THE MERMITHID (NEMATODA) AND OTHER ENDOPARASITES OF SIMULIDAE (DIPTERA) IN INSULAR NEWFOUNDLAND

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THE MERMITHID (NEMATODA) AND OTHER ENDOPARASITES OF SIMULIIDAE (DIPTERA) IN INSULAR NEWFOUNDLAND

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ABSTRACT

In 1971 and 1972, 198 streams in insular Newfoundland were examined for blackfly endoparasites. Forty streams yielded one or more species of the microsporida-- *Thelohania bracteata, T., fibrata, Plistophora simulii, Caudospora simulii* and *C. brevicauda*. The fungus *Coelomycidium simulii* was found in 14 streams. The blackfly mermithids *Gastromermis viridis, Isomermis wisconsinensis* and *Neomesomermis flumenalis* were recovered from 59 streams. Central Newfoundland had higher frequencies of mermithid infections (47.3-75.0%) than the more coastal areas (11.7-36.3%). The longitudinal distribution of mermithid infected blackflies within the stream showed that the upper 400 m. of the stream were devoid of mermithids, while the lower reaches of the stream harboured mermithids. Current, depth and chemical parameters of the stream water in streams with and without mermithids were examined. Mermithid parasitism did not appear to be significantly affected by these factors. *Neomesomermis flumenalis* was redescribed in light of the finding of eggs and pre-parasites. Adult males of *G. viridis* and *I. wisconsinensis* were also redescribed. The life cycle of *N. flumenalis* was described. Following emergence from the host, male and female post-parasites molt to adults in 9-15 days at 12°C., 10-13 days at 18°C., 37-40 days at 6°C., and failed to molt at 22-24°C. A double pre-adult molt and a parasitic molt were noted. Mating lasted for 12-24 hours, and usually occurred within a few hours of molting to adults. Eggs were laid 36-59 days after mating. Females laid 600-650 eggs over 3 days. The incubation period was 35-55 days at 12°C.; heaviest egg hatching occurred 4-11 days after the onset of hatching. No eggs were laid at 3°, 7°, 18°, or 22-24°C.

Pre-parasites live 2-3 days. The period from emergence from the host to egg laying was 45-74 days, and from emergence to egg hatching, 80-129 days. Mixed infections involving microsporida, mermithids and coelomycidians were noted. Seasonal fluctuations of host/parasite populations in Half Moon Brook and Long Pond Tributary were studied. *Neomesomermis flumenalis* infected the *Prosimuliums* in October and the early summer *Simuliums* in late May-early June. Carryover of mermithids to adult simuliids, based on extrapolated data from late larval and pupal infections, indicated that *N. flumenalis* probably carried over to the *Prosimuliums* and *Simuliums* at a rate of .026 and .062% respectively. *Gastromermis viridis* and *I. wisconsinensis* probably infect 1.3-26.8% of their adult simuliid hosts. Host specificity appeared to be related to the asynchronous life cycles of the host/parasite populations. Sex ratios of 1.4:1 males to females were noted for the mermithids from the *Prosimuliums* in Half Moon Brook. Female to male mermithid ratios of 1.33:1 and 9.2:1 for the *Prosimuliums* and *Simuliums* in Long Pond Tributary and 2.7:1 for the *Simuliums* in Half Moon Brook were also noted in 1972.

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INTRODUCTION

The Simuliidae are a cosmopolitan group of hematophagous Diptera which, as adults, are notorious pests of warm-blooded animals and vectors of a variety of pathogenic organisms. In Canada, the prolific simuliid populations of the northern part of the country place severe limitations on its development by man and hence constitute a factor of considerable economic importance for the future (Gordon *et al.*, 1973). Although not known to be vectors of human pathogens in Canada, the role of some simuliids, particularly the ornithophilic species, as vectors of pathogenic *Leucocytozoon* sp. to game birds (Fallis and Bennett, 1958; Bennett and Fallis, 1960; Bennett and MacInnes, 1972), may hinder development of waterfowl and game bird management programs. Excessive blood feeding by dense populations of *Simulium arcticum* influences cattle raising in parts of Alberta and Saskatchewan (Cameron, 1922; Millar and Rempel, 1944; Rempel and Arnason, 1947; Fredeen, 1958, 1969) and is a well documented case of financial loss to the Canadian livestock industry.

In other parts of the world, simuliids are more directly involved with man as vectors of serious pathogens. In certain regions of Africa, Central and South America, several simuliid species are responsible for the spread of *Onchocerca volvulus*, a filarial nematode which causes a debilitating human disease, Onchocerciasis (Lewis, 1953; Dalmat, 1955; Duke, 1971), frequently leading to blindness.

From an economic and medical viewpoint blackflies require stringent control measures. Blackfly control has been achieved in some localities (Garnham and McMahon, 1954), notably with the use of DDT.

Many new insecticides have been developed to supplant DDT, but all have inherent difficulties in that 1) they pollute the environment; 2) the target blackfly population may develop resistance to the pesticide in use; 3) they may eliminate non-target organisms, including would-be predators, which help naturally to control blackfly populations.

With such potential problems, alternate control measures should be investigated and perhaps one of the most promising methods is through the use of biological control. Biological control may be defined as the reduction in numbers of a pest species by means of another organism (that has been in some way managed or interfered with by man) to a level at which the pest species ceases to be an economic, medical or veterinary problem (Askew, 1971).

Biological control, using mass reared organisms, has been demonstrated to be an effective method of controlling some pest insect populations. *Bacillus popilliae* Dutky provided the first real encouragement for the use of microbial organisms as biological control agents (White and Dutky, 1940); kills of up to 95% were obtained on Japanese beetle grubs in Maryland for at least nine years post application (Cory and Langford, 1955). Nuclear polyhedrosis viruses (NPVs) have also been used successfully in controlling populations of *Trichoplusia ni* (Hubner), the cabbage looper on *Brassica* crops throughout North America (Getzin, 1962). Poinar (1971) reviewed the field trials involving *Neoaplectana glaseri* and the DD 136 strain of *N. carpocapsae*; it was demonstrated that these nematodes could parasitize a wide variety of pest insects with significant reductions in pest numbers occurring.

Many parasites and predators of blackflies have been reported in the world literature (Jenkins, 1964), but none have been mass reared in the laboratory for use as biological control agents. Several parasitic groups, including fungi and protozoa, have control possibilities, but perhaps the candidate group with the greatest potential is the nematode family Mermithidae (Welch, 1962b, 1964, 1965; Welch and Poinar, 1965; Weiser, 1963; Poinar, 1971; Gordon *et al.*, 1973).

The Mermithidae Braun together with the Tetradonematidae Cobb are aphasmidian nematodes of the Superfamily Mermithoidea Wulker. Mermithids are filiform worms, attaining lengths of up to 50 cms, that are parasites as juveniles of invertebrates, including leeches, spiders, molluscs, crustaceans, and other nematodes, but are primarily confined to about 15 orders of aquatic and terrestrial in insects (Welch, 1962b). Mermithids are unique among nematodes in that the esophagus, a non-muscular cuticularized tube, often runs posteriorly for over half the body length, but does not enter the intestine, although adhering to it. The intestine is also peculiar in that it lacks an anus and lumen and is highly modified to act as a food storage organ (trophosome) for the free-living adults which probably do not feed (Baylis, 1944; Rubtsov, 1965, 1966d; Gordon *et al.*, 1973).

Although studies by Pickavance *et al.*, (1970), Frost (1970), Frost and Manier (1971), Bradbury (1972) and Frost and Nolan (1972) defined the occurrence of certain simuliid species and their microsporidan or fungal symbionts in Newfoundland, nothing was known concerning the prevalence and distribution of the mermithid parasites of blackflies on the island. This study, therefore, was initiated to

determine the species of mermithids present in blackflies, their distribution in insular Newfoundland as well as longitudinal stream distribution, seasonal fluctuations of host/parasite populations, the biological and ecological factors affecting parasitism, and the factors affecting molting, mating egg laying and egg hatching. In addition, miscellaneous data on the distribution of fungal and microsporidan parasites recovered during the blackfly collections were also collated.

Three species of blackflies, the *Prosimulium fuscum/mixtum* Syme and Davies complex, and *Simulium venustum* Say, both of which are serious man biters and common pests during the early spring and summer months in Newfoundland, were most frequently encountered and parasitized, and provided the basis for this study. The mermithid *Neomesomermis flumenalis*, occurred in 99% of individual infections and this study is primarily based on this species.

HISTORICAL REVIEW

The first reference to a blackfly mermithid parasite was that of Siebold (1848), who found a *Mermis* parasite in *Simulium reptans* in Germany, Diesing (1851) naming this worm *Mermis simuliaereptantis*. Linstow (1889) recorded *Mermis crassa*, also from *S. reptans*, but later suggested (Linstow, 1898) that this species was synonymous with *M. simuliaereptantis*. Müller (1931) described another species, *Mermis simuliae* from a larval *Simulia* sp., from the Alps. Descriptions of all these species are incomplete and for any future taxonomic work are to be considered as *nomina dubia* (Welch, 1964).

The identification of Mermithidae is dependent principally on adult characters, and since the majority of simuliid workers only recovered the parasitic juvenile stages, specific determinations were not generally made. Hence, workers recorded the presence of *Mermis*, often a repository for questionable mermithids (Strickland, 1911, 1913; Webster, 1914; Malloch, 1914; Edwards, 1921; O'Kane, 1926; Bequaert, 1934; Twinn, 1936, 1939; Smart, 1944; Crisp, 1956). Other workers assigned mermithids to different genera, *Agamomermis* (Lutz, 1909), *Limnomermis* (Sommerman *et al.*, 1955; Abdelnur, 1968), *Hydromermis* Anderson and Dicke, 1960; Fredeen and Shemanchuk, 1960; Peterson, 1960), and *Paramermis* (McComb and Bickley, 1959).

Welch (1962a) was the first worker to describe three valid blackfly mermithid species. The species belonged to three genera and were designated as *Gastromermis viridis*, *Isomermis wisconsinensis*, and *Mesomermis flumenalis*. Phelps and DeFoliart (1964) redescribed these

three species, while Nickle (1972) reassigned *Mesomermis flumenalis* to a new genus *Neomesomermis flumenalis*. The generic change was necessitated since the original generic description for *Mesomermis* was basically incomplete and could fit several other common mermithid genera. Nickle (*op. cit.*,) also refigured *G. viridis*.

Rubtsov (1965) described in detail the anatomy of several genera of juvenile blackfly mermithids and proposed the adoption of various larval characters--the structure of the intestine, longitudinal cords, esophagus and associated giant cells--as valid criteria for the identification of mermithid species. These characters were stated to be more constant than the adult characters, and permitted quicker and more reliable identification of species which would not normally be recognized in the adult stage. This paper is the basis for much of his later work.

Welch and Rubtsov (1965) described a new species of *Gastromermis* plus six varieties, based mainly on anatomical differences in the free-living post-parasitic juvenile stages.

Rubtsov (1966a) described a new species of *Mesomermis* while Rubtsov (1966b, c, 1967a, b, 1968) and Rubtsov and Doby (1970) described new species and subspecies or varieties from the genera *Mermithonema*, *Aproctonema*, *Tetradomermis*, *Mesomermis*, *Limnomermis*, *Gastromermis*, *Isomermis* and *Hydromermis*.

Simuliid mermithids are widely distributed and have been recorded from: Nearctic--Webster (1914), Malloch (1914), O'Kane (1926), James (1950), Davies (1958), Wolfe and Peterson (1959), Fredeen and Shemanchuk (1960), Peterson and Davies (1960), Abdelnur (1968) and Fredeen

(1969); Palearctic--Edwards (1921), Smart (1934, 1944), Grenier (1943), Rubtsov (1950, 1963, 1964), Carlsson (1962) and Weiser (1963, 1964); Ethiopian--Lewis (1953, 1958, 1965), Crosskey (1954), Crisp (1956) and Carlsson (1968, 1970), and Neotropical regions--Bequaert (1934), Dalmat (1955) and Garnham and Lewis (1959). To date these mermithids have not been reported from either the Oriental or Australian regions. The reviews of Welch (1964) and Gordon *et al.*, (1973) contain more detailed discussions of distribution.

The life cycle of simuliid mermithids has been detailed only for *G. viridis* and *I. wisconsinensis* (Phelps and DeFoliart, 1964), but isolated observations on other blackfly mermithids were provided by Strickland (1911), Anderson and Dicke (1960), Peterson (1960), Anderson and DeFoliart (1962), and Welch and Rubtsov (1965).

Strickland (1911), the first worker to detail the pathological effects of simuliid *Mermis* infections, recorded that pupal histoblasts failed to develop, thereby preventing pupation. In late larval life, fat bodies were observed to be much reduced or absent, and infected larvae tended to be much longer than uninfected individuals. Other workers have since corroborated these findings (Anderson and Dicke, 1960; Peterson, 1960; Anderson and DeFoliart, 1962).

Wu (1930), Grunin (1949), Hocking and Pickering (1954), Davies (1958), Peterson (1960), and Phelps and DeFoliart (1964), reported mermithids from pupae and/or adults of various simuliid species. Hocking and Pickering (1954) recorded that *S. venustum* adult females infected with mermithids were devoid of the alimentary canal, fat bodies, reproductive and nervous systems within the abdomen. Peterson (1960),

and Phelps and DeFoliart (1964) reported similar findings. When parasitized, adult simuliids are invariably sterile (Lewis and Ibanez de Aldecoa, 1962; Shipitsina, 1963; Leberre, 1966). External indications of simuliid mermithid parasitism are evidenced by claw abnormalities (Peterson, 1960), gynandromorphism (Edwards, 1931) and intersex formation (Rubtsov, 1958; Fredeen, 1970).

Since mermithid infections in blackfly populations are always fatal to the host insect, the percentage of infection is an indicator, albeit an approximate one, of mortality incurred. Welch (1964) and Gordon *et al.*, (1973) reviewed much of the literature on infection percentages in wild simuliids, and concluded that mermithids have definite potential as control agents of blackflies. Other workers (Phelps and DeFoliart, 1964; Welch and Poinar, 1965) were also of the same opinion.

METHODS AND MATERIALS

A preliminary survey of roadside streams, selected for ease of access, occurring on the Avalon Peninsula was initiated in April 1971 to locate blackfly populations with a high level of mermithid parasitism. Four streams were originally selected for continuing study, but the number was later reduced (late in 1971) to two streams as adequate coverage of all four streams was not feasible.

The two streams selected for detailed investigation were both of the young stream class (Anderson and Dicke, 1960). The first, Half Moon Brook, was a roadside stream crossing the highway about 2 kilometers NNW of the N entrance to the village of Flat Rock, (1N/10G 699874).[1] Half Moon Brook originates at Half Moon Pond and flows 2.8 kilometers before emptying into the sea.

The stream and collection site, (Fig. 1a, b), were characterized by an emergent flora consisting largely of *Myrica Gale* L., *Picea mariana* (Mill.) BSP., *Alnus rugosa* (DuRoi) Spreng, *Juncus effusus* L., and *Chamaedaphne calyculata* (L.) Moench., while the submergent flora was dominated by *Potamogeton americanus* C. and S., *Sparganium* sp. and mosses.

The second stream crossed the highway 3 kilometers N of the village of Bay Bulls, (1N/7 633454), and drained a distance of 300 M. from a marsh into Long Pond. The collection site, (Fig. 2a, b) was characterized by a dominant emergent flora of *Myrica Gale* L.,

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[1]Canadian National Topographic Series.

Figure 1a.

Regular collection site at Half Moon Brook.

Figure 1b.

Upstream view of Half Moon Brook from regular collection site. Note the heavy shading by shrubbery.

Figure 2a.

Regular collection site at Long Pond Tributary.

