BLACK FLIES (DIPTERA, SIMULIIDAE) AS POSSIBLE VECTORS OF LEGWORM (*ONCHOCERCA CERVIPEDIS*) IN MOOSE OF CENTRAL ALBERTA

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Abstract: A filarioid nematode of moose (*Alces alces*) known as "legworm" and its possible vector, the black fly (Simuliidae), were studied in Swan Hills, Alberta from 1975 to 1977. Legworms recovered from the subcutaneous connective tissue of moose were identified as *Onchocerca cervipedis* Wehr and Dikmans, 1935. Sixty-four percent of the moose examined were infected with adult legworm. Most adult worms (80%) were in the forelimbs. There was a linear increase in number of adult legworms with increasing age of moose. *Onchocerca cervipedis* microfilariae were present in the skin of the fore and hind limbs of moose during June and July only.

Fifteen species of black fly were collected from live-trapped and a tame, penned moose. Individuals of *Simulium decorum, S. venustum, S. vittatum, S. arcticum, S. aureum,* and *Prosimulium formosum* took blood meals. Microfilariae of *O. cervipedis* were found only in blood meals of *S. decorum* and *S. venustum*, incriminating these species as possible vectors of moose legworm.

The filarioid nematode *Onchocerca cervipedis* Wehr and Dikmans, 1935 (Nematoda, Onchocercidae), a parasite of North American cervids, was studied in moose (*Alces alces*) from Swan Hills, Alberta during 1975-1977. Black flies feeding on moose were studied as well. The objective of the study was to provide a better understanding of this host-vector-parasite system. Specific goals were to: 1) confirm the identification of *O. cervipedis* in moose of Alberta; 2) determine the prevalence of legworm in relation to host age; 3) determine temporal and spatial distribution of microfilariae of legworm in moose; 4) determine the identity of adult black flies blood-feeding on moose in Swan Hills; and 5) identify possible black fly vector(s) of *O. cervipedis*.

Many species of hematophagous flies were collected from moose during the study, but due to limitations on time and since a black fly, *Prosimulium impostor*, is a vector of *O. cervipedis* in Columbian black-tailed deer (*Odocoileus hemionus columbianus*) (Weinmann *et al.* 1973), only black flies were examined in detail.

THE STUDY AREA

The study site was located on the eastern fringe of the Swan Hills, in Central Alberta (Figure 1). The area is a transition zone between the Transcontinental Boreal Forest and the Rocky Mountain Subalpine Forest (Cordilleran). The flora is comprised of characteristic species from both biomes, with species such as lodgepole pine (*Pinus contorta*), Englemann spruce (*Picea engelmanni*),

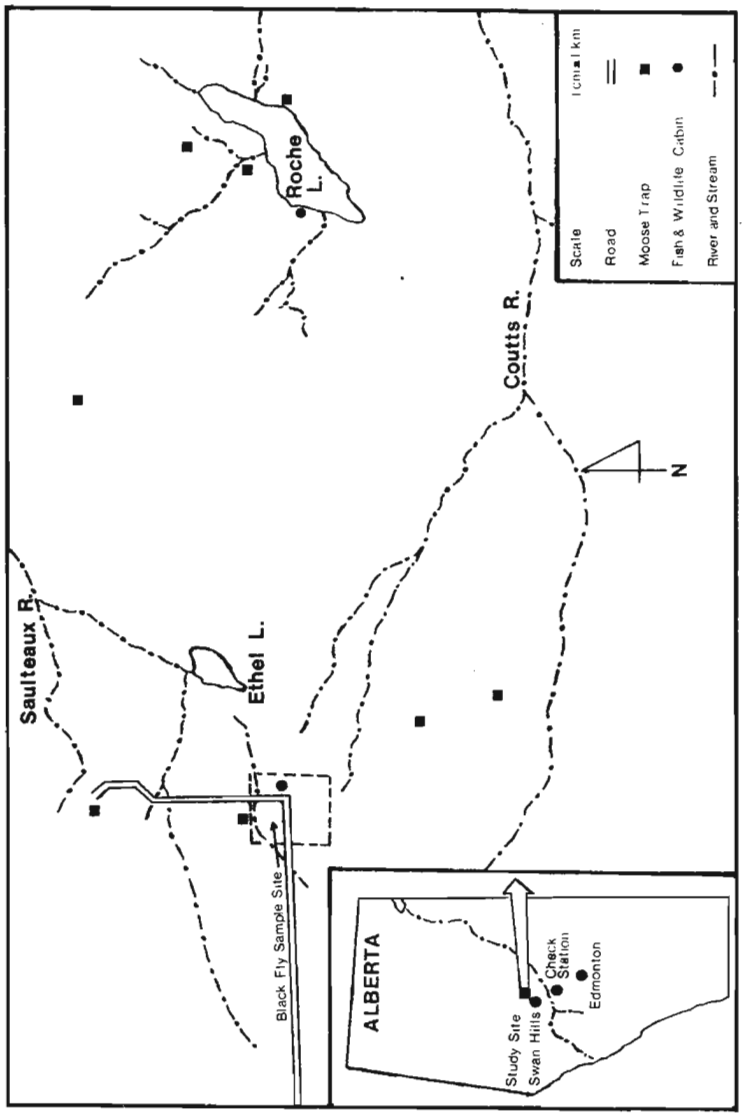

Figure 1. Location of Swan Hills study area.

