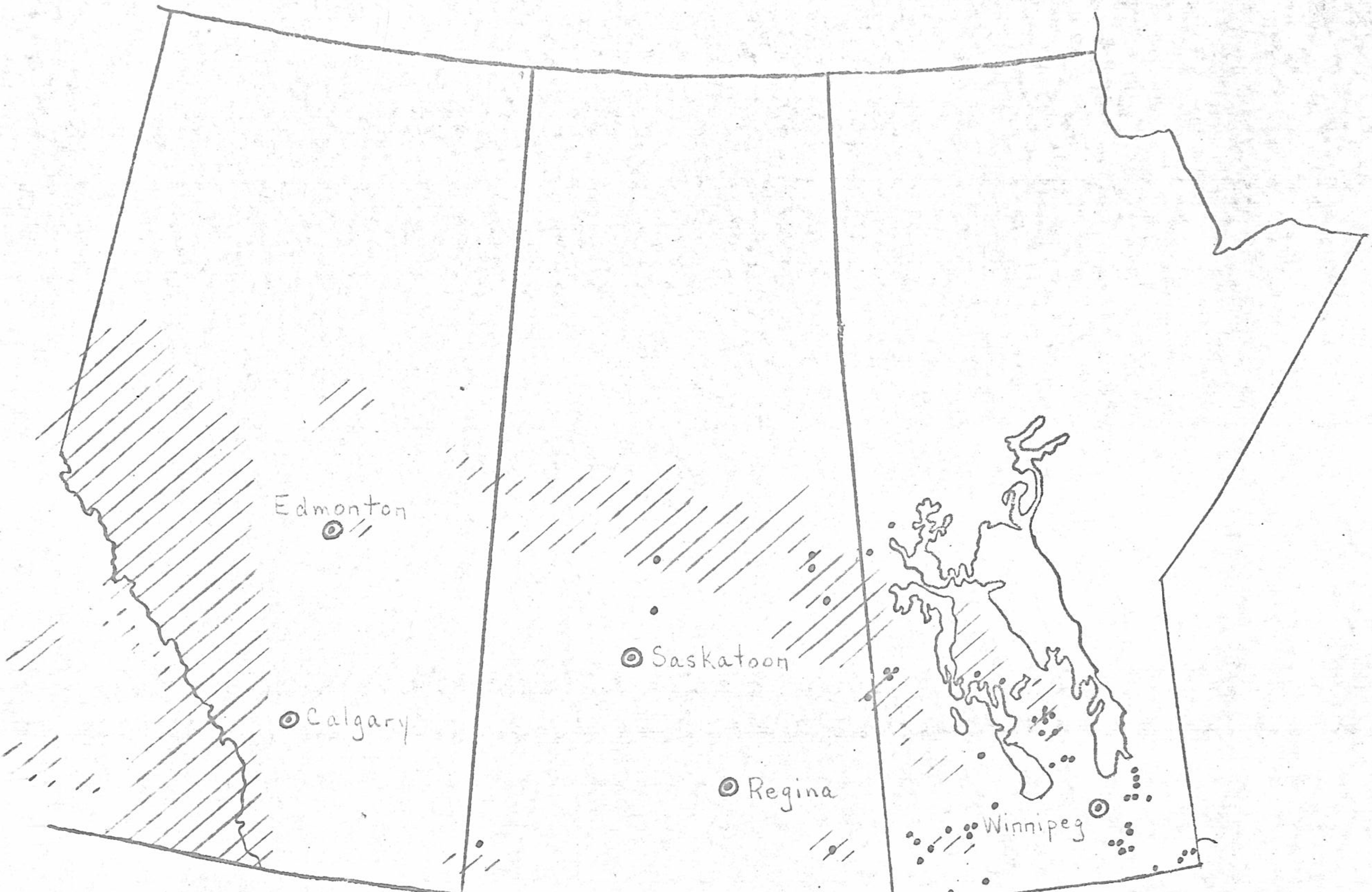
Elk occur along the Rocky Mountains and the foothills of Alberta and extend east somewhat sporadically along the forest fringe across Alberta and Saskatchewan into Manitoba. There are isolated populations in Alberta (Elk Island National Park, and Cypress Hills), Saskatchewan (Duck Mountain and Moose Mountain Provincial Parks), and Manitoba (Duck Mountain Provincial Park, Spruce Woods Provincial Forest, and Riding Mountain National Park) (Fig. 3).