Figure 2b.

Upstream view of Long Pond Tributary
above the regular collection site.

Carex rostrata Stokes, *Juncus effusus* L., a mixture of grasses and mosses, and a submergent flora of *Juncus bufonius* L.

Mermithids or other blackfly parasites were collected at least once from many other stream localities in Newfoundland and these are detailed in Appendices 1-4.

Simuliids were collected on a weekly basis from May to July and biweekly during August and through the winter months from Half Moon Brook and Long Pond Tributary. Collections were made in the morning and where possible, attempts were made to collect on the same day at the weekly or biweekly interval. A minimum sample of 100 larvae and/or pupae were usually collected. The temperature (^{o}C.) and depth (in cms.) were recorded on each collection day for each site. The rate of water flow and the water content analyses were conducted biweekly in 1971 and monthly in 1972. The velocity of the current was determined with an Ott, Small Current Meter[2], while the water analyses of pH, chlorides, silica, sulfides, nitrates, phosphates, dissolved oxygen, ammonia, carbon dioxide and total hardness were conducted in the field during the summer months using a LaMotte Water Analysis Kit.[3] During the fall and winter, water samples were brought back to the laboratory in sealed, 250 ml. jars, filled to overflowing, and analysed in 1 - 4 hours after collection.

Simuliid larvae and pupae were collected randomly in the field by scraping them from rocks and vegetation into 10 cm. diameter Petri dishes lined with saturated (covered with a film of water) filter paper.

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[2] A. Ott. Kempten-Allgaeu, Hydraulic Laboratory.

[3] LaMotte Chemical Products Company, Chestertown, Maryland

The dishes were carried in round, stainless steel, Petri dish storage containers (capacity 15 dishes),[4] which kept the simuliids moderately cool and out of direct sunlight. Survival rate was excellent using this method.

All larvae and pupae were examined in the laboratory within 1 - 4 hours following collection, and the species determined using keys by Stone and Jamnback (1955), Davies *et al.*, (1962), and Wood *et al.*, (1963).

Parasitized larvae were usually recognized by the presence of mermithid nematodes coiled in the abdomen (Fig. 3), large white or red cheese textured cysts (microsporida) (Fig. 4), or small, white, round sporangia of *Coelomycidium simulii* scattered in the coelomic fluid of the body cavity (Fig. 5). Non-parasitized larvae were separated from parasitized individuals and stored in 95% ethyl alcohol for future dissection and closer examination for parasites possibly overlooked during the initial separation.

When microsporidan and fungal infections were recognized, the abdomens of living infected larvae were pierced with jeweller's forceps and smears of the coelomic contents made. Smears were then air dried, fixed in absolute ethyl alcohol for 20 sec. and stained with a 1:9 dilution of Giemsa's stain for 15 minutes. Microsporidan and fungal parasites were identified using the results of Debaisieux (1920), Weiser (1961), Rubtsov (1969), and Jamnback (1970). Some of the microsporidan and *Coelomycidium* identifications were confirmed by

[4] E. H. Sargent and Co. Ltd., Toronto, Ontario.

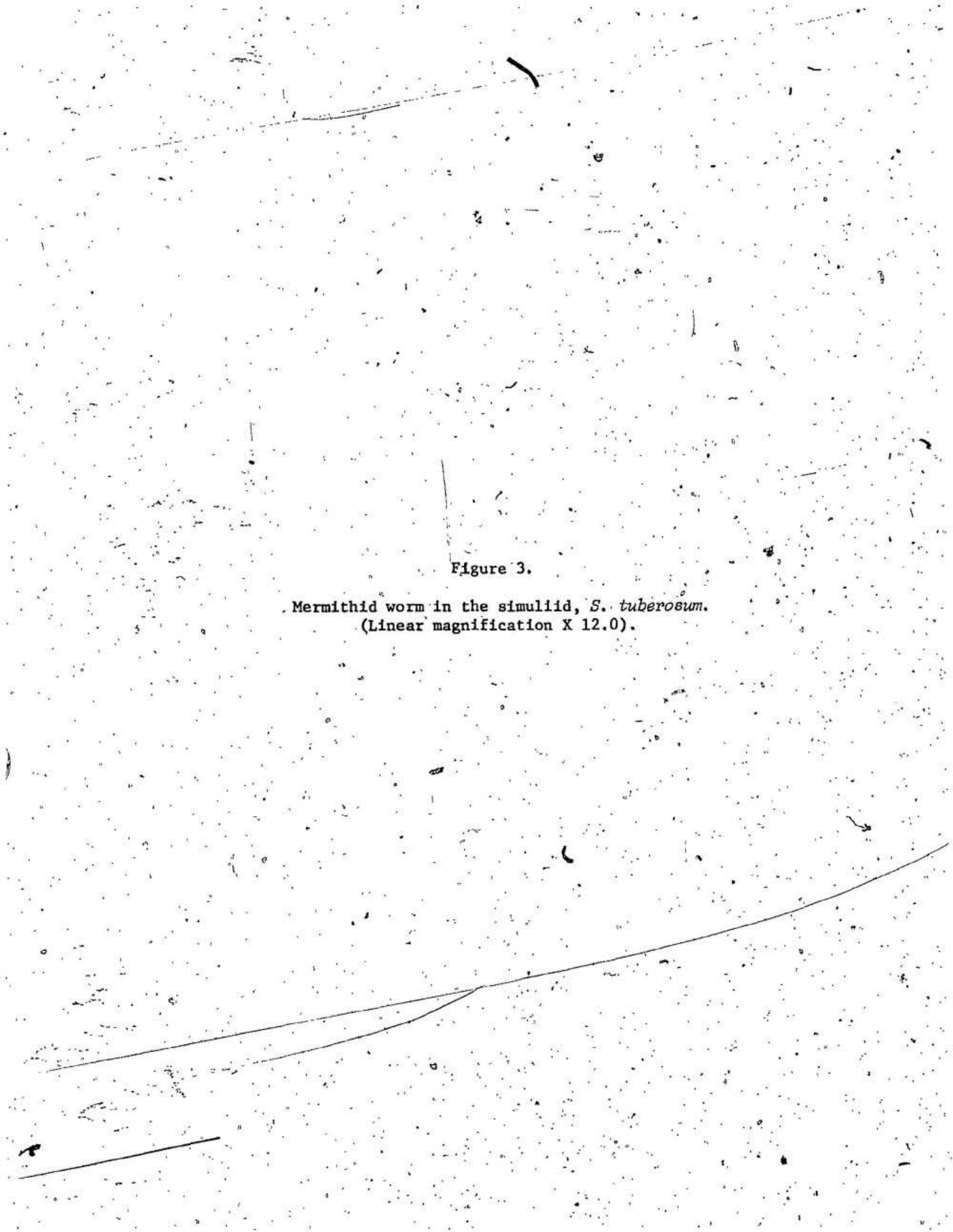

Figure 3.

Mermithid worm in the simuliid, *S. tuberosum*.
(Linear magnification X 12.0).

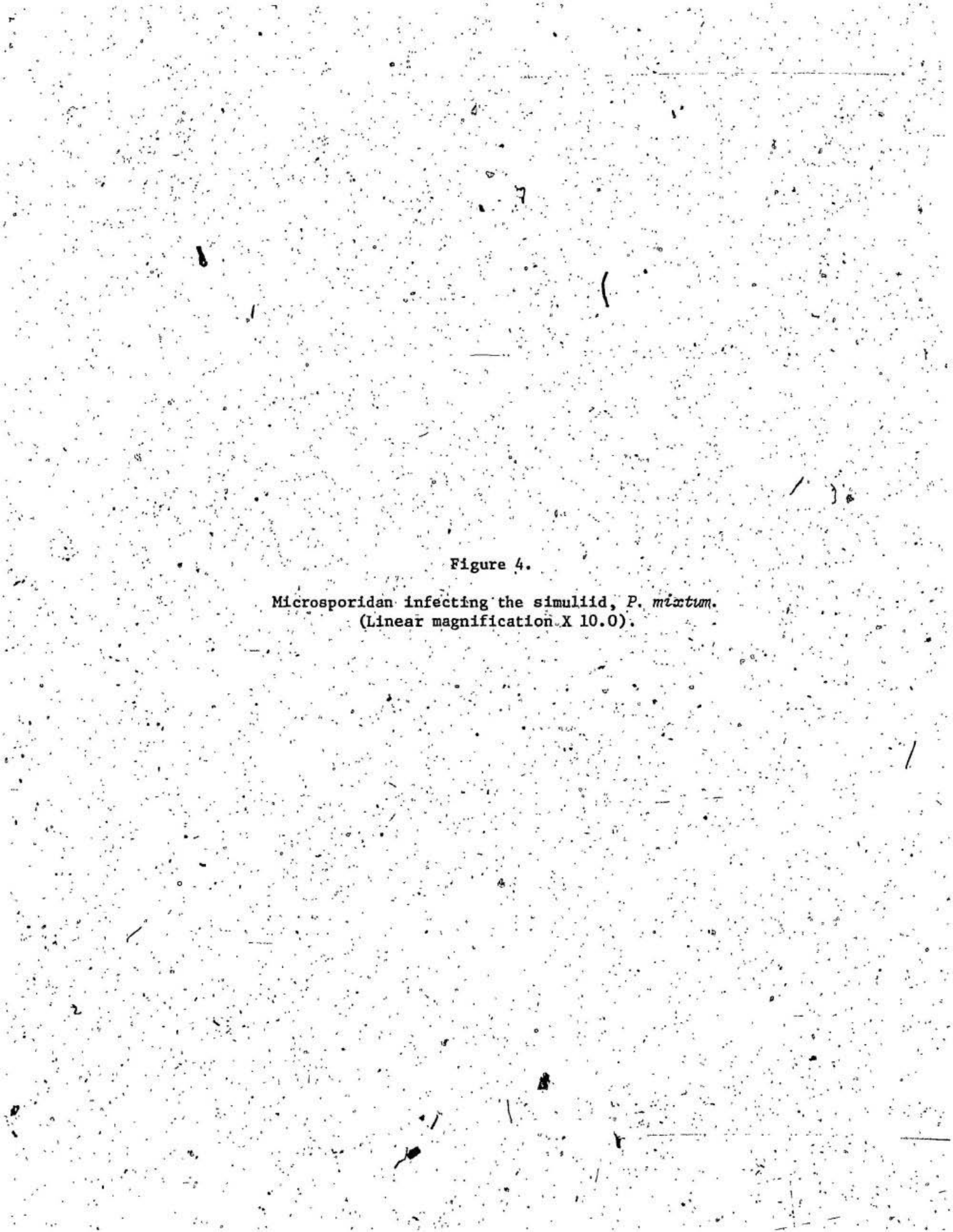

Figure 4.

Microsporidan infecting the simuliid, *P. mixtum*.
(Linear magnification X 10.0).

Figure 5.

Coelomycidium simulii infecting the simuliid, *S. venustum*.
(Linear magnification X 12.0).

Dr. J. Weiser.

Living first and second instar simuliids were squashed in Ringer's Physiological Insect Saline for examination for small mermithid parasites not visible in the intact larva when viewed under the dissecting microscope. Parasites from fixed material were mounted in Rubin's fluid (Rubin, 1951) for examination and identification.

Living simuliid larvae parasitized by mermithids were placed in 500 ml. graduated cylinders filled with stream water. A water current of 0.3 - 0.5 feet/sec. was created by passing a stream of fine air bubbles, derived from aquaria air pumps, through the water. The stream water apparently contained sufficient nutrients to maintain growth of simuliids for periods of up to one week, and no food additives such as yeast or algae were supplied. For extended rearing periods of up to one month, 100-200 ml. of water were removed from the rearing cylinders weekly and replaced with fresh water which presumably augmented the food supply. The spring and summer collected simuliids were reared at two temperatures (12° and 18°C.), while the rearing of species collected during the winter months was conducted at temperatures equal to those existing in the field at the time of collection.

Post-parasitic mermithids were sexed (on the basis of size), separated and placed in Stender dishes (6.25 cm. diameter) filled with water to a depth of about 1 cm. Stream water from the collection sites was regularly used but tap and distilled water were also utilized without noticeably increasing mortality. Several substrates were used during the course of the study. The most satisfactory substrate for observation of the worms (although not for oviposition) was found to

be 15 mm. x 5 mm. strips of Scotchbrite scouring pads,[5] initially boiled in three changes of water for fifteen minutes each and placed in the Stender dishes. The mermithids (up to 20 per dish) actively moved above, under and through the substrate and molted within it. Sand substrates about 5 mm. thick, similar to those used by Muspratt (1947), Phelps and DeFoliart (1964) and Petersen and Willis (1972), were used in one experiment on oviposition.

Phelps and DeFoliart (1964) and Gordon (personal communication) found that fungal infections increased the mortality rate of their mermithids, but in this study fungi were not a problem and no steps such as container sterilization or daily water changes were followed. Fungal infections did occur in isolated instances in this study, but only when the worms were reared at temperatures higher than 18°C. or when the worms were obviously damaged or injured.

Adult worms were relaxed for identification by gently heating until extended, for 4 - 6 seconds in a drop of water on a glass slide. The specimens were then fixed in T.A.F. (Courtney *et al.*, 1955). Identification was made following the scheme of Welch (1962a) and Nickle (1972); the latter confirmed the identification of mermithids in the study. Preparasitic juveniles were described from material mounted in Rubin's fluid. Relaxation of preparasites by gentle heating was attempted, but best results were obtained by directly placing them into Rubin's fluid. Eggs were described from fresh material held in water mounts.

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[5] Minnesota Mining and Manufacturing Company.

Measurements of preparasites were made on a Carl Zeiss Micro-Videomat[6] at a 3200 x magnification. Bennett and Campbell (1972) provide details on the operation of the Micro-Videomat for the measurement of length and width of bird blood parasites; this procedure was followed closely.

All drawings were made with the aid of a camera lucida attachment for the Carl Zeiss Research Microscope. Photographs were taken on a Carl Zeiss Tessovar.

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[6]Oberkochen, West Germany.

RESULTS AND DISCUSSION

Distribution

Two surveys for blackfly endoparasites were conducted in Newfoundland in 1971 and 1972. Fifty-eight streams on the Avalon Peninsula within a 40 kilometer radius of St. John's were examined in the first survey, while an additional 13 streams were examined in 1972 to further delimit the distribution of blackfly endoparasites on the Avalon. The second survey was concerned primarily with determining the distribution of blackfly parasites across insular Newfoundland, and therefore, a trans-island survey was conducted along the Trans Canada Highway (TCH) from Whitbourne (80 kilometers W. of St. John's) to Port-aux-Basques, and the Great Northern Peninsula as far north as Bellburn's; 104 streams were sampled during May 23 to June 8, 1972. The end of May-early June sampling period was selected as data collected in 1971 indicated that mermithids were present in the simuliid hosts during this time of year. Blackflies were also collected from 23 additional streams on the Avalon and Bonavista Peninsulas during 1970-1972 (Lewis). A total of 198 streams, from all sources, were examined. (Fig. 6).