and subalpine fir (*Abies lasiocarpa*), of the Cordilleran region and white spruce (*Picea glauca*), black spruce (*Picea mariana*), and jack pine (*Pinus banksiana*) of the Boreal Forest (Anonymous, 1976).

The climate is continental and characterized by cold winters and short, cool summers. The average January temperature is -15°C and the average July temperature is 15.6°C. The average May-September precipitation is 51 cm (Langley 1967).

METHODS

Collection of Adult Legworms

In autumn 1975 a roadside check station (Figure 1) was established on the main highway into the study area in co-operation with Alberta Fish and Wildlife Division. Hunters were asked to submit all four legs cut just below the tibio-tarsal joint, and the head and hide of moose to the check station. Parts of 43 moose were submitted by hunters; rarely were submissions complete (n=1). All (n=36) or some of the legs (n=6), lower jaw (n=17), head (n=12) and hide (n=1) were submitted. Skins of two moose were provided by the Alberta Fish and Wildlife Division.

The tendons of the legs were cut and removed from the tarsal bones to expose underlying connective tissue. These freshly-skinned areas were examined for adult *O. cervipedis*. Worm location was mapped and sex and condition of worm noted. Worms were removed from the connective tissue using needle-point forceps, dissecting needle and scalpel, and stored in 70% ethanol.

Collection of Microfilariae

Sixteen live-trapped moose (see trap sites on Figure 1) and 21 moose killed in the Swan Hills within 24 hours before examination were sampled for microfilariae of legworm. Moose killed were sampled from September 12 to October 12, 1975, while moose trapped live were sampled from June 15 to August 18, 1976.

Trapped moose were immobilized and skin biopsies taken from up to nine standard locations on the moose (Figure 2). No attempt was made to consistently sample one particular side of the moose.

On July 2, 1977 a two-year-old female moose (No. 122) was killed and sampled extensively for microfilariae. Skin sections were taken from 135 sites using a biopsy punch (Figure 3).

The overlying hair was first removed during biopsy then a 0.4 cm diameter core of dermal tissue was removed using a biopsy punch. Two adjacent cores constituted a sample. Skin biopsies were placed in Earle's Solution and stored in vials for 24 hours. The contents of the vials were examined with a microscope (100X) and the microfilariae counted.

Identification of Parasite

Onchocerca cervipedis specimens collected from nine wild moose were used for identification. Seven males, 10 females and 16 microfilariae were fixed in 70% ethanol, cleared in beechwood

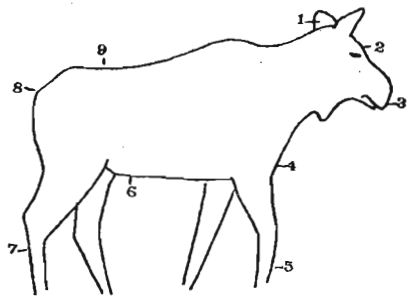

Figure 2. Biopsy sites for collection of microfilariae.

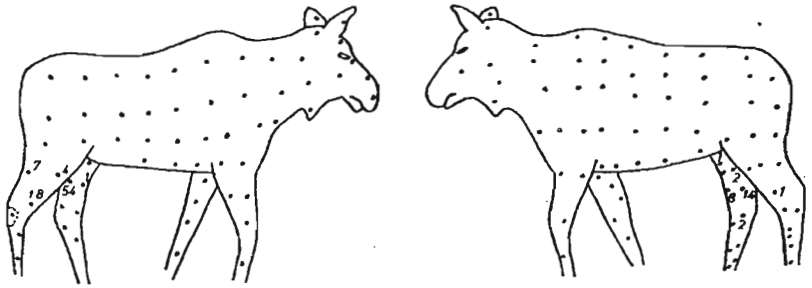

Figure 3. Sites of biopsies for collection of microfilariae from Moose 122 with location and numbers of microfilariae recovered.

creosote and lactophenol (1:1) and examined using a compound microscope. Measurements of all characters were made with a calibrated ocular graticule, except for the total length of female specimens which was determined using a metric ruler. Specimens were identified following descriptions of Wehr and Dikmans (1935), Annereaux (1941) and Caballero (1945) for adult *O. cervipedis* and that of Hibler (1965) for microfilariae.