Anderson *et al.* (1966) experimentally infected two young wapiti with *P. tenuis* larvae obtained from white-tailed deer. Whereas one animal survived the infection and began passing first-stage larvae in its faeces, the second animal showed severe neurological signs which terminated in general paralysis.

There are apparently no published reports of neurologic disease in wild elk although Carpenter *et al.* (1972) refer to neurologic disease in wapiti naturally infected with meningeal worm in western U.S.A.

Bindernagel and Anderson (1972) noted that elk and white-tailed deer appear to live in close association in Prince Albert National Park, Saskatchewan. Since larvae indistinguishable from those of *P. tenuis* were recovered from deer in the southern part of the park, the occurrence of neurologic disease in elk in this area is a possibility. Elk and infected white-tailed deer also coexist in several areas east of Prince Albert Park and neurologic disease may occur undetected in these elk populations.

Fig. 3. Distribution of elk in Western Canada



Shaded area represents approximate range of elk

Solid dots indicate locations where larvae indistinguishable from those of P. tenuis were recovered from white-tailed deer faeal pellets

Caribou
(*Rangifer tarandus*)

Whereas the ranges of caribou and white-tailed deer may have met and even overlapped in the past, this situation appears to occur only rarely today. It may occur in Manitoba in the Bissett area north of the Whiteshell Provincial Park, in the area around the Pas, and in northern Saskatchewan and Alberta.

Experimental infection of caribou with *P. tenuis* produced severe neurologic disease with sudden onset and rapid progression suggesting that this host is more sensitive to infection than moose, elk, or mule deer (Anderson and Strelive, 1968). Naturally acquired neurologic disease has been reported in caribou introduced into Maine (Behrend and Witter, 1968) and in reindeer introduced into Ontario (Anderson, 1971). Anderson and Strelive (1968) noted that declines in caribou in the past were sometimes apparently coincident with the arrival of white-tailed deer.

Areas where white-tailed deer infected with *P. tenuis* come into contact with native caribou are probably limited. However the advances of white-tailed deer into former caribou range probably precludes repopulation of these areas by caribou, at least so long as white-tailed deer inhabit the areas.

Mule Deer
(<u>Odocoileus hemionus</u>)

The range of mule deer formerly extended east into Ontario, but is now much more restricted. Mule deer are widespread in British Columbia and in Alberta but in Saskatchewan they are largely restricted to the southwest. Small numbers, however, occur in the sand hills of western Saskatchewan, in Prince Albert Park (around Waskesiu townsite), in a coal mining area of the south, and perhaps in Duck Mountain Provincial Park (Fig. 4). There are also reports of remnant mule deer populations in Manitoba in Duck Mountain Provincial Park and in Riding Mountain National Park.

A mule deer fawn experimentally infected by Anderson <u>et al</u>. (1966) showed severe neurological signs that terminated in general paralysis. There are, however, no known cases of neurologic disease in wild mule deer.