Table 1, details on a district basis, the distribution of mermithid, microsporidan and fungal parasites of the blackflies *P. fuscum/mixtum* Syme and Davies, *C. mutata* Malloch, *S. corbis* Twinn, *S. latipes* (Meigen), *S. tuberosum* (Lundstrom), *S. venustum* Say, and *S. vittatum* Zetterstedt. District 1 consists of the Avalon Peninsula, E. of Whitbourne, Districts 2-6 comprise the TCH from Whitbourne to

TABLE 1

DISTRIBUTION BY DISTRICT AND BLACKFLY SPECIES OF PARASITES RECOVERED FROM NEWFOUNDLAND IN 1971 AND 1972

District	Total Streams Examined	Blackfly Species	Total Presence in Streams	Total Infections / Blackfly Species*		
				Mermithids	Microsporida	*Coelomycidium simulii*
1. Avalon Peninsula, E. of Whitbourne	78	*P. fuscum/mixtum*	33	12	8	-
		C. mutata	11	-	1	-
		S. corbis	10	1	1	1
		S. latipes	18	5	5	-
		S. tuberosum	23	-	1	-
		S. venustum	50	16	16	7
		S. vittatum	15	1	3	1
2. Whitbourne to Terra Nova Park - Headquarters Access	25	*P. fuscum/mixtum*	18	5	3	-
		S. corbis	4	-	-	1
		S. tuberosum	10	-	1	-
		S. venustum	12	2	4	1
		S. vittatum	3	-	1	-
3. Terra Nova Park to East of Bishop's Falls.	11	*P. fuscum/mixtum*	8	6	1	-
4. Bishop's Falls to Birchy Lake Narrows	19	*P. fuscum/mixtum*	19	9	2	2

TABLE 1 (CONTINUED)

District	Total Streams Examined	Blackfly Species	Total Presence in Streams	Total Infections / Blackfly Species*		
				Mermithids	Microsporida	*Coelomycidium simulii*
5. Birchy Lake Narrows to Stephenville Crossing Access	16	*P. fuscum/mixtum*	16	5	1	1
6. Stephenville Crossing to Port-aux-Basques	17	*P. fuscum/mixtum*	17	2	3	-
7. Great Northern Peninsula, North of Deer Lake /	15	*P. fuscum/mixtum*	15	3	1	1
8. Bonavista Peninsula	17	*P. fuscum/mixtum*	4	1	-	-
Totals	198			68(59)	52(40)	15(14)

*The total number of streams harbouring mermithids, microsporida or *Coelomycidium simulii* is less than the total parasite infections indicated, since some of the streams harboured more than one infected blackfly species. Actual stream totals for each parasite group in brackets.

Port-aux-Basques, delimited at approximate 160 kilometer intervals. Districts 7 and 8 are of the Great Northern and Bonavista Peninsulas respectively.

Twelve other species of blackfly, from three genera, recovered in this survey were examined for their endoparasites during 1971 and 1972, but were uninfected. The species are as follows: *P. pleurale* Malloch; *C. dacotensis* Dyar and Shannon; *S. aureum* Fries; *S. croxtoni* Nicholson and Mickel; *S. euryadminiculum* Davies; *S. excisum* Davies, Peterson and Wood; *S. gouldingi* Stone; *S. longistylatum* (?) Shewell; *S. pugetense* Dyar and Shannon; *S. quebecense* Twinn; *S. rivuli* (?) Twinn, and *S. verecundum* Stone and Jamnback.

Microsporidans recovered were *Thelohania bracteata* Strickland; *T. fibrata* Strickland; *Plisteophora simulii* Lutz and Splendore; *Caudospora simulii* Weiser, and *C. brevicauda* Jamnback. The fungal parasite *Coelomycidium simulii* Debaisieux was also found. The number of blackflies examined and infected with microsporidans or the fungus are detailed in Appendices 2 and 3. Table 2 compares measurements of known Newfoundland microsporidan species with those of Weiser (1961) and Jamnback (1970). No significant differences were noted, except in *C. simulii* and *C. brevicauda* which varied slightly in spore size and caudal length. Measurements were based on 20 spores from each of 5 infected hosts.

Microsporidans are of scattered occurrence in Newfoundland blackflies (Table 1), with 40 of 198 streams (20.2%) harbouring one or more species. *Prosimulium fuscum/mixtum* larvae were found infected only with *C. simulii* in 19 of 40 (47.5%) infected streams; *C. mutata*

TABLE 2

COMPARISON OF MEASUREMENTS OF NEWFOUNDLAND MICROSPORIDANS WITH THOSE OF WEISER (1961) AND JAMNBACK (1970)

Parasite Species*	Spore Length		Spore Width		Cauda Length	
	A	B	A	B	A	B
T. bracteata	2.5 - 4.0	3.5 - 4.0	2.3 - 3.6	2.8 - 3.5	-	-
T. fibrata	5.0 - 7.0	4.5 - 6.0	3.0 - 4.0	3.5 - 4.5	-	-
P. simulii	4.0 - 5.5	4.0 - 4.5	2.5 - 3.5	3.0 - 3.5	-	-
C. simulii	4.5 - 5.0	5.0 - 6.5	5.0	3.0 - 5.0	14 - 24	20 - 32
C. brevicauda	4.8 - 6.0	5.0 - 6.0	2.9 - 3.9	3.0 - 3.5	5.6 - 10	3.5 - 12

*all measurements in microns.
A. all measurements from Weiser (1961), except *C. brevicauda* which is from Jamnback (1970).
B. Newfoundland data.

with *C. brevicauda* in 1 of 40 (2.5%); *S. corbis* with *T. bracteata* in 1 or 40 (2.5%); *S. latipes* with *T. bracteata, T. fibrata* or *P. simulii* in 5 of 40 (12.5%); *S. tuberosum* with *T. fibrata* or *P. simulii* in 2 of 40 (5.0%); *S. venustum* with *T. bracteata, T. fibrata,* or *P. simulii* in 20 of 40 (50.0%); and *S. vittatum* with *T. bracteata, T. fibrata,* or *P. simulii* in 4 of 40 (10.0%) of infected streams. Levels of parasitism (Appendix 2) for all recorded species were generally less than 5.0%, although infections of up to 100.0% were obtained from certain indicated biased samples. *Thelohania bracteata* and *T. fibrata* are new records for Newfoundland.

The fungus *Coelomycidium simulii,* also a new Newfoundland record, was recovered from 14 streams (Table 1), and infected the blackflies *P. fuscum/mixtum, S. corbis* and *S. venustum.* The incidence of parasitism was generally less than 5.0%, but 20.9% was recorded on one occasion (Appendix 3).

Mermithids are of widespread, but scattered distribution in Newfoundland (Table 1, Fig. 6) and were recovered from 59 of 198 (29.7%) streams yielding blackflies. The two regular collection sites, Half Moon Brook and Long Pond Tributary, are included in Fig. 6, but excluded from tabulation in Tables 1 and Appendix 4, and are considered later in much more detail. The average mermithid infection rate was usually less than 10.0%, but heavily infected scattered populations of 20.0% or more occurred.

Three species of blackfly mermithids were recovered, namely *Neomesomermis flumenalis* (Welch, 1962) Nickle, 1972, which was the most common, and present in 56 of 59 (94.9%) of the streams harbouring

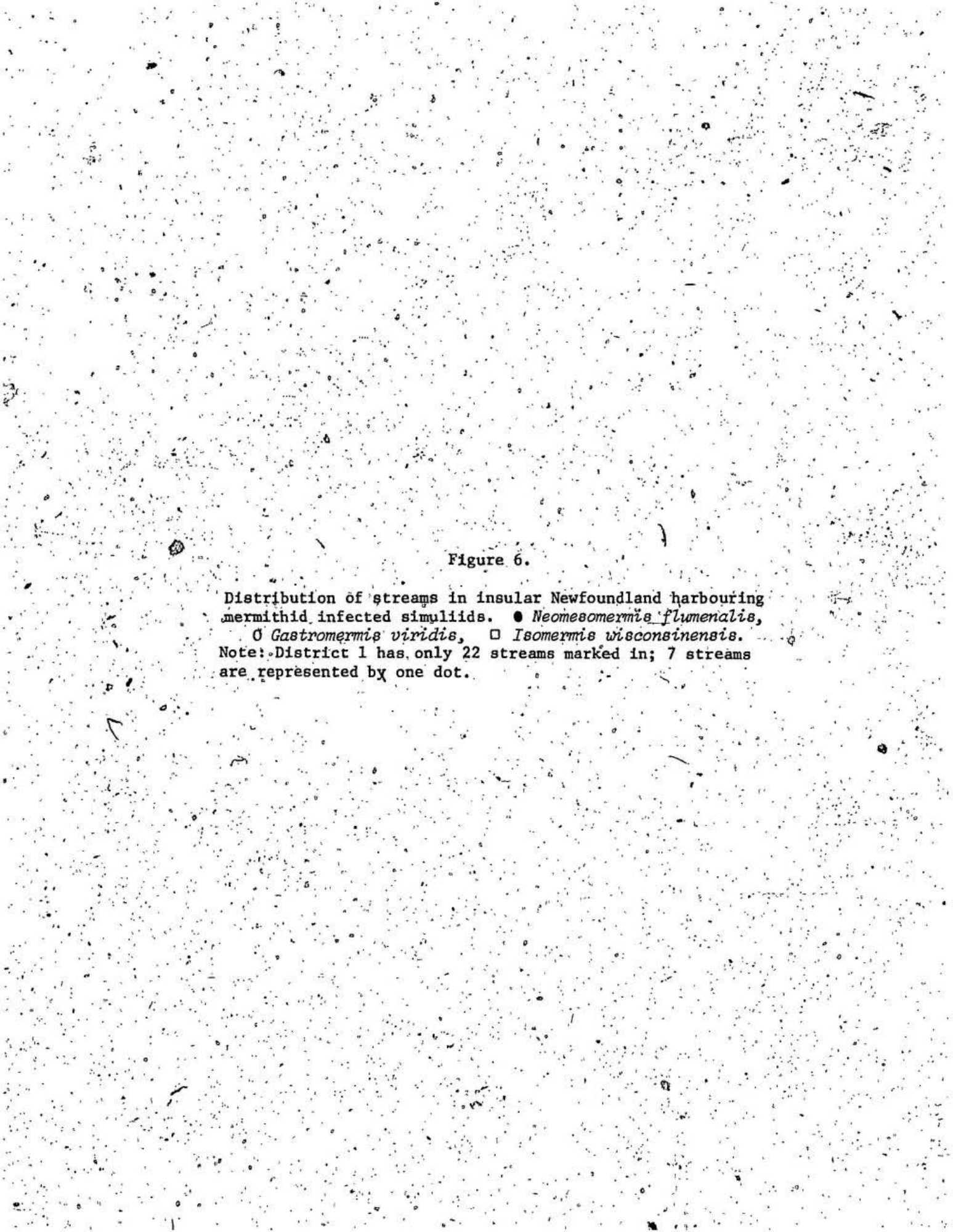
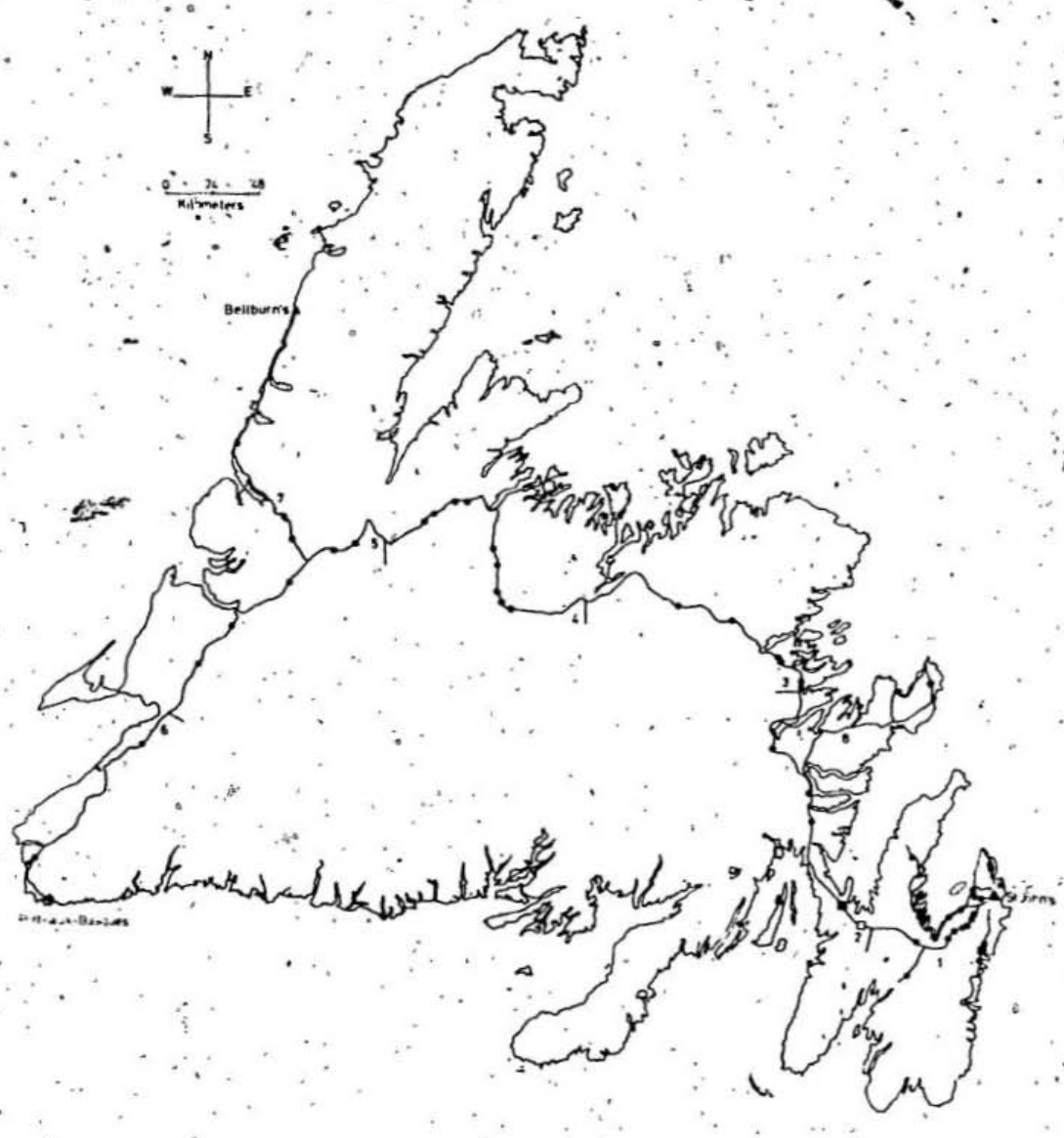


Figure 6.

Distribution of streams in insular Newfoundland harbouring mermithid infected simuliids. ● *Neomesomermis flumenalis*, ○ *Gastromermis viridis*, □ *Isomermis wisconsinensis*. Note: District 1 has only 22 streams marked in; 7 streams are represented by one dot.


N
W
E
S
0 74 148
Kilometers
Bellburn's

mermithids. *Gastromermis viridis* Welch, 1962 was present in 2 of 59 (3.3%) and *Isomermis wisconsinensis* Welch, 1962 in 4 of 59 (6.7%) of the streams having simuliid mermithids. These three mermithids are new records for Newfoundland.

Neomesomermis flumenalis regularly infects *P. fuscum/mixtum* and *S. venustum* in Newfoundland, but was also recorded from *S. latipes* and *S. tuberosum*. *Isomermis wisconsinensis* was recovered from *S. venustum* and *S. vittatum*, while *G. viridis* was found in *S. corbis* and *S. vittatum*.

Table 3 shows the incidence of mermithid infection in *P. fuscum/mixtum*, the only simuliid species which were common to all 8 districts. The data clearly show that the central regions of Newfoundland (Districts 3 and 4) had a higher incidence of infection with mermithids (75.0 and 47.3%) than the more coastal districts. District 6 had the lowest incidence of infection (11.7%) while the remainder of the districts had simuliids infected within the range of 20.0 - 36.3%.