Black Fly Adults Attracted To and Blood-Feeding on Moose

Black flies attracted to and blood-feeding on moose were collected from immobilized wild moose (n=13) and a penned moose used as bait. Moose were swept for black flies using an insect net. Individual engorging flies were picked from immobilized moose with forceps and a paint brush moistened in alcohol and stored in 70% ethanol.

An orphaned, hand-reared, female, moose calf (No. 3) (approximately six weeks old) was taken to the study site on May 16, 1976. This moose was used to facilitate regular sampling of black flies attracted to and feeding on it during 1976 and 1977. Black flies were collected from it using a sweep net and a fly trap baited with the moose. A sweep net sample consisted of 20 sweeps over and around the length of the standing moose. A regular sampling schedule was maintained on alternate days at 0900, 1700 and 2000 hr. from May to August in 1976. In 1977, samples were taken every third day at 0900, 1700, and 2000 hr.

The moose-baited fly trap was a rectangular enclosure constructed of plywood and insect screening (Hudson 1977). A one-way fly entrance ran the length of the trap on either side. The trap was cleared of flies immediately prior to introducing the moose to the trap. A sample consisted of flies trapped in a one-hr period. A regular sampling schedule was maintained on alternate days at 0900, 1700 and 2000 hr. An unpublished taxonomic key by F. J. H. Fredeen (Simuliidae Check List of Species in Manitoba, Saskatchewan and Alberta) was the source for identification of adult black flies, but published works by Stone and Jamnback (1955), Abdelnur (1968) and Peterson (1970) were also used. Selected specimens of each species were submitted to Dr. R. V. Peterson, Research Branch, Biosystematics Research Institute, Agriculture Canada for confirmation or identification.

Determination of Vectors

Many (364) engorged female black flies, collected from wild-trapped and penned moose, were dissected for microfilariae. Black flies were identified and placed in hot 2% potassium hydroxide for 10-15 min. to liquify the blood meal. They were then mounted on a microscope slide, and the abdomen removed. The intact blood meal was removed by applying gentle pressure with forceps to the abdomen behind the meal and moving the forceps arteriorly. A cover slip was placed over the blood meal and squeezed to form a thin-layer blood squash. This was examined for microfilariae under a compound microscope (100X).

RESULTS

Adult Legworm

The 45 moose examined for adult *O. cervipedis* consisted of three complete moose, 42 sets of legs (36 - all 4 legs, 5 - 2 legs, 1 - one leg), 11 heads (18 lower jaws for aging) and one hide.

Adult *O. cervipedis* occurred in 29 (64%) moose. All worms were located in the subcutaneous connective tissue beneath the skin of the legs, except for two located in the brisket and belly area of a heavily infected moose. Eighty percent (475) of the adult worms recovered were in the lower forelegs while 20% (118) were in the lower hind legs. In the leg, 38% (223) of the legworms were in the tibio-tarsal joint area, 56% (334) in the tarsus and 6% (36) in the phalanges.

The moose calf and two yearlings were not infected; most (15) of the 18 adult moose of known age were infected. There was a positive linear relationship between the number of adult legworm per moose and age of moose (correlation coefficient $r=0.75$, $N=21$, $P<0.05$).

Only 13 of 595 adult *O. cervipedis* recovered in this study were males (2.2 males:100 females). Adult legworms were either in an extended or coiled position. Coiled worms were found either loose in the subcutaneous connective tissue or surrounded by fibrous tissue. Legworms were either normal or "calcified" in appearance. Calcification was apparently not influenced by host age (correlation coefficient $r=0.13$ $N=12$, $P>0.05$), or abundance of *O. cervipedis* (correlation coefficient $r=0.01$, $N=12$, $P>0.05$), in the host. Neither was it related to the

coiled or extended state of the parasite ($x^2=3.45$, $p>0.05$). Nodules contained from one to seven legworms; most (71%) had only one female with microfilariae in the uteri. Only one male legworm was recovered from a nodule, with one female also with microfilariae in the uteri.

Microfilariae

Skin samples were taken from 21 moose killed by hunters in September-October 1975 and 16 moose captured live between June 15 and August 18, 1976. Microfilariae were recovered from eight of the live-trapped moose (Table 1), but not from moose killed by hunters even though 8 of these moose had adult legworms and microfilariae survived in moose skin for at least 48 hrs.

The number of microfilariae recovered varied substantially among individual moose and biopsy sites (Table 1). Microfilariae were found only in skin of the hind legs of 5 moose, only in the front legs of 1 moose and in the front and hind legs of 2 moose.