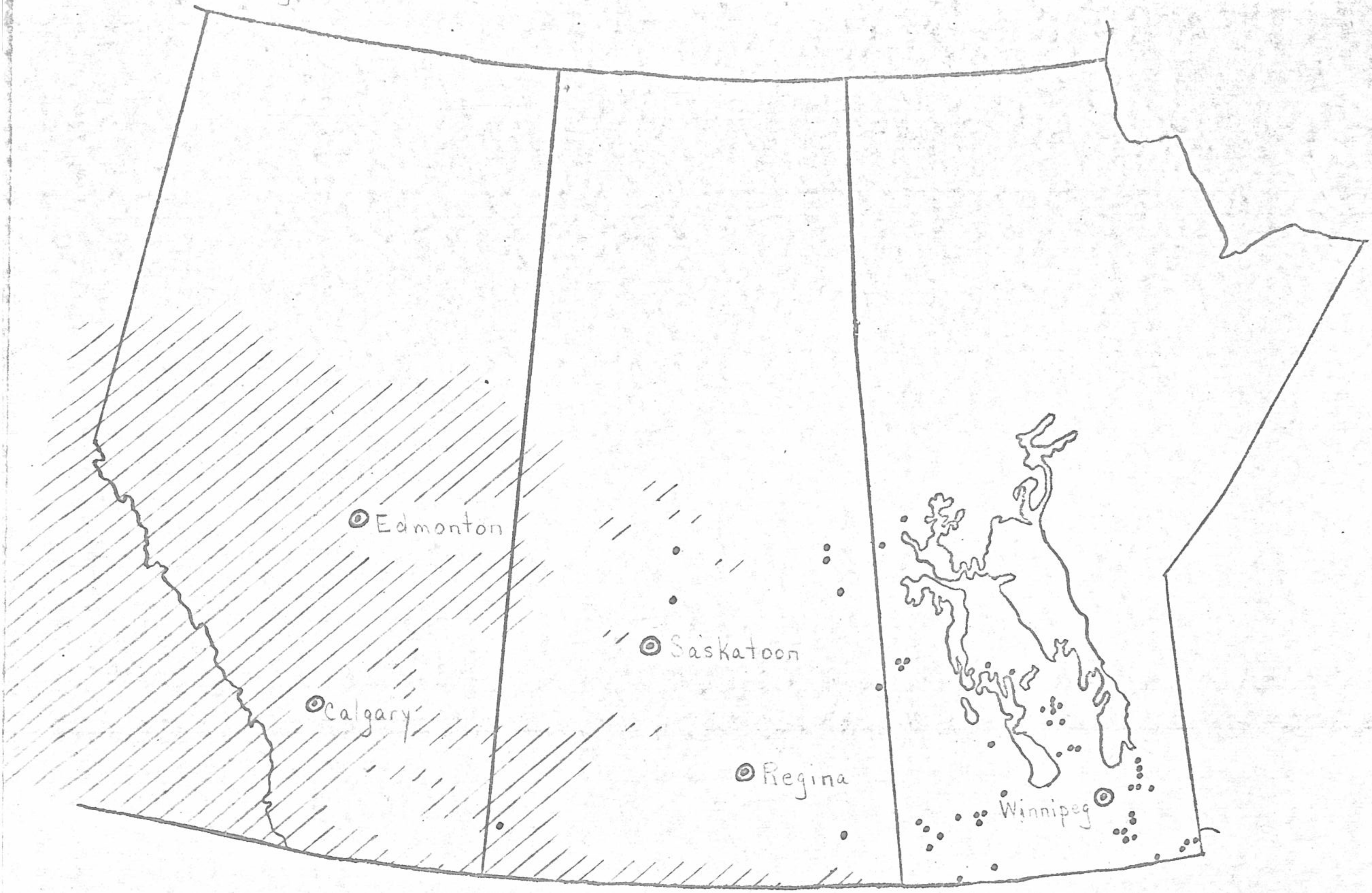
The decline in mule deer numbers in Manitoba and Saskatchewan is usually attributed to its failure to compete successfully for food with the white-tailed deer. Runge (personal communication) has suggested that the white-tailed deer is able to take advantage of alfalfa and grain crops better than mule deer, and that this high plane of nutrition contributes to a high reproductive rate and good body condition. These factors may lead to more successful competition with mule deer in winter range where both species come together for browse.

In Alberta mule deer and white-tailed deer occur together in many areas and white-tailed deer occur in the absence of mule deer in relatively few areas (e.g. Elk Island National Park, parts of Crowsnest Pass).

In southeastern British Columbia white-tailed deer and mule deer are separated altitudinally for much of the year but come together in winter and spring in the valley bottoms.

Although <u>P. tenuis</u> may have been a factor in the decline of mule deer in Manitoba and Saskatchewan there is no evidence to support this, whereas habitat destruction and competition for food with white-tailed deer appear to have been important. The recovery of larvae indistinguishable from those of <u>P. tenuis</u> reported in this study indicates that <u>P. tenuis</u> may be available to mule deer in southern Saskatchewan.

Fig. H. Distribution of mule deer in Western Canada



Shaded area represents approximate range of mule deer

Solid dots indicate locations where larvae indistinguishable from those of P. tenuis were recovered from white-tailed deer faecal pellets

Other Susceptible Hosts

Pronghorn (*Antelocapra americana*)

The pronghorn (antelope) occurs in Canada on the prairies of southweatern Saskatchewan and southeastern Alberta.