The reason for the higher prevalence of mermithid nematodes in the interior regions of Newfoundland is largely speculative at this time. However, it may be that climatic factors (colder winters and warmer summers) are decisive in influencing mermithid parasitism in Central Newfoundland. It is also conceivable that the simuliid populations, which are generally conceded to be more prolific in Central Newfoundland than in the coastal areas, warrant the carryover of more parasitic mermithids from larvae to adults than in other areas,

TABLE 3

DISTRICT DISTRIBUTION OF STREAMS HARBOURING *P. FUSCUM/MIXTUM* MERMITHIDS IN NEWFOUNDLAND

District	Total Streams Yielding Hosts	Total Streams Harbouring Mermithids	Percent of Streams Harbouring Mermithids
1	33	12	36.3
2	18	5	27.7
3	8	6	75.0
4	19	9	47.3
5	16	5	31.2
6	17	2	11.7
7	15	3	20.0
8	4	1	25.0

thereby permitting wider and easier dispersal of the mermithids to new localities.

The data from District 6 appears to be anomalous when compared with the other 7 districts. To test possible reasons for lower parasite prevalence in District 6, water analyses of seven streams, six without and one with blackfly mermithid infections, were carried out in late December, 1972.

The results (Table 4) indicate that there were no significant differences between infected and uninfected streams for pH, chlorides and ammonia. No explanations are currently available for the anomaly noted in District 6, but it may be related to reduced mermithid carryover to the adult simuliids or the coastal climatic conditions in this region. The possibility that mermithid infected simuliids were missed during collections should also not be excluded.

Longitudinal Stream Distribution

The distribution of blackfly mermithids in a stream from source to mouth was studied to determine if infections were maintained at constant levels in all areas or were confined to localized portions of the stream. Half Moon Brook (2.8 km. long) and Pickavance Creek (1.2 km. long) were examined at intervals of approximately 200 m. Both streams originated from ponds, proceeded through open scrub-marshy areas to mixed forest of *Picea mariana, Alnus rugosa, Prunus*

TABLE 4

COMPARISON OF WATER ANALYSES BETWEEN INFECTED AND UNINFECTED STREAMS IN DISTRICT 6

Streams	Ammonia	Chlorides	pH.
126	0	20	7
127	0	25	7
128	0	20	6
129	0	20	7
57*	0	20	7
130	0	25	6.5
58	0	20	6.0

*Infected.

pennsylvanica and *Myrica Gale*, where the bulk of the collecting was done.

Pickavance Creek was examined once, 27/VI/72, while Half Moon Brook was examined 9/V/72 and 15/VI/72. The only mermithid species recovered from both streams was *N. flumenalis* . The mermithids from Half Moon Brook were collected from *P. fuscum/mixtum* (9/V/72), *S. venustum* and *S. tuberosum* (one specimen only at station 10, 15/VI/72), while Pickavance Creek yielded only parasitized larvae of *S. venustum*.

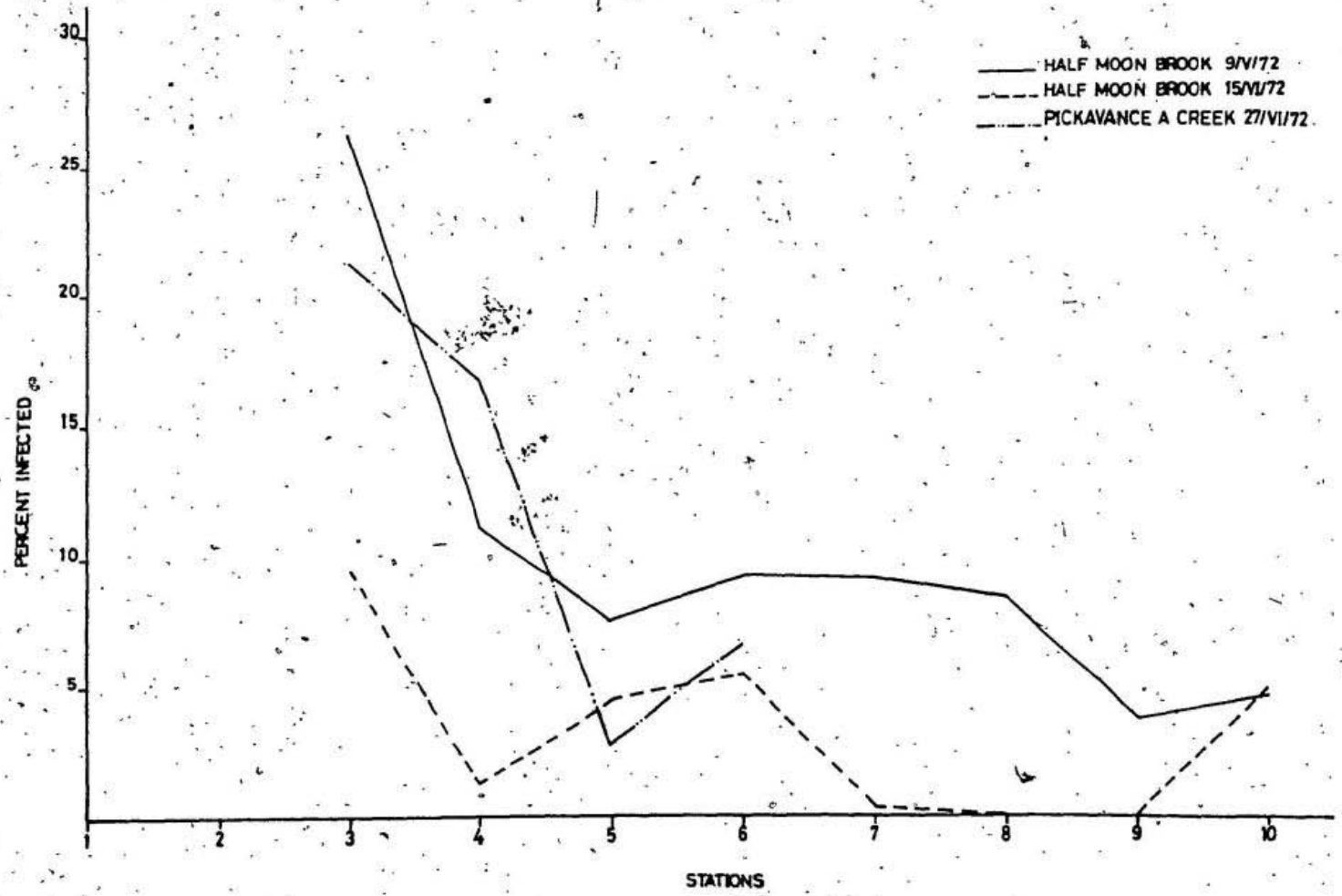
Figure 7 shows that the first 400m., or the open scrub areas, of the upper portions of the streams were devoid of mermithid parasites, but not the host species. Mermithids occurred initially where the streams entered shaded, mixed forest areas, and the level of parasitism declined in a downstream direction, rising again slightly at the stream mouth. The reason for this distribution pattern is obscure at present, and additional detailed research should be undertaken to help clarify this problem.

Physical and Chemical Parameters

In an effort to define the chemical and physical environmental requirements of simuliid mermithids, and thus possibly provide a means of predicting the suitability of a stream for them, a comparison was made of such factors existing in two streams with, and one stream without

Figure 7.

Longitudinal stream distribution of *N. flumenalis* infected simuliids. Note: Station 1, head waters of stream.


HALF MOON BROOK 9/V/72
HALF MOON BROOK 15/VI/72
PICKAVANCE A CREEK 27/VI/72
PERCENT INFECTED
30
25
20
15
10
5
1
2
3
4
5
6
7
8
9
10
STATIONS

blackfly mermithids. Ten chemical parameters (dissolved oxygen, carbon dioxide, ammonia, nitrates, phosphates, chlorides, total hardness, silicon dioxide, hydrogen sulfide and pH), and the physical factors of water current, depth and temperature were measured. The streams studied were Half Moon Brook and Long Pond Tributary, both streams with simuliids infected with mermithids, and Piccos Brook (Appendix 1), in which only a single mermithid infection was found (April, 1972) in two years of sampling. In all the streams, ammonia, nitrates, phosphates and hydrogen sulfide were virtually absent and are omitted from further consideration.

The results of the current, depth and water content analyses over the period 23/VI/71 to 17/VII/72 are presented in Figures 8 and 9 and Appendix 5; the effects of temperature will be considered in more detail in the seasonal fluctuations section. It will be noted (Table 5) that all ranges of the various parameters overlap, and no characteristic was found which could be stated as being a specific requirement for mermithids.

Isolated observations on water analyses from other Newfoundland streams harbouring mermithid infected simuliids provides the basis for the establishment of a guide line to the chemical tolerance limits for *N. flumenalis*. Maximum and minimum chemical parameter limits for carbon dioxide of 2 - 15 ppm, chlorides of 15 - 250 ppm, total hardnes of 20 - 250 ppm and pH of 4.5 - 7.5 were noted. To further elucidate the tolerance limits for *N. flumenalis*, additional detailed investigations of water from streams with and without mermithids, should be undertaken.

During the winter months, January to March, when the streams were ice-covered, a slight decrease in dissolved oxygen and a slight

Figure 8.

Comparison of minimum and maximum monthly depths for the two regular collection sites in 1971 and 1972.

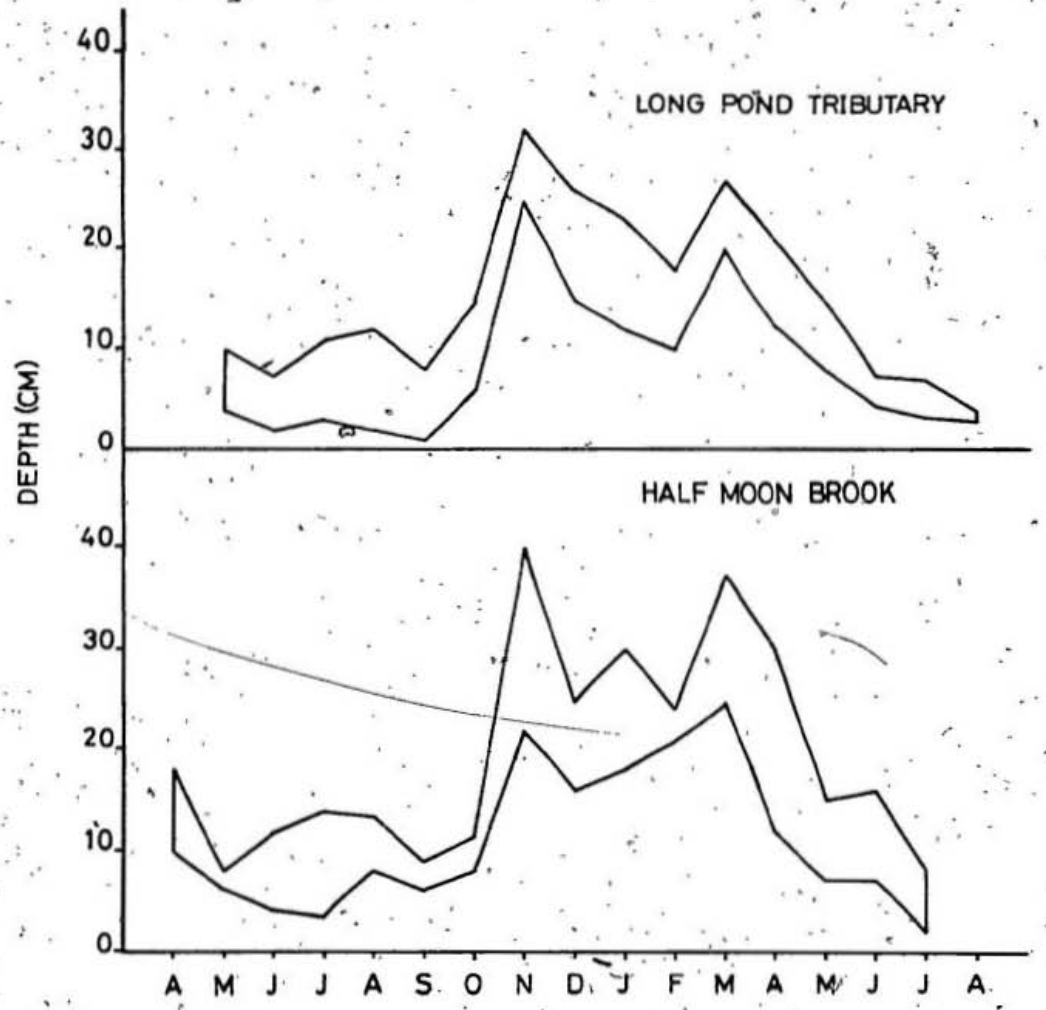

LONG POND TRIBUTARY
HALF MOON BROOK
DEPTH (CM)
40
30
20
10
0
A M J J A S O N D J F M A M J J A

Figure 9.

Comparison of minimum and maximum monthly currents for the two regular collection sites in 1971 and 1972.

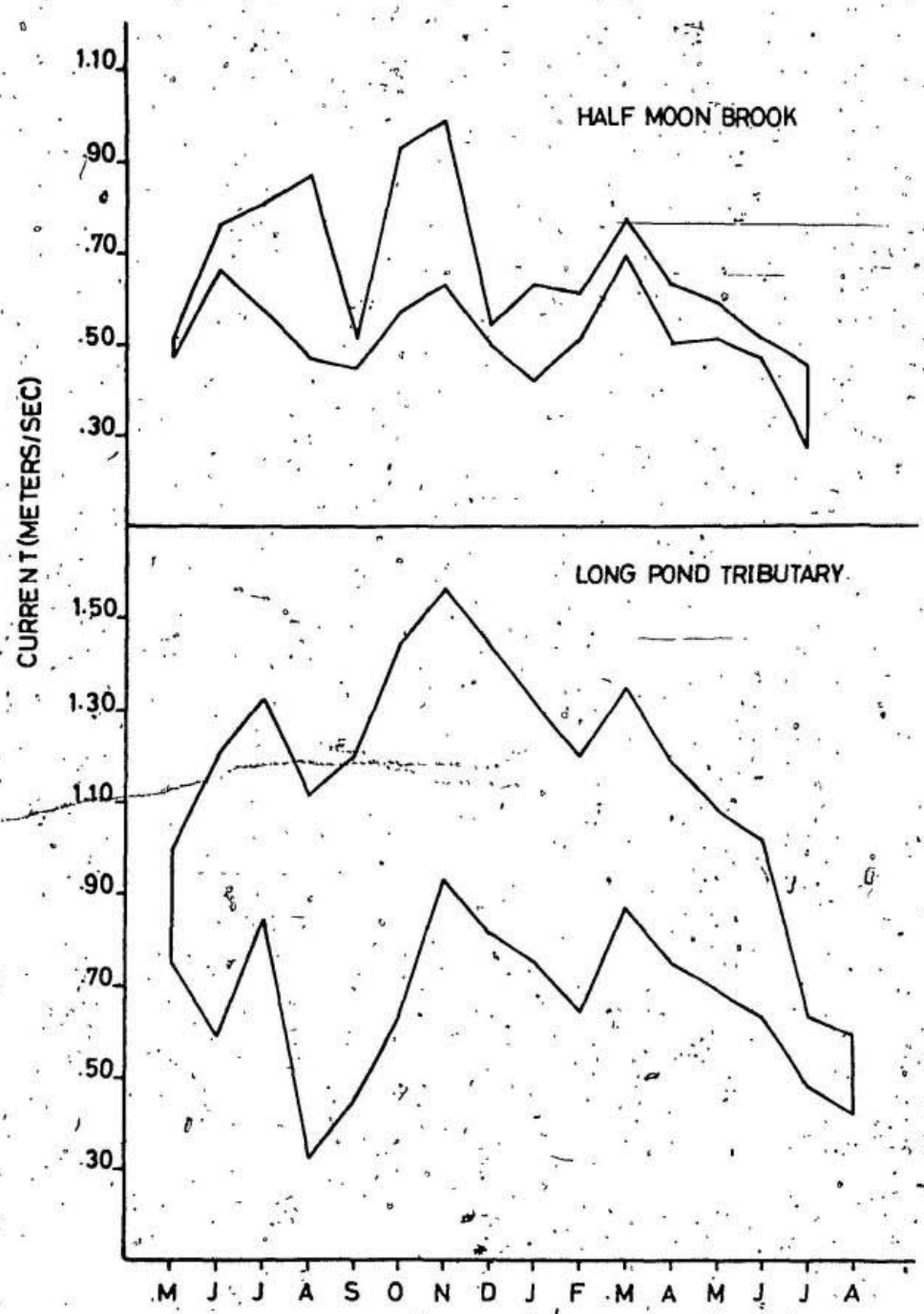

HALF MOON BROOK
LONG POND TRIBUTARY
CURRENT (METERS/SEC)
1.10
.90
.70
.50
.30
1.50
1.30
1.10
.90
.70
.50
.30
M J J A S O N D J F M A M J J A

TABLE 5

RANGE OF ENVIRONMENTAL PARAMETERS FOR STREAMS WITH AND WITHOUT BLACKFLY MERMITHIDS

Parameters	Half Moon Brook**	Long Pond Tributary**	Piccos Brook
Carbon dioxide*	2.0 - 5.0	2.0 - 7.0	2.0 - 5.5
Dissolved oxygen*	6.0 - 9.0	6.8 - 9.4	6.0 - 8.8
Chlorides*	20 - 30	15 - 25	15 - 25
Total hardness*	20 - 30	45 - 70	20 - 30
pH	4.5 - 6.5	4.5 - 6.0	5.5 - 6.5
Silicon dioxide*	1.0 - 2.5	1.5 - 2.5	1.0 - 2.5
Temperature (°C.)	0 -20.0	0 -22.0	0 -21
Current (meters/sec.)	.27- .99	.32- 1.56	-
Depth (cm.)	2 - 40	1 - 32	-

*in parts per million.
**harbour mermithid infected blackflies.

increase in carbon dioxide were noted in all streams (Appendix 5). This was expected as the ice probably prevented oxygenation of the water. All other parameters maintained a relatively constant level throughout the year.