Microfilariae were found only in the skin of the hind legs of the two-year-old moose (No. 122) sampled extensively in July 1977 (Figure 3). Microfilariae were recovered from dermal tissue samples taken from the medial aspect of the upper and lower legs (n=82) and the lateral aspect of the upper hind legs (n=30).

Table 1. Number of microfilariae of *Onchocerca cervipedis* in skin biopsies from moose during 1976.

Date Sampled	Area Sampled: Ear	Brisket	Fore Limb Upper	Fore Limb Lower	Abdomen	Hind Limb	Rump	Antler in Velvet
16-VI-76	0	-	1	-	0	1	-	-
16-VI-76	0	-	0	-	-	1	-	-
23-VI-76	0	-	0	-	-	434	-	-
29-VI-76	0	-	1	-	-	17	-	-
30-VI-76	0	-	0	-	-	39	-	-
15-VII-76	0	0	-	0	0	1	0	-
16-VII-76	-*	0	0	97	0	0	0	-
18-VII-76	0	0	0	0	0	7	0	0
Total	0	0	2	97	0	500	0	0
Median No. Microfilariae	0	0	1	97	0	7	0	0

* = no sample taken

Identification of Parasite

Description of Adult

Adults show characteristics of members of the genus *Onchocerca*. The adult is filiform and tapered at both ends with fine transverse striations on the cuticle, a simple oral opening, long and narrow esophagus and an intestine only slightly wider than the esophagus.

Measurements of diagnostic characters are given for female and male worms (Table 2 and 3). The long spicule of the male has heavily chitinized walls with a diagonal chitinized ridge in the middle. In lateral view, it is tapered distally to a fine curved point. The short spicule also has thick chitinized walls. The anterior extremity is concave with heavy chitinized edges in lateral view. It tapers distally and expands to a spatulate end with rounded edges. Perianal papillae were most readily seen in oblique, lateral-ventral view: two pair of adanal papillae along the ventral midline, four pair of papillae in close grouping lateral to and one pair posterior to the anus, and one large pair of papillae positioned near the tip of the tail.

Description of Microfilariae (Table 4)

Microfilariae, like the adults, are filiform and transversely striated. They are rounded anteriorly and tapered posteriorly. No sheath was apparent.

Table 2. Measurements of some important features of female *Onchocerca cervipedis*.

Character	This study n = 10 host = 1* Means	S.D.	Range	Wehr and Dikmans (1935) n = ? host = 2,3,4*	Annereaux (1941) n = 6 host = 5*	Caballero (1945) n = ? host = 2,3,5,6,7*
Total length (mm.)	187	13.4	164 - 202	180 - 200	140 - 220	158 - 200
Max body width (um.)	399	43.5	315 - 440	416	345	368
Nerve ring to anterior (um.)	579	34.1	525 - 630	327	335	328
Esophagus to anterior (um.)	1658	299.6	1134-2016	1100-1530	1520-1560	1592
Vulva to anterior (um.)	1675	299.9	1092-2121	1250-1530	1129	1028
Cloaca to posterior (um.)	537	138.4	336 - 756	-	-	304

* 1. *Alces alces* 2. *Odocoileus virginianus* 3. *O. hemionus columbianus* 4. *O. hemionus* (probably) 5. "*O. hemionus*" 6. *Cervus canadensis* 7. *Antilocapra americana*

Table 3. Measurements of some important features of male *Onchocerca cervcpedis*.

Character	This study n = 7 host = 1* Means	S.D.	Range	Wehr and Dikmans (1935) n = ? host = 2,3,4*	Annereaux (1941) n = 2 host = 5*	Caballero (1945) n = ? host = 2,3,5,6,7*
Total length (mm.)	57	3.6	52 - 63	55 - 60	40	55.0 - 64.8
Ant. max. width (um.)	224	8.9	213-241	-	224	-
Mid. max. width (um.)	232	5.4	224-234	228	211	240
Nerve ring to anterior (um.)	306	12.8	287-308	320	268	272
Esophagus to anterior (um.)	1463	320.2	934-1595	700	1070	1260
Length long spicule (um.)	226	8.5	217-238	245	226-245	256
Length short spicule (um.)	137	6.5	126-147	112	112-120	132
Anus to posterior (um.)	181	15.6	168-203	145	155-180	180

* 1. *Alces alces* 2. *Odocoileus virginianus* 3. *O. hemionus columbianus* 4. *O. hemionus* (probably) 5. "*O. hemionus*" 6. *Cervus canadensis* 7. *Antilocapra americana*

Table 4. Measurements of some diagnostic characteristics of microfilariae of *Onchocerca cervipedis*.