Karns(personal communication) reported a case where a pronghorn died while in a pen with a white-tailed deer. Adult *P. tenuis* was apparently found in its subdural space at necropsy. This report suggests that *P. tenuis* infection is fatal to Pronghorn.

The findings of the present study suggest that *P. tenuis* is present but rare in the area of Saskatchewan occupied by pronghorns. It appears that white-tailed deer and pronghorn are normallly widely separated ecologically but that transmission of the parasite to pronghorms could occur on common, snail-populated range.

Bighorn Sheep (*Ovis canadensis*) and Mountain Goat (*Oreamnos americanus*)

Although the susceptibility of bighorn sheep to infection with *P. tenuis* is untested, domestic sheep (*Ovis* sp.) may apparently succumb to neurologic disease when exposed to *P. tenuis* (Kennedy *et al.*, 1952; Whitlock, 1952; Nielson and Aftosmis, 1964). Anderson and Strelive (1966) experimentally infected six domestic lambs with *P. tenuis* and three of these developed obvious clinical signs. The authors concluded, however, that sheep evidently have a good natural resistance to infection with *P. tenuis*.

The susceptibility of mountain goat to infection with *P. tenuis* is similarly untested. Anderson and Strelive (1969) found that domestic kids experimentally infected with *P. tenuis* became moribund or dead within 4 to 11 days. These early deaths were caused by colitis and peritonitis which was presumeably associated with the penetration of *P. tenuis* larvae. Two kids that survived these inflammations, developed severe neurologic signs and appeared much less resistant than sheep.

If the evidence of Karns (personal communication) regarding the susceptibility of a pronghorn and Anderson and Strelive (1966) can be extrapolated to suggest possible effects of *P. tenuis* infection on mountain goats, it would appear that this host may be quite susceptible to infection with *P. tenuis*.

Bighorn sheep and mountain goat appear to be well separated ecologically from white-tailed deer. It also appears that white-tailed deer in the Rocky Mountains may have originated in British Columbia and be discontinuous with those of the foothills and prairies to the east (Banfield, 1958; Webb, 1967). On the other hand there are areas in southern Alberta where populations of prairie white-tailed deer appear to penetrate the mountains along major river valleys. The ability of the white-tailed deer to populate new habitats is legend. The descent of both bighorn sheep and mountain goats to low elevation salt licks, and, in the case of the former, grazing, could serve to bring these species together and conceivably facilitate parasite transmission. Should the prescence of *P. tenuis* in white-tailed deer of southern Alberta be established at some future date, the possibility of exposure to bighorn sheep and mountain goats should be considered.

III The Use of the Baermann Technique in Monitoring Future Changes in the Distribution and Prevalence of *Parelaphostrongylus tenuis* in White-tailed Deer

The present western limit of the distribution of P. tenuis in Canada approximates a line extending southeast from Prince Albert National Park and Duck Lake to a point east of Regina and then extending west to within about ten miles of the Alberta border before descending south to the Montana border (Fig. 1).

Occasional monitoring for larvae indistinguishable from those of P. tenuis west of this line is advisable so that future spread of the parasite can be detected and assessed. Monitoring in areas where the parasite presently occurs in low frequency (e.g. Moose Mountain Provincial Park, Prince Albert and Riding Mountain National Parks) would be useful to indicate whether the parasite is becoming more prevalent in deer populations where its present prevalence is very low. This latter form of monitoring appears to be particularly important in light of recent work suggesting that the incidence of parelaphostrongylosis may be almost directly related to the prevalence of the parasite in white-tailed deer (Saunders, 1973).

The most effective method of monitoring such changes is with the Baermann technique. This technique has been used in almost all Parelaphostrongylus tenuis investigations. It has been used perhaps most extensively in the study of Bindernagel and Anderson (1972) wherein over 1400 white-tailed deer faecal pellet groups were examined. During this study simple modifications were adapted to increase the efficiency and/or the speed of processing samples. This information is contained in the following manuscript.

The Use of the Baermann technique in Investigations of *Parelaphostrongylus tenuis*

Abstract

The Baermann technique provides a highly sensitive yet easily applied method for detecting *Parelaphostrongylus* sp. infections in white-tailed deer. The technique, which is based on the recovery of characteristic larvae from faecal pellet groups of infected deer, is more efficient and less laborious than the examination of heads for adult *P. tenuis*.