Current and depth measurements (taken as close to the substrate and simuliids as possible) from Half Moon Brook and Long Pond Tributary, were also measured regularly throughout the course of the study. The maximum and minimum monthly depths (Fig. 8) and currents (Fig. 9) for both streams are correlated throughout the year. Generally, when the water was deepest during November to April, 1971/72, the current was fastest, and the current was slowest in the late spring and summer when the water was shallowest.

It is doubtful whether mermithid parasitism can be correlated with chemical factors, depth or current, since it is possible that blackflies and mermithids have similar tolerance limits, due to co-evolution, and when factors effectively limit blackflies, they also probably limit the mermithids as well. The presence or absence of mermithids in blackfly inhabited streams, therefore, is probably due largely to chance dispersal of mermithid-infected adult blackflies and not to environmental factors.

Taxonomy

Nickle (1972), in a badly needed taxonomic revision of the Mermithidae, redescribed the blackfly mermithids *M. flumenalis* and *G. viridis*. Since all the stages of development of *N. flumenalis* were

not known to Nickle (*op. cit.*) or to previous workers (Welch, 1962a; Phelps and DeFoliart, 1964), a complete description of all stages is provided herein. Brief descriptions of *G. viridis* and *I. wisconsinensis* are also provided. Only adult males of these two species are described since no adult females of *G. viridis* and only one badly damaged female of *I. wisconsinensis* were obtained. Appendix 6 compares the three Newfoundland mermithid species with the pertinent adult data of Welch (1962a), Phelps and DeFoliart (1964) and Nickle (1972).

Neomesomermis Nickle, 1972, emended.

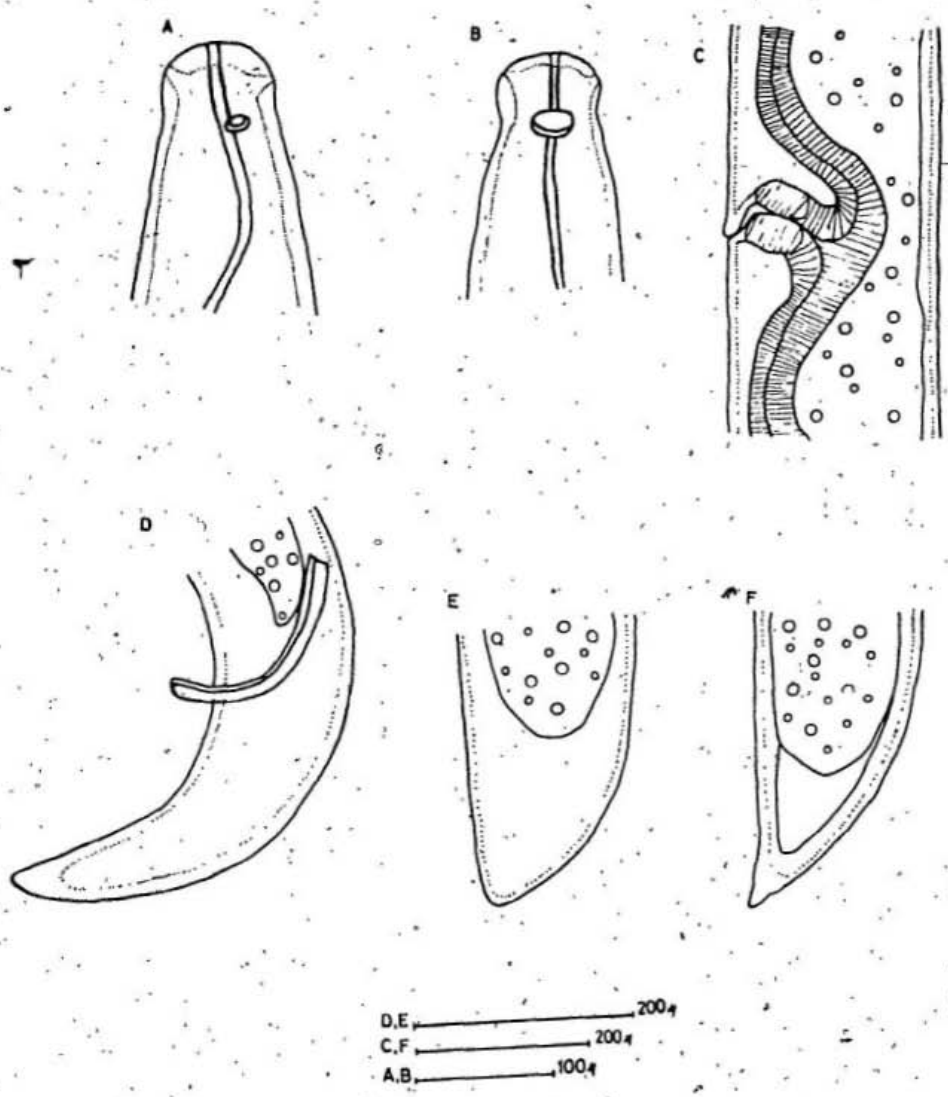
Length 10 - 24 mm.; mouth terminal; amphids sexually dimorphic, large; six cephalic papillar groups; male and female adult tails bluntly rounded. Male: two medium-sized spicules; tail papillae in three single rows, center row bifurcating around spicular opening. Female: with short barrel-shaped vagina; vulval cone weakly developed. Pre-parasitic larvae: with long cauda and short stylet. Male and female post-parasitic larvae: tails with bluntly rounded, cone-shaped appendages. Eggs: medium-sized, tightly packed in uterus; without byssi.

Neomesomermis flumenalis (Welch, 1962) Nickle, 1972.

Female (Fig. 10, A, C, E.): eleven specimens. Body length 13.4 (11.1 - 17.8)mm. Body width 87.5 (80.0 - 100.0) μ at level of head papillae, 146.6 (130.0 - 160.0) μ at level of nerve ring, 255.6 (232.0 - 292.0) μ at vulva, and at termination of trophosome in tail, 146.2 (127.0 - 172.0) μ.

Figure 10.

Neomesomermis fluminalis. A. Female head, lateral view. B. Male head, lateral view. C. female, vagina. D. Male tail. E. Female tail. F. post-parasitic female tail.


A
B
C
D
E
F
D,E 200µ
C,F 200µ
A,B 100µ

Amphidial pouch globular, 12.5 x 10.0 (12.0 - 16.0 x 7.0 - 15.0) μ with a sub-elliptical pore 7.5 x 6.25 (7.0 - 10.0 x 5.0 - 8.0) μ . Vagina short, barrel-shaped 88.3 (77.0 - 97.0) μ long, lying 45° to the body axis, directed posteriad. Vulva transverse slit, lipped, 52% (46.6 - 54.7%) of the distance from the mouth.

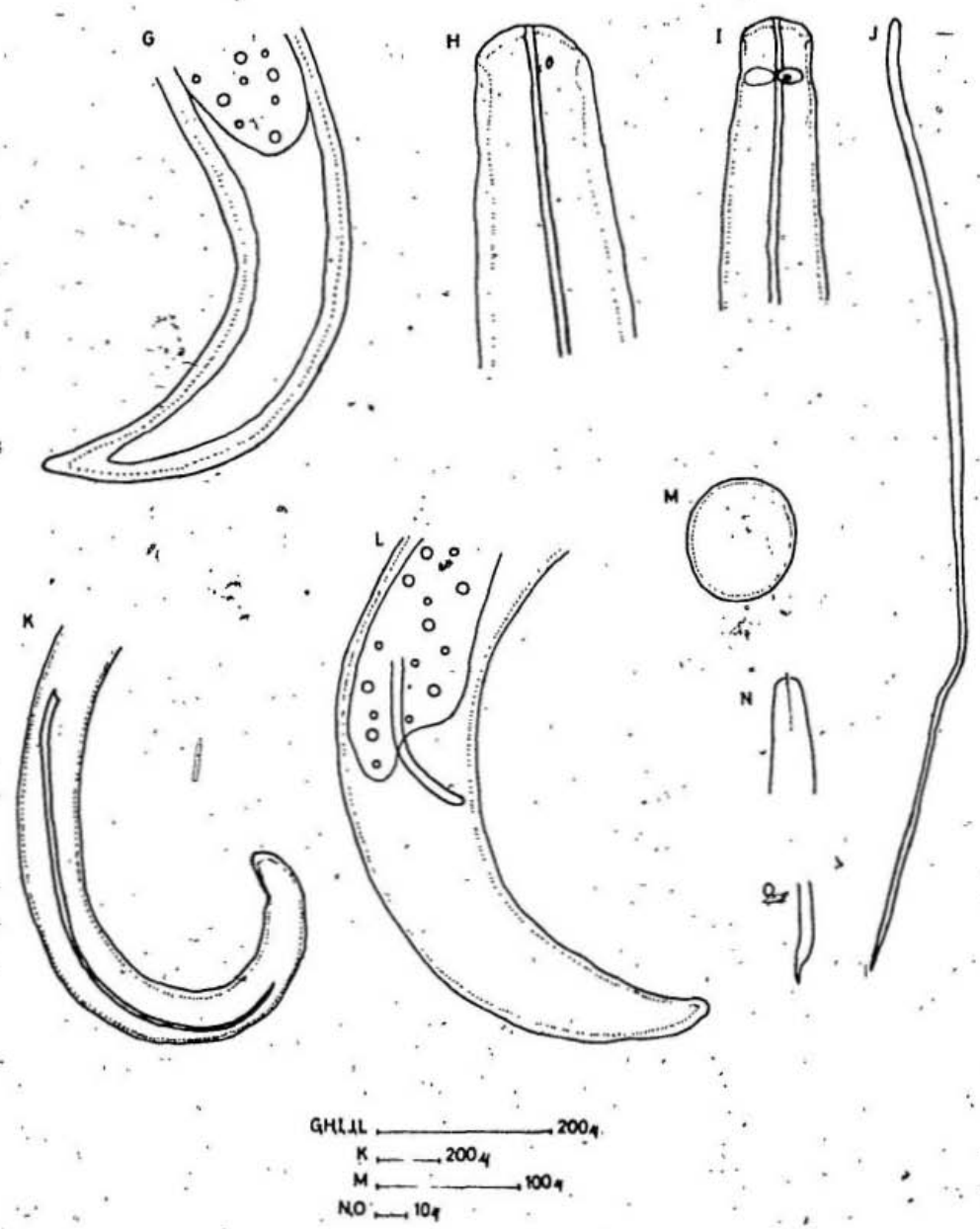
Male (Fig. 10 B, D): eleven specimens. Body length 9.6 (6.7 - 12.0) mm. Body width 73.4 (67.0 - 80.0) μ at the level of head papillae, 110.2 (100.0 - 130.0)μ at level of nerve ring, 138.6 (112.0 - 155.0) μ at mid-body, 122.0 (100.0 - 142.0) μ at spicule opening. Length of tail from spicule opening 265.0 (205.0 - 327.0) μ . Amphidial pouch ellipsoidal, 28.1 x 20.0 (27.0 - 32.0 x 17.0-27.0) μ with an elongate elliptical pore 27.5 x 12.5 (25.0 - 32.0 x 7.0 - 17.0) μ . Two spicules 222.5 (200.0 - 242.0) μ long, 10.25 (10.0 - 12.0) μ wide, uniform throughout except for separate bases which are 1 - 2 wider. Spicules extended, slightly reflexed with rounded tips bordered by small spines.

Post-parasitic female (Fig. 10, F): eight specimens. Length 19.5 (14.3 - 23.8) mm. Body width 97.5 (92.0 - 100.0) μ at level of head papillae, 157.5 (150.0 - 195.0) μ at level of nerve ring, 237.5 (212.0 - 337.0) μ at vulval primordium, and at tip of trophosome in tail, 142.5 (125.0 - 175.0) μ . Tail with cone-shaped tip, sometimes tipped with a long cuticular filament. Trophosome begins 317.5 (287.0 - 350.0) μ from the mouth opening, touching or up to 5 μ posterior to the nerve ring, never before.

Post-parasitic male (Fig. 11 G.): seven specimens. Length 12.2 (11.2 - 19.4) mm. Body width 80.0 (70.0 - 90.0) μ at level of head papillae,

Figure 11.

Neomesomermis flumenalis. G. Post-parasitic male tail. J. Preparasite. M. Egg. N. Head region of preparasite. O. Tail region with characteristic tip. *Gastromermis viridis*. H. Male head, lateral view. K. Male tail. *Isomermis wisconsinensis*. I. Male head, lateral view. L. Male tail.


G
H
I
J
K
L
M
N
O
G,H,I,J,L 200µ
K 200µ
M 100µ
N,O 10µ

126.5 (105.0 - 145.0)μ at nerve ring, 172.5 (137.0 - 180.0) μ at mid-body, and 147.5 (117.0 - 167.0) μ at terminus of trophosome. Tail more sharply pointed than in female, but also cone-tipped. Trophosome begins 312.5 (261.0 - 330.0) μ from mouth opening, touching or 75 - 175 μ posterior to the nerve ring.

Parasitic juveniles: five specimens. Size depends largely on the stage of development. Body width at head 7.5 - 125.0μ , mid-body 22.0 - 250μ , length 1.07 - 15.4 mm. The head is rounded, the tail drawn out to a long caudal appendage. Early parasites still possess the characteristic caudal tip (Fig. 11, O) of the pre-parasites as well as the stylet.

Pre-parasites (Fig. 11, J, N, O): six specimens. Body length 1.15 (1.04 - 1.28) mm. Width at head region 6.68 (6.08 - 7.33)μ ; at mid-body 8.6 (7.45 - 10.3)μ . Stylet length 3.86 (3.15 - 4.54)μ , sharp and thin, arising from a bulb set in the esophageal pocket. Tail long, whip-like with a characteristic shaped appendage, 7.65 (5.35 - 10.62) μ.