	This Study n = 16 host = *Alces alces*			Hibler (1965) n = 20 host = *Odocoileus hemionus* *O. virginianus*	
	Mean	S.D.	Range	Mean	Range
Total length (um.)	270.0	30.5	224-322	224	209-238
Max. width (um.)	6.6	0.6	5.8-7.3	6	5- 7

Black Fly Activity on Moose

Response to Biting Flies

Both trapped, wild moose and the penned moose responded to increased activity of flies. Field conditions did not permit isolation of behavioural responses of moose to black flies in particular, so observations here are a summation of all biting fly activity. Prior to losing its natal hair in late July, 1976, the penned moose calf reacted less to the presence of biting flies than did older moose. The long, dense, natal hair covered the entire body surface except the nose and deep recessions of the inner ear where hair was short. The moose calf used ear twitching, head and body shaking, and scratching in an apparent

effort to dislodge flies. On occasion, it raced erratically around the pen for long periods, apparently in response to flies, then would lie down. Most commonly, it would lie under low shrubs or in a lean-to shelter constructed to offer some protection from adverse weather.

Wild, trapped moose and the penned yearling moose moved around constantly during peak activity of biting flies, frequently twitching the ears and rubbing the hind legs together in a quick, jerking motion. Muscle spasms, in the form of quivering along the body core and the legs, were also observed.

Feeding Sites of Black Flies

Observations clearly showed that black flies concentrated their probing and feeding activities in the less dense and short-haired areas on the moose. Most activity occurred on the legs, in particular the inner and outer aspect, from the hoof to about 10 cm above the tibio-tarsal joint. Other preferred sites included the belly, brisket, and anal areas. Few black flies were observed on the head and ears. A hairless callused area on the hind legs just distal to the tibio-tarsal joints, a preferred site for the moose fly *Lyperosiops* sp., [possibly *L. alcis* (Muscidae, Diptera)], was used occasionally by adult black flies.

Black Flies Attracted to Moose

Fifteen species of black flies were attracted to moose (Table 5). In 1976, when adults of 11 black fly species were collected from the

Table 5. Black flies attracted to moose in the Swan Hills

Species	Wild Moose 1976		Penned Moose (No. 3) 1976 (calf)		Penned Moose (No. 3) 1977 (yearling)	
	Sweep Net	Hand Picked	Sweep Net	Fly Trap	Sweep Net	Fly Trap
Simulium arcticum	+	+	+	+	+	+
S. decorum	+	+	+	+	+	+
S. venustum	+	+	+	+	+	+
S. vittatum	+	+	+	+	+	+
S. meridionale	+	-	-	+	-	+
S. furculatum	-	-	-	+	-	-
S. euryadminiculum	-	-	-	+	+	+
S. pugetense	-	-	-	+	-	-
S. aureum	-	-	-	-	+	+
S. latipes	-	-	-	-	-	+
S. croxtoni	-	-	-	-	-	+
S. jenningsi	+	-	-	-	-	-
Prosimulium formosum	-	-	+	+	+	+
P. decemarticulatum	-	-	-	+	+	+
P. exigens	-	-	-	+	-	+

moose-baited fly trap and insect sweep net, *Simulium decorum*, *S. venustum*, *S. arcticum*, *S. vittatum*, and *Prosimulium formosum* were the most abundant (Figure 4). Of these species, adults of *S. decorum* and *S. venustum* were most abundant from late June to August. Both methods showed similar trends in black fly abundance, however, 6 species of black flies were taken in the moose-baited trap and not in the insect sweep net (Table 5). All but *S. meridionale* were taken in low numbers. The disturbance created while "sweep netting" around the moose and the short sampling period may have adversely influenced trapping some of these less abundant black fly species.

In 1977, the numbers of black fly adults attracted to moose were higher (Figures 5, 6 and 7) than in 1976 (Figure 4). The summer of 1976 was unusually wet and was followed by a mild winter with above normal snowfall.

In 1977, when the penned moose was a yearling, 13 species of black fly were collected; the most abundant were: *S. decorum*, *S. venustum*, *S. arcticum*, *S. vittatum*, *S. aureum*, and *P. formosum* (Figures 5, 6 and 7). Of these, *S. decorum*, *S. venustum*, *S. arcticum* and *S. vittatum* were abundant in June and July.