Introduction

White-tailed deer infected with meningeal worm (*Parelaphostrongylus tenuis*) pass characteristis first-stage larvae in their faeces. The larvae leave the faecal pellets when submerged in water or probably when the pellets are rained upon (Lankester and Anderson, 1968). The Baermann technique, a standard method in parasitology, is used to recover larvae from faecal pellets of infected animals. It is an excellent method for determining the occurrence and prevalence of meningeal worm in a white-tailed deer population. The technique requires only a few readily available components, is simple to use, and is adaptable to field use. Anderson (1963) has shown that it is a more sensitive method than the examination of heads for detecting meningeal worm infections.

Materials and Methods

The components of the Baermann apparatus consist of a glass or polyethelene funnel of an appropriate size (a six-inch diameter funnel is most suitable for a deer pellet group), a "basket" to support the pellet group (made from half-inch hardware cloth or large-mesh screen), and six-inch diameter disc of tissue "Kimwipes" in the bottom of the basket, a short length of rubber tubing attached to the funnel stem, and a shell vial or similar vial inserted into the tubing (Fig. 5).

The funnel is filled with warm tap water to a level that will cover the faecal pellets which are subsequently placed on the paper disc in the basket. After the pellets have been in the Baermann apparatus for at least five hours (or preferably overnight if frozen) the rubber tube is clamped shut and the vial removed. After drawing off the upper two-thirds of the water the flat-bottomed shell vial can be examined directly under a dissecting microscope for larvae using transmitted light. If a round-bottomed vial is used or if the contents of the vial are too murky for direct examination, the contents of the vial may be transferred to a syracuse dish (and diluted if necessary) for microscopic examination. Examination should be carried out at about 200X initially but can be reduced to about 80X after experience in the recognition of Parelaphostrongylus sp. larvae is acquired. Initially all larvae recovered should be mounted on a glass slide and examined with a compound microscope (at about 400X) for the presence of the characteristic spine near the tip of the tail (see Anderson, 1963, for drawings or Karns, 1966, for photograph of first-stage P. tenuis larva).

The recovery of characteristic "spine-tailed" larvae from white-tailed deer faeces indicates an animal infected with Parelaphostrongylus sp. or Leptostrongylus sp. Since at least three other species of deer lungworms are now known to have spine-tailed larvae indistinguishable from those of P. tenuis, a sample of heads must be examined and adult nematodes recovered for proper identification.

Discussion

The Baermann technique depends on the movements of live larvae to free themselves from the faecal matter, pass through the layer of porous tissue paper and descend by gravity through the water coming to rest on the floor of the vial attached to the funnel stem. Since meningeal worm larvae occur in the layer of mucus covering the deer pellets they readily leave the pellet and enter the water. In fact Lankester and Anderson (1968) showed that over 80 per cent of the larvae migrate from fresh pellets into warm water within five minutes of being submerged.

Lankester and Anderson (1968) also showed that 70 per cent of P. tenuis larvae survived freezing at -20°C for up to six months. This permits the storage of pellet groups in a freezer until such time as they can be examined. The collection and examination of pellet groups in the winter months give the most satisfactory results. The pellets become frozen soon after defaecation so that larvae cannot leave the pellets. Deer in most areas of Canada and northern U.S.A. tend to concentrate, often in traditional yards, in late winter facilitating the sampling of a large number of deer in a relatively small area.

By collecting pellet groups after snowfall, two problems in dealing with spring, summer and fall pellets are avoided. One is the inevitable migration of larvae from the pellets when rained upon, and the other is the migration of soil nematodes into the pellets from the soil and leaf litter. Although these free-living soil nematodes can be differentiated from P. tenuis larvae fairly readily by a trained eye, they nevertheless reduce the efficiency of examination of larvae recovered by the Baermann apparatus.

Three lungworms of deer having larvae indistinguishable from those of meningeal worm are Leptostrongylus alpenae known from white-tailed deer in New York (Cheatum, 1948) and Georgia (Anderson, personal communication), Parelaphostrongylus odocoilei from the California black-tailed deer and mule deer (Brunetti, 1969), and P. andersoni from white-tailed deer in southeastern U.S.A. (Prestwood, 1972). To confirm that spine-tailed larvae recovered from white-tailed deer pellets are those of meningeal worm, a number of heads should be examined for adult P. tenuis in the subdural space. The adults of L. alpenae occur in the lungs, and those of P. odocoilei and P. andersoni occur in the musculature.