Eggs (Fig. 11, M): 20 specimens. Sub-spherical shape, 89.5 x 78.0 (85.0 - 93.75 x 75.0 - 81.25)μ , with egg shell 1 μ thick, unornamented, covered with a gelatinous substance which sticks them to the substrate when laid. Eggs generally unembryonated when laid, consisting of one egg cell (but one preserved female found with full term, coiled larvae). Eggs in ovaries irregularly shaped, possibly due to uterine pressure, 72.0 - 95.0 x 57.0 - 80.0 μ.

Gastromermis Micoletzky, 1923 (modified from Nickle, 1972).

Length 13 - 22 mm.; mouth opening ventrally; amphids large; six cephalic papillar groups; male and female adult tails bluntly rounded. Male: one long, slender spicule; tail papillae in three single rows, center row bifurcating around spicule opening. Female: with long, S-shaped vagina, with weakly developed vulval cone.

Gastromermis viridis Welch, 1962 (Fig. 11, H, K).

Male: eight specimens. Body length 15.0 (13.2 - 21.5) mm. Body width at level of head papillae 70.0 (65.0 - 75.0) μ, and at spicule opening, 150.5 (117.0 - 168.0)μ . Spicule 1.35 (1.0 - 1.65) mm. in length; width of shaft at base 39.0 (27.0 - 42.0)μ and 18.6 (17.0 - 21.0) μ at mid-length, tapered to a fine point.

Isomermis Coman, 1953 (modified from Welch, 1962a).

Length 9 - 17 mm.; mouth terminal; amphids large; six cephalic papillar groups; male and female adult tails tapered to rounded terminus. Male: two medium-sized spicules; tail papillae in three single rows bifurcating around the spicule opening. Female: with S-shaped vagina, with weakly developed vulval cone.

Isomermis wisconsinensis Welch, 1962 (Fig. 11, I, L).

Male: six specimens. Body length 15.0 (9.8 - 16.4) mm. Body width at level of head papillae 75.2 (60.0 - 80.0)μ , and at spicule opening 136.2 (125.0 - 150.0) μ. Two spicules 210.0 (200.0 - 250.0) μ long, 10 μ wide at mid-length. Spicules extended appear separated, when withdrawn, appear as one in lateral view.

BIONOMICS

Life Cycle.

The life cycle of *N. flumenalis* is similar to that described by Phelps and DeFoliart (1964) for *Gastromermis viridis* and *Isomermis wisconsinensis*.

Female *N. flumenalis* worms laid eggs in the laboratory on the Scotchbrite and sand substrates. All eggs examined shortly after laying were unembryonated, which agreed with the results of Phelps and DeFoliart (1964) for *G. viridis* and *I. wisconsinensis*. However, examination of one preserved female, which died during egg-laying, showed that some eggs had full term, coiled larvae.

In September, 1971, one female laid 200 eggs in the Scotchbrite substrate, but died before completion of oviposition; approximately 400 eggs remained in the ovaries. The interval between mating and oviposition of this worm, maintained at 21°C. except for the night prior to egg-laying when the temperature dropped to 4°C., was 75 days. Possibly the lowered temperature regime initiated oviposition.

In 1972, females maintained at 12° and 18°C. on Scotchbrite substrates did not oviposit. In August, 1972, 14 of 39 females (35.8%) maintained at 12°C. oviposited on sand substrates, suggesting that this substrate was superior to Scotchbrite for oviposition, but not as good for observation of molting and mating. Initiation of oviposition could not be determined precisely for 10 females, but all oviposited 36 - 59 days post-mating; four females oviposited 56-59 days after mating; one of them laying 650 eggs over a three day period.

Eggs of the approximate same age and all maintained at 12°C. following laying, were placed at temperatures of 3°, 12°, 18° and 22 - 24°C. (room temperature); the eggs were embryonating. Eggs placed at 18° and 22 - 24°C. died within two days; eggs maintained at 3°C. completed embryonation after 95 days but did not hatch, although coiled, motile larvae could be seen in the eggs 150 days following laying. Eggs maintained at 12°C. hatched, producing pre-parasitic larvae 35 - 55 days after oviposition, with most eggs hatching 39 - 46 days after they were laid. In an attempt to simulate hatching under natural temperature regimes encountered in the field during October, some eggs were transferred from 3° to 7°C., but after 120 days these eggs, although obviously still viable, had not hatched.

Phelps and DeFoliart (1964) stated that eggs of *G. viridis I. wisconsinensis* were not resistant to dessication but shrivelled if dried, returning to normal if placed back in water. In this study viable eggs of *N. flumenalis* were air dried at 12°C. for 15 minutes until shrivelled, returning to normal when flooded with water. The theory proposed by Phelps and DeFoliart (*op. cit.*) that as *N flumenalis* was obtained from temporary streams in Wisconsin, its eggs might be resistant to dessication, proves to be unfounded. All dessicated eggs of *N. flumenalis* died.

Johnson (1955) reported survival rates of 12 days at 2°C and 6 days at 17°C. for the pre-parasites of *Hydromermis contorta*. Pre-parasites of *Reesimermis nielseni* were observed to survive 3 - 4 days after hatching (Tsai and Grundmann, 1969; Petersen *et al.*, 1968). Phelps and DeFoliart (1964) reprted that the pre-parasites of *G. viridis* and

I. wisconsinensis survived for 1 - 2 days at 23.9°C. and 3 days at 14.4 - 15.6°C.

In this study, pre-parasites of *N. flumenalis*, upon hatching at 12°C., had long, whip-like tails used to aid in propulsion and appeared to lack any guided directional movement. The pre-parasites were most active on the day of emergence but became progressively more sluggish until they died 2 - 3 days later. Motility of the pre-parasites may be a prerequisite to establishment of infection in blackflies, and if so, then infection potential in *N. flumenalis*, like that in *G. viridis* and *I. wisconsinensis* (Phelps and DeFoliart, 1964), may be lost after one day.

Mermithid pre-parasites of chironomids, culicids and tabanids have been reported by many workers to enter the host via cuticular penetration (Iyengar, 1927; Comas, 1927; Svabenik, 1928; Johnson, 1955; Welch, 1960; Petersen *et al.*, 1967; Tsai and Grundmann, 1969; Shamsuddin, 1966; Wulker, 1970). Strickland (1911) postulated that cuticular penetration of blackflies by the pre-parasites was possible, but he felt that ingestion of the infective stage by the blackfly, thereby permitting penetration of the gut wall and entrance to the hemocoele, was more likely. Phelps and DeFoliart (1964), following laboratory studies, produced inconclusive evidence that infection of blackflies occurs via ingestion of the infective pre-parasites. Rubtsov (1971) similarly found that blackflies become infected by ingestion of the pre-parasitic stage.

Laboratory infections at 12°C. with small *P. fuscum/ mixtum* larvae and the pre-parasites of *N. flumenalis* were unsuccessful. The simuliid larvae and preparasites were placed together in 500 ml. of stream water in the rearing cylinders in ratios of 1:1 (40 simuliids and 40 pre-parasites) and 2:1 (70 simuliids and 35 pre-parasites).

Observations under the dissecting microscope showed that *N. flumenalis* pre-parasites, like those of *G. viridis* and *I. wisconsinensis* (Phelps and DeFoliart, 1964) were not attracted to the simuliid larvae, even when they were in contact with each other. This is taken to support the theory of infection by ingestion.

Ingestion of pre-parasites was not observed, but two blackflies were noted to seize with their mouthparts, the posterior extremities of the pre-parasite's tail, but the pre-parasites thrashed wildly and escaped.

Parasitic development is initiated when the pre-parasites enter the hemocoele of the simuliid host. The duration of the parasitic development varies with the host and the time of year in which the infection was acquired. In the *P. fuscum/mixtum* populations, infections occurred in the fall; the parasites overwinter in the host, emerging in the spring after approximately seven months development (Figs. 12, 13). The summer simuliids, *S. latipes* and *S. venustum*, become infected in early summer, the development of parasites taking four to eight weeks before emergence (Figs. 12, 13).

The mode by which mermithids feed is largely unknown, but Rubtsov (1967c) proposed that the blackfly mermithids, *Isomermis* sp. and *Mesomermis* sp. secrete proteolytic enzymes through the cuticle which pre-digest the host fat body, releasing nutrients (fats, proteins and probably amino acids) which are absorbed via cuticular endosmosis. This view is not supported by Gordon and Webster (1971) and Gordon *et al.* (1973).

Gordon and Webster (1971) working with the mermithid *Mermis nigrescens* from the desert locust, *Schistocerca gregaria*, demonstrated that parasitism effected a decrease in the total level of host hemolymph

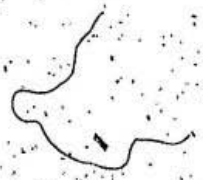


Figure 12.

Seasonal fluctuations of *N. flumenalis* populations in Half Moon Brook.

Arrow indicates time of infection of *Prosimulium* species.

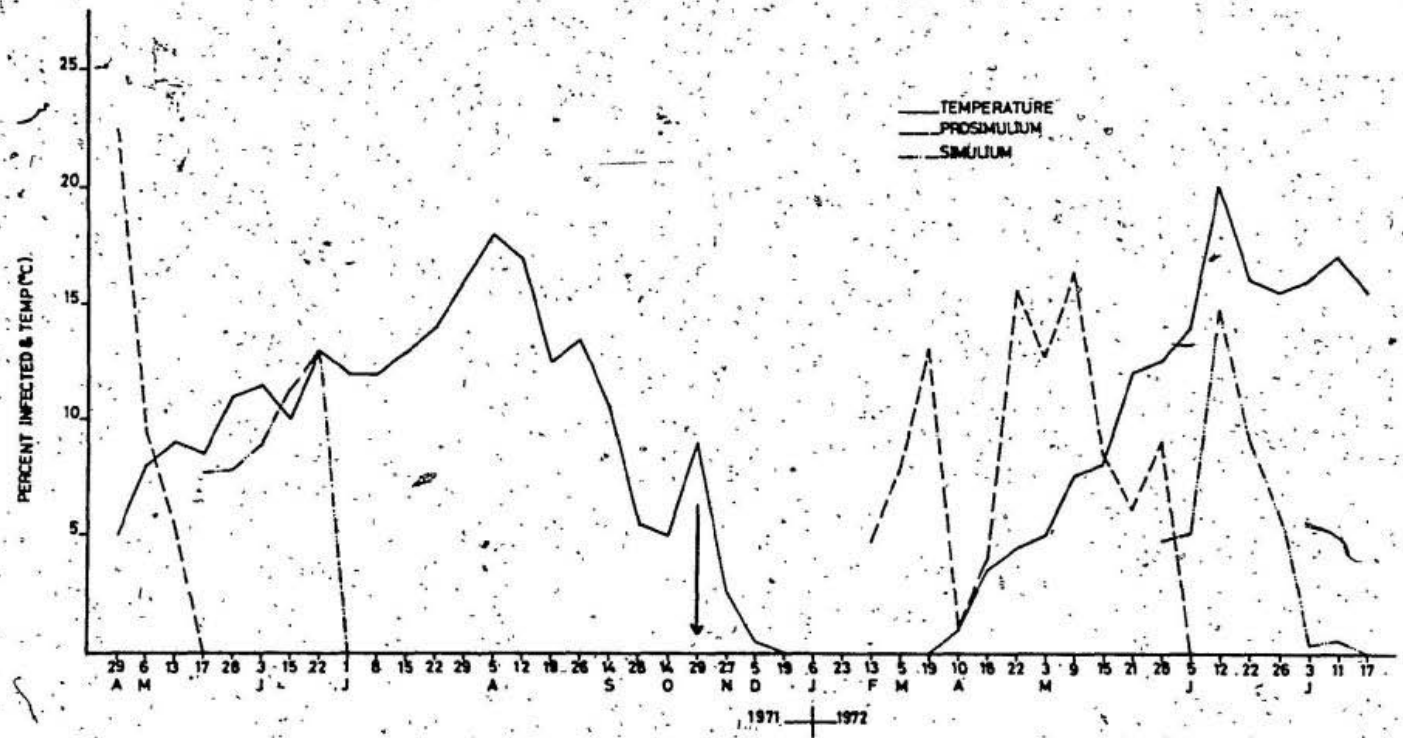
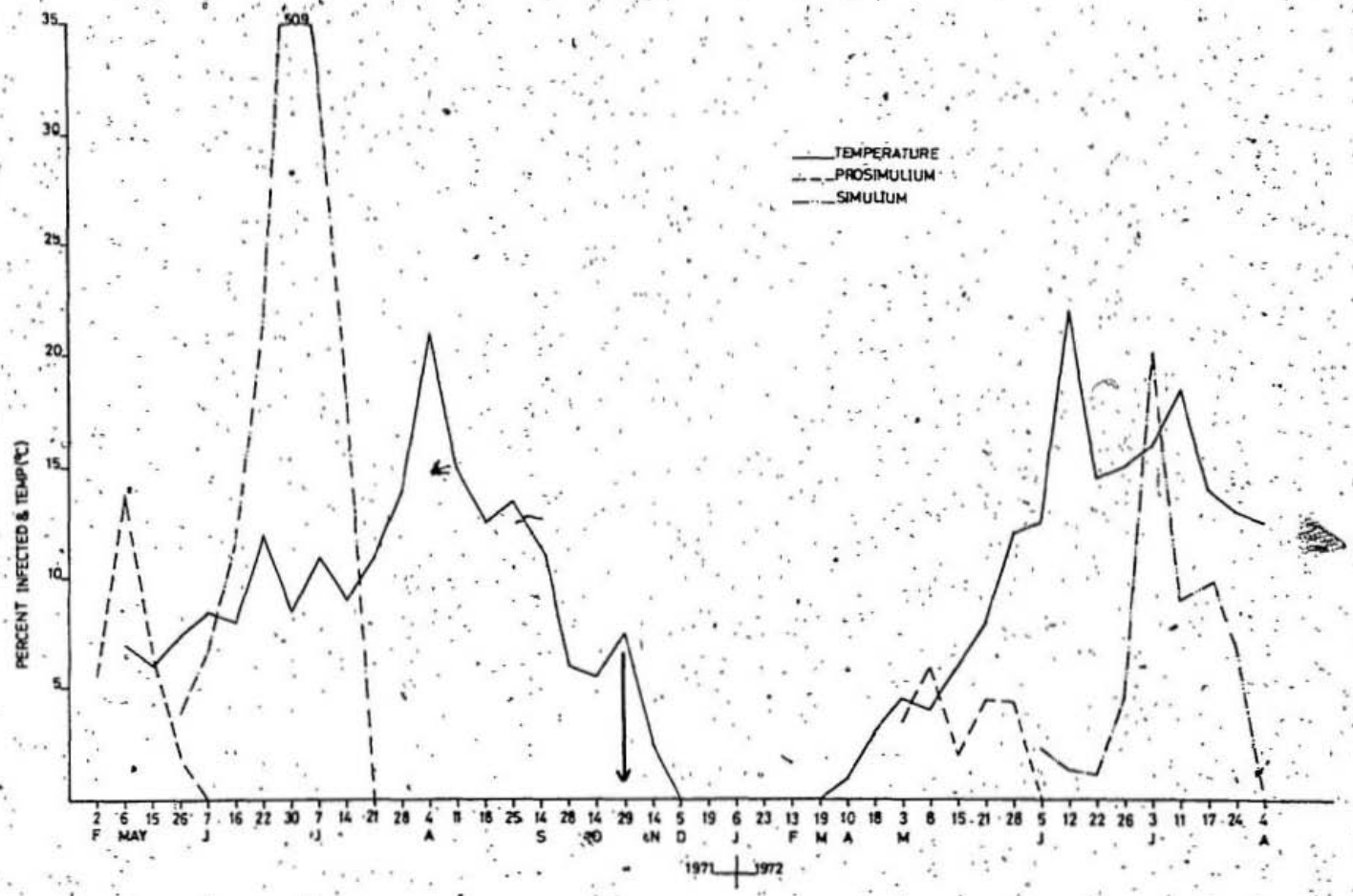

TEMPERATURE
PROSIMULIUM
SIMULIUM
PERCENT INFECTED & TEMP (°C).
25
20
15
10
5
29 6 13 17 28 3 15 22 1 8 15 22 29 5 12 19 26 14 28 14 29 27 5 19 6 23 13 5 19 10 16 22 3 9 15 21 28 5 12 22 26 3 11 17
A M J L J A S O N D J F M A M J J
1971 1972

Figure 13.