Adults of six black fly species were collected from immobilized, wild moose in 1976 (Table 5). The same black fly species were collected from the penned moose in 1976, with the exception of

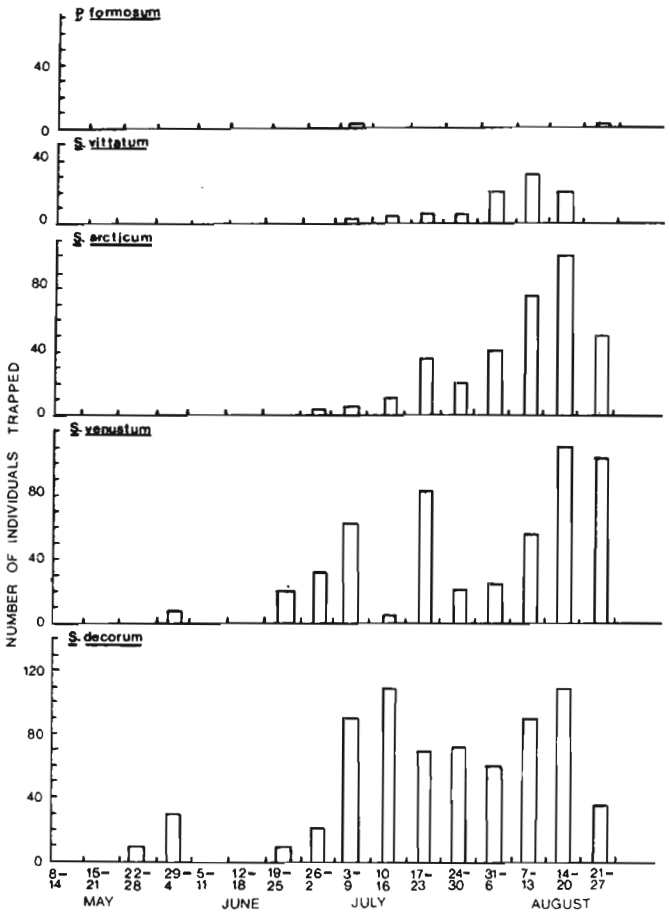

Figure 4. Number of several species of black flies caught near (in moose-baited fly trap and sweep net) moose, 1976.

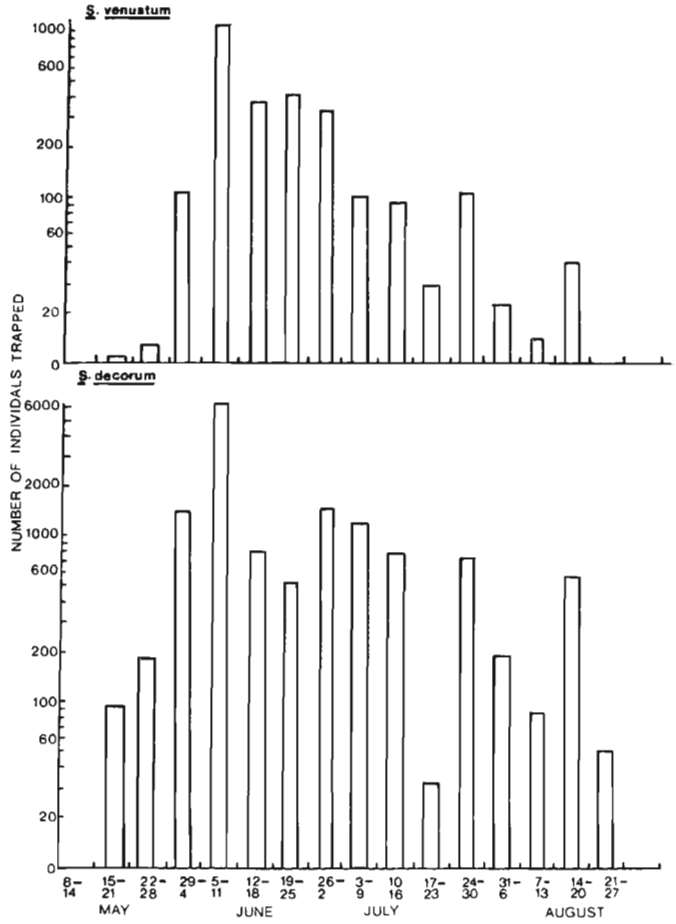

Figure 5. Number of *S. venustum* and *S. decorum* caught near (in moose-baited fly trap and sweep net) moose, 1977.