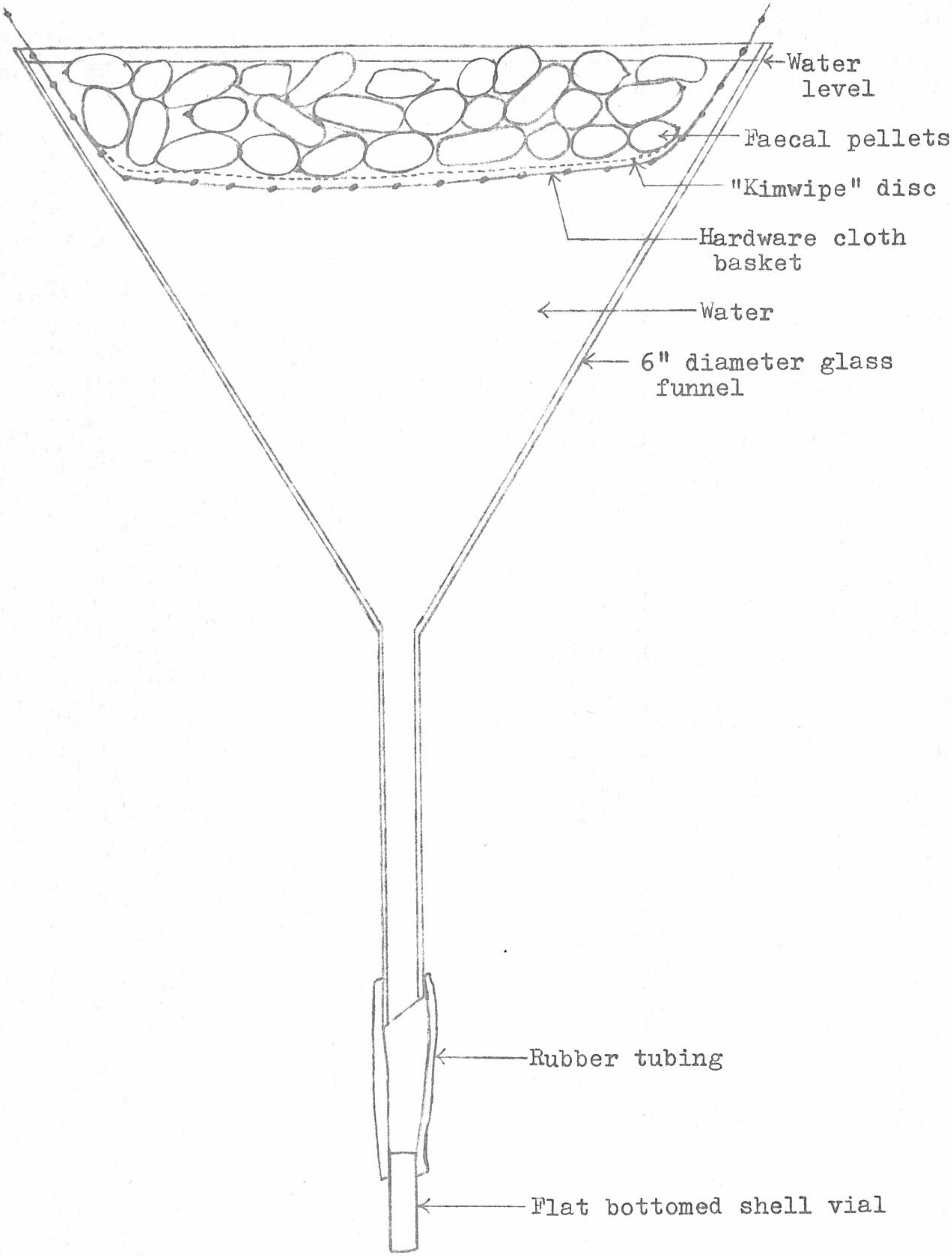
In a survey of meningeal worm distribution or prevalence, the examination of faecal pellet groups with the Baermann technique is less laborious, less time consuming and more efficient than the examination of heads for adult nematodes. Anderson (1963) could find adult nematodes in only 12 of 17 deer from which larvae had been recovered by the Baermann technique. This discrepancy arises from the occasional occurrence of adult nematodes between the meninges of the spinal cord or in the intercavernous sinus where they are not readily apparent.