Seasonal fluctuations of *N. flumenalis* populations in Long Pond Tributary.

Arrow indicates time of infection of *Prosimulium* species.


TEMPERATURE
PROSIMULIUM
SIMULIUM
PERCENT INFECTED & TEMP(°C)
509
35
30
25
20
15
10
5
2 6 15 26 7 16 22 30 7 14 21 28 4 11 18 25 14 28 14 29 14 5 19 6 23 13 19 10 18 3 8 15 21 28 5 12 22 26 3 11 17 24 4
F MAY J J A S O N D J F M A M J J A
1971 1972

carbohydrates, while Gordon *et al.* (1971) indicated that the nematode also depleted the fat body non-glycogen carbohydrates, which suggested that *M. nigrescens* utilized the essential carbohydrate precursors in the hemolymph before incorporation into the fat body during glycogenesis. It would seem, therefore, that the host's blood carbohydrates provide the nematode with an energy source needed for the structural and metabolic requirements of the free-living, non-feeding adult stages (Rubtsov, 1965, 1966d; Gordon *et al.*, 1973), and for rapid parasitic growth and protein storage (Chitwood and Jacobs, 1938; Baylis, 1947).

Gordon and Webster (1971) also noted that mermithid parasitism, although not reducing the total level of blood proteins and amino acids, did effect a reduction of proteins and amino acids in the fat body which suggested that the nematode stimulated fat body catabolism. The breakdown of the fat body protein and the release of the amino acids into the hemolymph would furnish the parasite with a suitable and readily available source of protein nitrogen for active uptake. In this manner, the host hemolymph maintained a relatively constant level of amino acids throughout the parasitic development of *M. nigrescens*.

The mermithid presumably ingests the low molecular weight metabolites (amino acids and carbohydrates) from the hemolymph via the non-muscular esophagus (Gordon and Webster, 1972) and not via the cuticle as suggested by several workers (Steiner, 1933; Chitwood and Jacobs, 1938; Baylis, 1947; Rubtsov, 1965). Although the method of obtaining nutrients in simuliid mermithids is unknown, it is possible that mechanisms similar to those in *M. nigrescens* may also exist, but these remain to be demonstrated.

The parasitic phase of the *N. flumenalis* life cycle is found

coiled up in the ventral region of the abdominal enlargement of the larval blackfly host, causing displacement of the intestine. In late parasitic stages the simuliid abdomen was frequently distended by the worms and transparent due to fat body depletion. The color of *N. flumenalis* infected simuliids was usually reddish brown in comparison to the normal greyish-brown, green or brown pigmentation of uninfected individuals. The various histoblasts of pupal and adult organs were poorly developed and pupation rarely occurred in simuliids infected with *N. flumenalis*. Parasitized larvae were also less active and did not react as readily to probing as did normal blackflies. These observations are similar to those of Strickland (1911) and Phelps and DeFoliart (1964).

N. flumenalis when prepared for emergence from the host, does so by pushing with the head region at the weak intersegmental regions of the abdomen (Fig. 14). In some instances, emergence is via natural openings such as the anus and mouth. Emergence, which kills the host, probably through the loss of hemolymph and mechanical damage, is usually completed in less than 5 minutes. Emergence of mermithids from dead simuliid hosts was not observed.

Mermithids, subsequent to emergence, drop to the substrate and are termed free-living post-parasitic juveniles. Post-parasitic *N. flumenalis* females were found in the stream substrates, coiled around vegetation or tightly coiled on the upper surface of rocks in the swiftly flowing current. On one occasion, one mermithidwas found in an empty pupal case of *S. venustum*, but emergence from an infected pupa

Figure 14.

N. flumenalis emerging from *S. venustum*.
(Linear magnification X 10.0).

could not be established.

Post-parasitic juvenile mermithids were maintained at four temperatures (6°, 12°, 18° and 22 - 24°C.). All 39 mermithids maintained at 24°C. died within 4 days. Mermithids maintained at 18°C. molted to the adult stage in 10 - 13 days, but a 50% mortality of the 126 worms was experienced. Of the 388 mermithids held at 12°C., 26% died, but the rest molted to the adult stage in 9 - 15 days. Mermithids held at 6°C. required 37 - 40 days to molt to the adult stage, but 83% of the 48 worms died. A temperature regime of 12°C., based on mortality, was therefore considered to be optimal. Male and female *N. flumenalis*, at specified temperatures in the laboratory, molt at the same rate.

Phelps and DeFoliart (1964) showed that molting commenced 12-18 days and 6 - 9 days post emergence for *G. viridis* and *I. wisconsinensis* reared at 14.4 - 15.6°C. In this study, isolated observations on molting at 12°C., indicated that *G. viridis* molted in 13 - 20 days, while *I. wisconsinensis* molted in 9 - 10 days after host emergence. Mating and egg production were not noted in either *G. viridis* or *I. wisconsinensis*.

The number of molts in the Mermithidae has been subject to considerable controversy, since the usual four nematode molts have not been previously described. Poinar and Gyrisco (1962) reported a double pre-adult molt following emergence of *Hexamermis arvalis*. A single molt was also discovered within the egg. Poinar (1964) reported only a double pre-adult molt from *Orthomermis oedobranchus*, while Ipateva (1966) figured the same for *H. albicans* and *H. kirjanovae*. Poinar (1968) found only a single pre-adult molt plus a molt in the egg of *Hydromermis conopophaga*. Phelps and DeFoliart (1964) recorded only a single

pre-adult molt of a thick cuticle and a parasitic molt of a thin cuticle 2 - 3 days prior to emergence from the host. Sometimes, however, the parasitic cuticle remained attached to the outside of the post-parasitic cuticle, both being shed together.

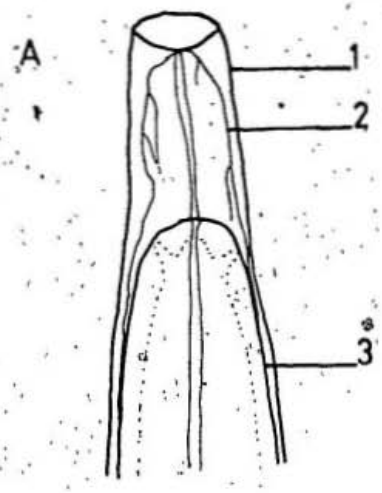
In this study, a double pre-adult molt (Fig. 15,), consisting of a thick outer and a thin, inner cuticle was found in *N. flumenalis*. Occasionally, parasitic worms, following dissection, were noted to be molting a thin, membranous cuticle, at least one month before emergence from the *Prosimuliums* and two weeks before emergence of the *Simulium* mermithids. The size of the mermithids at this time was approximately three-quarters the length and two-thirds the width of normal emerged post-parasitic juveniles. No molt within the egg was noted. Both *G. viridis* and *I. wisconsinensis* were noted to have a single pre-adult molt which confirms the data of Phelps and DeFoliart (1964).

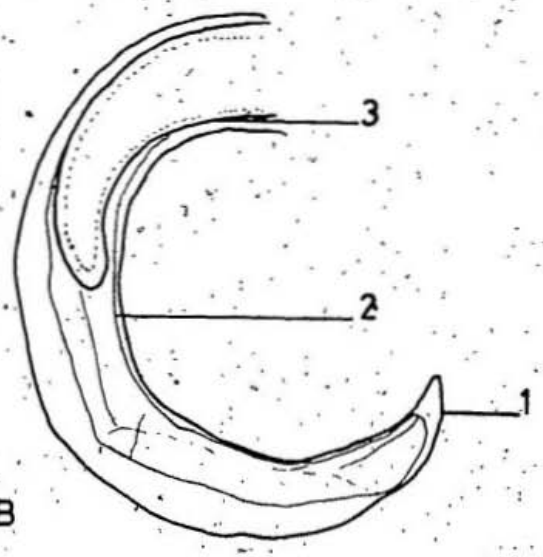
The molting process in *N. flumenalis* is similar to that described by Poinar and Gyrisco (1962) for *Hexamermis arvalis*. An impending molt is indicated by the presence of a double cuticle. Molting to the adult stage begins with a transverse split in the cuticle one-quarter to one-third the body length posterior to the mouth. The anterior and posterior portions are worked off the new cuticle underneath, the anterior portion being molted together with the esophageal lining before the posterior portion. The molting of the thin inner cuticle is initiated when the anterior portion of the outer cuticle has slightly separated from the new cuticle underneath. Shedding of the thick outer cuticle and the thin inner cuticle is completed together.

Mating frequently commenced within a few hours of molting to the

Figure 15.

Semidiagramatic. Pre-adult molt in *N. flumenalis*.
1. Thick outer cuticle. 2. Thin inner cuticle.
3. Adult cuticle.


A
1
2
3


3
2
1
B

adult stage, but may occur up to 14 days afterwards. Mating of individuals often continued for 1.5 - 2 days, but was usually completed in 12 - 24 hours. Christie (1929) found that *Agamermis decaudata* males mated more than once while Phelps and DeFoliart (1964) recorded that both sexes of *Gastromermis viridis* and *Isomermis wisconsinensis* mated only once, but on five occasions *N. flumenalis* adult males and females were noted to mate twice and one pair mated three times; sex ratios were maintained at 1:1 throughout these studies.

Recently mated females may be frequently recognized by the presence of a brown amorphous substance clinging to the outside of the vulva. Closer examination reveals this substance within the vulva itself, possibly functioning as a sperm plug.

Parthenogenesis has been reported for mermithids (Christie, 1929; Couturier, 1963). Limited observations on isolated *N. flumenalis* adult females indicated that parthenogenesis does not occur. Similar observations were made on *G. viridis* and *I. wisconsinensis* (Phelps and DeFoliart, 1964).

Briefly summarizing the *N. flumenalis* life cycle, molting to adults occurred in 9 - 15 days post-emergence at 12°C., 10 - 13 days at 18°C., 37 - 40 days at 6°C., and failed to occur at 22 - 24°C. Mating usually followed within a few hours, but occasionally occurred up to 14 days afterwards, continuing usually for 12 - 24 hours. Eggs were laid after 36 - 59 days post-mating. Females have an egg-laying potential of 600 - 650 eggs, and lay them over a period of three days. An incubation period of 35 - 55 days was recorded at 12°C., with the greatest number hatching 4 - 11 days after the onset of hatching. No

eggs were laid at 3°, 7°, 18°, or 22 - 24°C. The pre-parasite life span was 2 - 3 days. At 12°C., the total time elapsed from host emergence to egg-laying was 45 - 74 days, and from emergence to egg hatching, 80 - 129 days. Parasitic development takes approximately seven months in the *Prosimulium* and 4 - 8 weeks in the *Simulium* generations.

Mixed Infections.

Mixed infections (more than one species of parasite per host) were recorded on a number of occasions throughout this study. Fourteen different instances of mixed infections (Table 6) involved four microsporidan species, *Thelohania bracteata*, *T. fibrata*, *Plistophora simulii* and *Caudospora simulii* 13 times, the fungus *Coelomycidium simulii* twice and the mermithid *N. flumenalis*, six times. The combinations *T. fibrata* and *P. simulii*, *T. bracteata* and *N. flumenalis* and *P. simulii* and *N. flumenalis* were each recorded twice from the simuliid hosts. *Thelohania bracteata* and *T. fibrata* were recovered five times from infected simuliids; the remaining combinations all occurred once.

Rubtsov (1971) stated that he failed to find any mixed infections between blackfly microsporida and mermithids, but did frequently encounter *Coelomycidium simulii* and mermithids occurring together. He suggested that mermithids and microsporida were incompatible, and depending upon which parasite entered the host first, a defence or immune reaction was initiated by that parasite against subsequent infections. Thus, only microsporida or mermithids, never both, were maintained in the host.

TABLE 6

MIXED PARASITE INFECTIONS RECOVERED FROM NEWFOUNDLAND BLACKFLIES

Stream Number	Date	Blackfly Species	Parasite	Total Hosts Examined	Number Infected	Percent Infection
60	27/V /72	*P. mixtum*	*C. simulii* + *N. flumenalis*	24	1	4.1
65	12/VI /72	*S. corbis*	*T. bracteata* + *T. fibrata*	93	1	1.0
4	25/VI /71	*S. venustum*	*T. bracteata* + *N. flumenalis*	32	1	3.1
6	2/VII/71	*S. venustum*	*T. bracteata* + *Coel. simulii*	8	1	12.5
62	7/VII/71	*S. venustum*	*T. fibrata* + *P. simulii*	38	1	2.6
62	7/VII/71	*S. venustum*	*T. bracteata* + *T. fibrata*	38	1	2.6
63	7/VII/71	*S. venustum*	*T. bracteata* + *T. fibrata*	248	1	.40
16	8/VI /72	*S. venustum*	*T. fibrata* + *P. simulii*	134	1	.79
67	15/VI /72	*S. venustum*	*Coel. simulii* + *N. flumenalis*	1536	1	.06
63	3/VII/72	*S. venustum*	*T. bracteata* + *T. fibrata*	333	1	.30
63	11/VII/72	*S. venustum*	*P. simulii* + *N. flumenalis*	663	1	.15
63	17/VII/72	*S. venustum*	*T. bracteata* + *N. flumenalis*	245	1	.40
63	24/VII/72	*S. venustum*	*P. simulii* + *N. flumenalis*	232	1	.43
10	2/VII/71	*S. vittatum*	*T. bracteata* + *T. fibrata*	60	1	1.6

Strickland (1911) noted that mixed infections with mermithids and microsporida occurred in blackflies, but in each instance, the worm was very small (less than 7 mm. in length). In this study, mermithids when recovered from microsporidan or Coelomycidian-infected blackflies were never more than 5 mm. in length. It is likely that mixed infections involving these parasites had an overall deleterious effect on the mermithid by creating a competition for the available food supply.

Host/Parasite Seasonal Fluctuations

To obtain some indication of the size and age of the simuliid populations under investigation, and the stages of development at which the simuliids acquired their mermithid infections, a larval aging technique was modified from Sommerman *et al.*, (1955). Five larval age classes (Fig. 16), based on observations at 20X under the dissecting microscope, were used: small, 1 - 2 mm. in length, lacking any indication of histoblasts; medium-small, 2 - 4 mm. in length, histoblasts evident, but appearing as small, white dots on the thorax; medium-large, 4 - 8 mm. in length, with large obvious structurally undifferentiated white histoblasts; maturing, the pupal respiratory filaments present and white; mature, pupal respiratory filaments light brown to black. Parasitized larvae, even those up to 8 mm., usually possessed reduced histoblasts; in this case, body size alone was used to assign the simuliid to an age class.

Regular collections of simuliid larvae, from Half Moon Brook and Long Pond Tributary were made during April 1971 to August 1972.

Figure 16.

Simuliid age classes. L-R. Mature, maturing, medium-large, medium-small, small. (Linear magnification X 6.0).