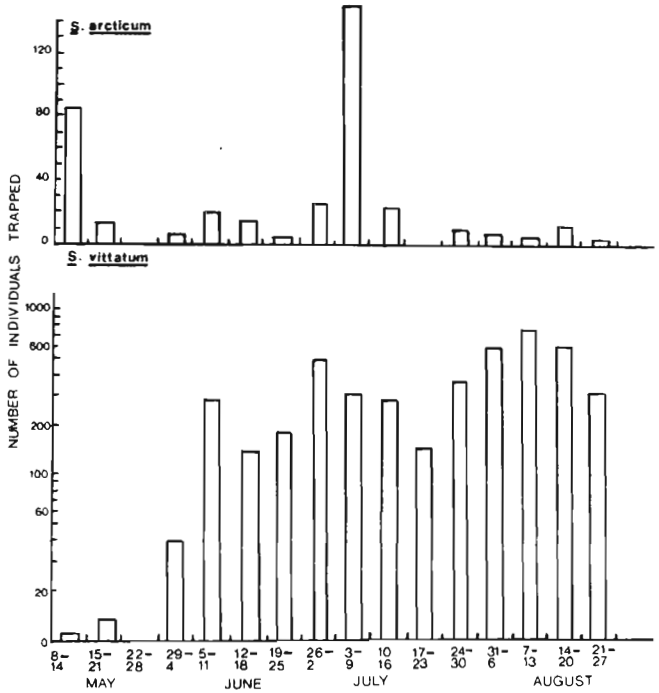

Figure 6. Number of *S. arcticum* and *S. vittatum* caught near (in moose-baited fly trap and sweep net) moose, 1977.

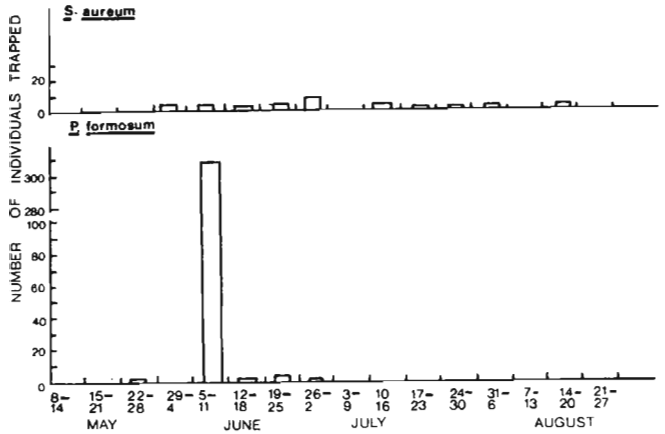

Figure 7. Number of *S. aureum* and *P. formosum* caught near (in moose-baited fly trap and sweep net) moose, 1977.

Simulium jenningsi which was collected in the sweep net on July 16. This is the first known record of *S. jenningsi* in Alberta and identification is based on one female.

Of the 15 species of black flies attracted to moose, only *S. arcticum*, *S. aureum*, *S. decorum*, *S. venustum*, *S. vittatum*, and *Prosimulium formosum* fed on moose. *Simulium arcticum*, *S. decorum*, and *S. venustum* fed on the penned moose in both 1976 and 1977, while *S. vittatum* and *P. formosum*, though collected both seasons from the penned moose (Table 5), only fed on the yearling moose in 1977 (Table 6). *Simulium aureum* was collected from moose only in 1977.

Table 6. Black flies engorging on a penned moose, 1976 and 1977.

Species	Number Trapped	Number Engorged	Percent Engorged
1976			
S. arcticum	333	1	0.3
S. decorum	648	3	0.5
S. venustum	355	20	5.6
S. vittatum	59	0	0.0
1977			
S. arcticum	5,628	39	0.7
S. aureum	327	3	0.9
S. decorum	14,879	127	0.9
S. venustum	3,434	211	6.1
S. vittatum	533	36	6.7
P. formosum	28	15	53.6

Determination of Vectors

Of the six species of black flies that fed on the penned moose, only *S. venustum* and *S. decorum* contained microfilariae (Table 7). No microfilariae were found in black flies from wild, trapped moose.

Table 7. Presence of *Onchocerca cervipedis* microfilariae in blood meals of black flies from a penned moose.

Engorged	No. Examined	No. with Microfilaria	% with Microfilaria
S. venustum	169	5	3
S. decorum	101	2	2
S. arcticum	31	0	0
S. vittatum	22	0	0
S. aureum	2	0	0
P. formosum	4	0	0

DISCUSSION

Barnett (1960) outlined four basic criteria incriminating an arthropod with transmission of the causal agents of disease. Briefly, there must be: 1) effective contact with the host under natural conditions, 2) a temporal and spatial association of suspected arthropod species and occurrence of infection in a host; 3) repeated

demonstration that the specific arthropod harbours the infectious agent in the infective stage under natural conditions, and 4) demonstrated transmission of the infectious agent to the definitive host under controlled conditions. The last two criteria need further study before a definitive statement can be made regarding transmission of legworm in moose. In this study, six species of black fly fed on moose and two, *Simulium decorum* and *Simulium venustum*, ingested larvae thus best satisfying the above criteria. All may be suitable vectors provided they bite the lower legs, and the microfilariae are ingested and complete development in them.