Fyvie (personal communication) found adult P. tenuis in the subdural space of one of six deer heads examined, whereas larvae were recovered from three of the six faecal samples from the same deer. Bindernagel and Anderson (1972) found adult nematodes in only 10 per cent of 57 deer heads examined in southwestern

Manitoba but recovered larvae from 31 per cent of faecal pellet groups from the same area. In Quebec they recovered larvae from 63 per cent of 155 pellet groups but found adults in only 30 per cent of 20 heads. They found no adults in 54 deer heads from eastern Saskatchewan where larvae were recovered from 12 per cent of the faecal pellets examined with the Baermann technique.

The Baermann technique is particularly valuable in areas closed to hunting where deer heads are not available for examination.

Fig. 5. The Baermann Apparatus



IV Recommendations

There were apparently no attempts to detect the existence of *P. tenuis* in western Manitoba and eastern Saskatchewan prior to 1972. It is, therefore, impossible to state whether the parasite is extending its range or whether it has, in fact, existed in these areas for a number of years. The work of Bindernagel and Anderson (1972) established the existence of *P. tenuis* in these areas and the results of this study showed, with one remarkable exception, that the parasite does not exist further west. These results constitute a basis on which any future evidence of *P. tenuis* can be assessed as westward movement or as merely an additional occurrence within its present range.

To determine whether *P. tenuis* is spreading westward, periodic monitoring is advisable. Such monitoring should take the form of examination of about a hundred white-tailed deer faecal pellet groups from the western end of each of the three main zones of high deer density in Saskatchewan (Fig. 1), every three to five years.

Similarly it is advisable to monitor the prevalence of *P. tenuis* in eastern Saskatchewan and in Prince Albert National Park for possible increase. The examination of 25 - 50 white-tailed deer faecal pellet groups from Prince Albert Park, the Carrot River-Hudson Bay area, and Moose Mountain Provincial Park every three to five years would indicate if the prevalence of larvae is increasing.

If the results of monitoring indicate that *P. tenuis* is apparently extending its range westward, further consideration must be brought to bear on its eventual spread to the Rocky Mountain foothills.

At present there is a relatively wide gap between the western edge of prairie white-tailed deer range in central Alberta north of Calgary and the small isolated populations of white tails in Jasper and Banff National Parks. Perhaps this gap could be maintained by liberal hunting seasons and bag limits in the area.

South of Calgary, however, such a gap, if it exists at all, is narrower and intermittent. There is a substantial population of white-tailed deer in the eastern end of the Crowsnest Pass and white-tailed deer occur in continuity across the southern Alberta prairies into the eastern end of Waterton Lakes National Park. It should be noted that this park, unlike Banff and Jasper, extends out of the mountains and foothills to include parkland and prairie white-tailed deer. White-tailed deer and mule deer coexist in the eastern end of the park but the former apparently rarely penetrate the mountains. (A single white-tailed deer observed near Cameron Lake high in the mountains is considered to have originated in British Columbia.)

If it appears, at some future date, that P. tenuis is in fact spreading westward in white-tails, a detailed study of the distribution, origin and movements of white-tailed deer in western Alberta would be very useful. Such a study could reveal any gaps between the western limit of prairie white-tailed deer and populations of mountain white-tails which could be maintained or even widened through hunting and/or deer reduction programmes.

The possibility of prairie white-tailed deer extending their range into the mountains and into the range of bighorn sheep and mountain goats, although an open question, should not be discounted. What is perhaps more important is the possibility of prairie white-tails mixing with the mountain populations of white-tails. Observations made in Jasper National Park in October evenings confirmed that elk, mule deer, and mountain sheep all utilize roadside grass verges in which wardens have reported local white-tailed deer. Since the white-tailed deer resident in the mountain National Parks may have originated in British Columbia and may winter there even now (Banfield, 1958), these animals could carry parasites acquired from mountain-penetrating prairie white-tails to the western slopes of the Rockies and to white-tailed deer populations of the Columbia valley.

Although the foregoing projection may appear speculative it nevertheless suggests a possible pathway that a parasite such as P. tenuis can and may take in years to come. By considering the possibility now, when P. tenuis is apparently only on the doorstep of Alberta, possible future spread can be anticipated and plans to arrest it considered.

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