Simulium decorum was the most abundant species of black fly attracted to the penned moose. It and *S. venustum* have a wide geographic distribution (Fredeen 1973) (as does *O. cervipedis*) and both feed on large mammals (Fredeen 1958; Davies et al. 1962; Abdelnur 1968). Both species were abundant in mid-June and July when microfilariae were recovered from moose. Other flies that fed on moose, *S. vittatum*, *S. arcticum*, *S. aureum* and *Prosimulium formosum*, were either most abundant before or after this period or did less feeding on moose (see Table 6).

Unfortunately, no infective stage of *O. cervipedis* was found. Microfilariae were found only in *S. decorum* and *S. venustum*.

Simulium venustum was the second-most abundant species attracted to the penned moose, being most active in June and July. Adults consistently fed on wild, trapped and penned moose in 1976

and 1977. In 1976, 5.6% and in 1977, 6.1% of the females taken in the moose-baited fly trap were engorged. This percentage was considered reasonable since Davies (1957) indicated 8 to 25% of the *Simulium ornatum* landing on cattle actually fed. On wild moose, feeding activity was concentrated on the inner and outer aspects of the legs, particularly the hind leg. Reduced activity was noted in the belly, brisket, and anal regions. There was no marked tendency to blood-feed on the ear or head region of moose as observed by Smith in Algonquin Park, Ontario (cited in Anderson and Lankester 1974).

Adults of *S. decorum* were the most abundant black fly collected from moose. This multivoltine species is widely distributed in Canada (Fredeen 1973). Adults were attracted to the moose-baited fly trap, with 0.5% and 0.9% engorged in 1976 and 1977, respectively. Feeding activity of *S. decorum* was concentrated on the hind legs of immobilized, wild moose.

Adults of *S. arcticum* were abundant throughout the summer with peaks in mid-July and August, suggestive of two generations. Restricted to western North America, this species is a blood feeder of horses and cattle (Abdelnur 1968), gathering on the sparsely haired portions of the animal to feed (Peterson 1959). Although adults were attracted to and fed on moose, their restricted geographic distribution may reduce their significance as a vector of *O. cervipedis*.

In 1976, blood-fed adults of *S. vittatum* were collected from wild, trapped moose, but not from the penned moose. At that time, the penned moose was a calf and may not have had all the correct stimuli to induce engorgement. It is likely that the long, dense natal hair prevented

the black flies from reaching the skin to obtain a blood meal. In 1977, when the natal hair was gone, 6.7% of the adults taken from the moose-baited fly trap were engorged (Table 5).

Similarly, *P. formosum* was attracted to the penned moose in 1976 but no blood-engorged individuals were collected. In 1977, 54% of those from the moose-baited fly trap were engorged (Table 6), but unlike *S. vittatum*, this species was present in low numbers throughout the summer.

Results of this study regarding prevalence and general location of *O. cervipedis* and host-age and prevalence characteristics are similar to those of Samuel et al. (1976). Prevalence is high, particularly in older moose, and most adult worms occur in the lower front legs. In young moose, the length and density of the natal hair possibly afforded some protection from biting flies. Black flies generally blood-fed on the sparsely haired areas of the host. By late July, when the natal hair of moose calves has been shed, the peak period for transmission of legworm could be over. This plus the probable long pre-patent period may explain the low prevalence of *O. cervipedis* in young moose. Weinmann et al. (1973) suggested that young Columbian black-tailed deer fawns probably missed the peak period of transmission in their first year of life in northern California. The possibility exists that moose calves enter winter infected with immature legworms that remain undetected (see Beaudoin et al. 1970). Seven of the engorged adult black flies (five *S. decorum*, two *S. venustum*) taken from the penned moose (No. 3) in 1977 contained microfilariae in the blood meal indicating that the moose had been exposed to the infective stage larvae

as a calf in 1976. This moose spent from September 1976 to May 1977 in Edmonton, Alberta at a location where few black flies are found and *O. cervipedis* does not occur (W.M.S. unpubl.).

Microfilariae were found in skin of the fore and hind limbs, but were more abundant in hind limbs. Thus microfilariae and adult *O. cervipedis*, like many members of this genus, are spatially separated in the definitive host (Eichler and Nelson 1971, Weinmann 1973, and Schulz-Key 1975). Schulz-Key (1975) reported a complex of subcutaneous filarioids in red deer (*Cervus elaphus*) from Germany. Adults of *Onchocerca flexuosa* inhabited the back and flanks of the host while microfilariae localized in the skin of the inner aspect of the hind limbs; *Onchocerca tarsicola* adults were located in the abductor tendons of the tibio-tarsal or radio-carpal joints while the microfilariae localized in the skin of the outer parts of the ear and nose; and *Onchocerca tubingensis* adults were found in the caudal part of the back with the microfilariae concentrating around the sternum and the inner aspect of the hind legs.

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