The results of the seasonal fluctuation study (Figs. 12, 13, Tables 7, 8) indicate that *N. flumenalis* was found in the 1971 simuliid populations from as early as February (Fig. 13, Table 8) to the end of July, but was not found in simuliids after the end of July through to February (Half Moon Brook) and early May (Long Pond Tributary) in 1972.

N. flumenalis is a univoltine mermithid species which infects the univoltine *P. fuscum/mixtum* generations, and only the first generations of the multivoltine *S. venustum* and *S. latipes* populations.

Mermithids were most prevalent in the *Prosimulium* species in late April to early May, and in the *Simulium* species from mid-June to early July for both streams (Figs. 12, 13). Mermithid population peaks, during these periods, are not the result of an increasing infection rate, but are due to the maturation and pupation of healthy larvae with mermithid infected blackfly populations being residual. When collections are made at such times, false indications of the actual incidence of parasitism are obtained, since the overall total infection rate is not increasing, but decreasing, due to mermithid emergence from the hosts. Thus, seasonal variation in levels of parasitism for the two study areas prevents definitive determination of simuliid control obtained by *N. flumenalis*. However, it is possible to obtain an index to simuliid control from an average of the infections incurred in each simuliid population. Thus the level of control obtained with *N. flumenalis* for the 1971/1972 simuliid populations in Half Moon Brook and Long Pond Tributary would be in the range of 3 - 23%.

Egg hatching may be influenced by chemical parameters (viz. pH, dissolved oxygen, etc.) in the stream water, but in view of their general

TABLE 7

SEASONAL FLUCTUATIONS OF HOST SIMULIID/*N. FLUMENALIS* POPULATIONS IN HALF MOON BROOK

Date	Blackfly Species	Blackfly Age Class										Overall Infection (%)
		Small		Medium-small		Medium-large		Maturing		Mature		
		A*	B**	A	B	A	B	A	B	A	B	
29/IV /71	*P. fuscum/mixtum*	–	–	–	–	45	40	84	1	53	–	22.5
6/ V /71	" " "	–	–	–	–	54	15	53	–	51	–	9.5
13/ V /71	" " "	–	–	–	–	31	7	54	–	40	–	5.3
17/ V /71	*S. venustum*	13	1	–	–	–	–	–	–	–	–	7.1
28/ V /71	"	–	–	13	1	90	11	42	–	9	–	7.8
3/VI /71	"	–	–	21	2	38	6	19	–	12	–	8.9
15/VI /71	"	–	–	–	–	67	14	45	–	12	–	11.3
22/VI /71	"	–	–	2	–	40	16	39	–	42	–	13.0
13/II /72	*P. fuscum/mixtum*	25	–	5	4	54	–	–	–	–	–	4.8
5/III/72	"	–	–	12	2	104	7	–	–	–	–	7.8
19/III/72	"	–	–	–	–	44	8	17	–	–	–	13.1
10/IV /72	"	–	–	–	–	68	1	19	–	7	–	1.1
18/IV /72	"	3	–	–	–	68	5	39	–	11	–	4.1
22/IV /72	"	1	–	–	–	23	5	6	–	2	–	15.6

TABLE 7 (CONTINUED)

Date	Blackfly Species	Blackfly Age Classes										Overall Infection (%)
		Small		Medium-small		Medium-large		Maturing		Mature		
		A*	B**	A	B	A	B	A	B	A	B	
3/ V /72	*P. fuscum/mixtum*	-	-	-	-	230	42	51	-	48	-	12.8
9/ V /72	"	-	-	14	-	157	73	146	-	127	-	16.4
15/ V /72	"	-	-	6	1	90	18	60	-	67	-	8.5
21/ V /72	"	-	-	6	-	21	5	34	1	42	-	6.1
28/ V /72	"	-	-	-	-	4	1	2	-	5	-	9.1
28/ V /72	*S. venustum*	50	4	33	-	-	-	-	-	-	-	4.8
5/ VI/72	"	18	1	63	6	179	8	27	-	5	-	5.1
12/ VI/72	"	21	4	53	2	136	44	75	-	53	-	14.8
22/ VI/72	"	9	-	52	3	250	35	72	-	37	-	9.1
26/VI/72	"	15	-	70	3	345	28	107	-	56	-	5.2
3/VII/72	"	21	-	149	-	402	3	82	-	70	-	.41
11/VII/72	"	-	-	16	-	101	1	43	-	20	-	.55

* A uninfected simuliids.
**B infected simuliids.

TABLE 8

SEASONAL FLUCTUATIONS OF HOST SIMULIID/*N. FLUMENALIS* POPULATIONS IN LONG POND TRIBUTARY

Date	Blackfly Species	Blackfly Age Classes										Overall Infection (%)
		Small		Medium-small		Medium-large		Maturing		Mature		
		A*	B**	A	B	A	B	A	B	A	B	
20/II /71	*P. fuscum/mixtum*	-	-	3	-	51	3	-	-	-	-	5.6
6/ V /71	"	-	-	8	-	9	9	29	-	19	-	13.8
13/ V /71	"	-	-	1	-	20	5	33	-	21	-	6.7
26/ V /71	"	-	-	-	-	58	4	75	-	72	-	1.9
26/ V /71	*S. venustum*	30	5	126	1	-	-	-	-	-	-	3.8
26/ V /71	*S. latipes*	-	-	3	1	1	-	1	-	-	-	20.0
7/VI /71	"	-	-	1	-	7	5	4	-	2	-	35.7
7/VI /71	*S. venustum*	9	-	56	11	161	12	74	-	43	-	6.7
16/VI /71	"	5	-	32	2	52	18	51	-	32	-	11.6
22/VI /71	"	-	-	29	3	77	31	23	-	28	-	21.7
30/VI /71	"	-	-	9	1	173	129	46	-	27	-	51.0
7/VII/71	"	-	-	-	-	127	82	52	-	69	-	33.1
14/VII/71	"	-	-	3	-	59	25	39	-	36	-	18.2
3/ V /72	*P. fuscum/mixtum*	-	-	-	-	50	40	26	-	38	-	3.5
8/ V /72	"	-	-	2	-	19	4	26	-	20	-	6.0

TABLE 8 (CONTINUED)

Date	Blackfly Species	Blackfly Age Classes										Overall Infection (%)
		Small		Medium-small		Medium-large		Maturing		Mature		
		A*	B**	A	B	A	B	A	B	A	B	
15/ V /72	*P. fuscum/mixtum*	–	–	–	–	36	2	6	–	58	–	2.0
21/ V /72	"	–	–	–	–	26	3	12	–	30	–	4.4
28/ V /72	"	–	–	–	–	25	3	30	–	14	–	4.3
5/VI /72	*S. latipes*	–	–	–	–	7	1	6	–	–	–	7.7
5/VI /72	*S. venustum*	4	1	24	–	14	–	–	–	–	–	2.4
12/VI /72	"	1	–	4	3	208	–	8	–	–	–	1.4
22/VI /72	"	28	–	52	–	124	4	85	–	36	–	1.2
26/VI /72	"	–	–	68	5	108	10	93	–	63	–	4.5
3/VII/72	"	–	–	15	12	209	58	71	–	53	–	20.1
11/VII/72	"	–	–	60	–	341	60	122	–	140	–	9.1
17/VII/72	"	–	–	11	–	142	24	55	–	37	–	9.8
24/VII/72	"	–	–	4	–	77	16	89	–	62	–	6.9
30/VI /71	*S. venustum*†	–	–	9	–	173	2	46	–	27	–	.78
26/VI /72	"	–	–	68	3	108	–	93	–	63	–	.9
3/VII/72	"	–	–	15	4	209	–	71	–	53	–	1.1
11/VII/72	"	–	–	60	–	341	1	122	–	140	–	.15

* A uninfected simuliids.
**B infected simuliids.
† infected with *Isomermis wisconsinensis*.

seasonal uniformity (Appendix 5, Table 5), the effect is probably slight, thus, it is likely that egg hatching is dependent on the seasonal fluctuations of temperature (Figs. 12, 13). *N. flumenalis*, therefore, has two periods of egg hatching; the emerging preparasites infecting the *Prosimulium* species in the fall and the *Simulium* generation in the spring.

Although data on the acquisition of infection by the *Prosimulium* generations was missed in 1971, due to high water levels and flooding which prevented collection of larvae during November, and because no infected material was collected until February (Half Moon Brook) and May (Long Pond Tributary) 1972, data obtained in mid-October 1972 indicated that the *Prosimulium* populations of both streams had recently hatched and were infected by October 11. Only small *Prosimulium* larvae were present and infected, with infections of 26.6% (Half Moon Brook) and 17.8% (Long Pond Tributary) being recorded. Water temperature at the time of collection was 7.0°C. From laboratory life cycle data previously considered, egg hatching was found to occur at 12°C., but not at temperatures of 7.0°C. It is possible, however, that under field conditions mermithid eggs hatch in the general range of 7.0 - 12°C.

It is probable that the *Prosimulium* generations of 1971 became infected at the end of October. Infection probably would not have occurred before the middle of October, as observations at Pickavance Creek (Lewis, personal communication) indicated that the *Prosimulium* generation did not hatch before the end of October, and no reason has yet been found to significantly alter the hatching date for the two streams studied here.

Infection of the *Simulium* generations occurred from the middle of May to the first of June in 1971 and 1972. The age class data (Tables 7, 8) indicate that the small and medium-small larvae were the first age classes to become infected. It is possible that both the small and medium-small larvae become infected during this period, but it is considered more likely, based on the larger size of dissected parasites of medium-small larvae, that the small age class is the prime stage at which infection occurs. Dissected parasites of small larvae were less than 2.0 mm. in length and many still possessed their stylets, while parasites of medium-small larvae were larger, 2 - 4 mm. indicating a longer developmental period and an earlier infection than the small larvae collected on the same date.

Isomermis wisconsinensis probably overwintered in the egg stage and was first found in *S. venustum* at the end of June 1971 and 1972 (Table 8). It is unlikely that they overwintered as preparasites since their life span at 14.4 - 23.9°C. is only 1 - 3 days. (Phelps and DeFoliart, 1964). Two females were collected 30/VI/71, while 6 males infected 3 simuliids 26/VI/72, 4 simuliids yielded 1 female and 6 males, 3/VII/72, and 1 female was found 11/VII/72.

Infected *Simulium* populations were first noted in the spring when the stream temperature was in a range of 7.5 - 12.5°C. (Figs. 12, 13). It would seem, therefore, that both the *Prosimulium* and *Simulium* generations become infected during the fall and spring, when similar temperature regimes occur in the streams. Further research is needed, however, to precisely elucidate the temperature range, both in the field and laboratory, at which egg hatching and infections occur.

Based on the length of the laboratory life cycle in *N. flumenalis*, from host emergence to the hatching of eggs (80 – 129 days), it is highly improbable that the *Prosimulium* mermithids could develop sufficiently quickly to infect the *Simulium* generations of the same year. Consideration of the maximum developmental period (129 days), and the time at which mermithid emergence was completed (late May - early June), shows that mermithids derived from the *Prosimuliums* would probably be producing infective preparasites in early October, and hence, could infect the *Prosimuliums* which hatch at approximately this time. The *Simulium* mermithids, on the other hand, complete their emergence by the mid to end of July and theoretically would be producing preparasites in mid-December. However, as was previously demonstrated, eggs hatch in the general range of 7 – 12°C., and probably do not hatch at temperatures significantly below 7°C. As the temperature in the field in mid-December to mid-March, is close to 0°C. hatching probably does not occur until the spring when the water reaches an acceptable temperature, whereupon mermithid egg hatching occurs. In the spring the *N. flumenalis* hatching temperature (7 – 12°C.) probably coincides with the timing of hatching of the first *Simulium* generation in late May - early June. Thus, it would appear that the *N. flumenalis* life cycle is well synchronized with that of its hosts and that mermithids derived from *Prosimuliums* and *Simuliums* infect only the respective *Prosimulium* and *Simulium* generations of the subsequent year during October and April – May.

Prosimulium and *Simulium* generations usually become infected during the small and, possibly in some instances in the medium-small larval stage. This is further supported by Strickland (1911), Anderson

and DeFoliart (1964), Anderson and Dicke (1960) and others, who recorded that mermithid parasitism in blackflies inhibited pupal histoblast development such that infected larvae failed to pupate. As normal histoblast development is initiated in early larvae life (the small to medium-small stages), it would be expected that if mermithid infections occurred during this period, pupal histoblast development would be impaired. This always occurred in *N. flumenalis* infected simuliids in this study, except for the data in Table 9 where, presumably as a result of late larval infections, histoblast development was only partially affected. *N. flumenalis* continued development in the host under such circumstances, and was carried over to larvae undergoing maturation and to pupae. *G. viridis* and *I. wisconsinensis* were also observed in these simuliid stages.

Adult flies were not examined for mermithids in this study, as experience in 1971 indicated that for all mermithid streams investigated, only a very small proportion (4 of 7351 or .05%) of maturing and mature larvae harboured mermithids. Thus, it was concluded that the potential number of mermithid infected adults would probably be even less than the number of infected pre-imagines, due to emergence from the host and longer exposure to predation, and hence adult investigations were not attempted.

The potential carryover of *N. flumenalis* to adult *P. fuscum/mixtum* and *S. venustum* populations (based on data extrapolated from the number of maturing and mature larvae and pupae harbouring mermithids, assuming all infected individuals pupate to adults), is .026 and .062% respectively (Table 9). All infected larvae, however, probably would not pupae to the adult stage, and therefore, the carryover potential is probably even

less than the figures cited above, but by what proportion is not known. Adult simuliids infected with *N. flumenalis*, however, do occur in Newfoundland as 2 of 87 *P. fuscum/mixtum* pupae collected from the Pickavance Creek area (20/V/71) and reared to adults, were infected (Lewis, personal communication).

In *S. corbis*, *S. vittatum* and *S. venustum* populations infected with *I. wisconsinensis* and *G. viridis*, the number of mermithids carried over to adult simuliids is probably higher than for *N. flumenalis*, since a significantly larger proportion of maturing and mature larvae harboured mermithids. Thus, the carryover potential may be close to 1.3% for *I. wisconsinensis* from *S. venustum*, 26.8% for *G. viridis* in *S. corbis*, and 13.7% in *S. vittatum* (Table 9). It is possible that with larger samples of *G. viridis* and *I. wisconsinensis* infected simuliids, a more precise estimation of the carryover potential may be ascertained.

With the carryover potentials of the three Newfoundland mermithid species, it would be logical to find *G. viridis* and *I. wisconsinensis* widely distributed, and *N. flumenalis* of restricted occurrence; such, however, is not the case as the reverse occurs. No explanation is currently available.

Welch (1964), Phelps and DeFoliart (1964) and Gordon *et al.* (1973) suggested that mermithid carryover to adult simuliids was a useful method of maintaining mermithids within the stream environment, and prevented them from being washed out of the stream. Since the carryover of *N. flumenalis* to adult simuliids is probably extremely low in Newfoundland, it is possible that alternate methods of maintaining them within the stream exist. Recent studies on the drift of benthic

TABLE 9

CARRYOVER POTENTIAL OF MERMITHIDS FROM INFECTED PRE-IMAGINES TO ADULT SIMULIIDS IN NEWFOUNDLAND

Blackfly Species	Total Simuliids Infected with the Parasites			Blackfly age class			Carryover potential (%)
	N. flumenalis	*G. viridis*	*I. wisconsinensis*	Maturing larvae	Mature larvae	Pupae	
P. fuscum/mixtum	7491*	-	-	2	-	-	.026
S. venustum	11284**	-	-	-	6	1	.062
"	-	-	377	1	4	-	1.3
S. corbis	-	93	-	2	23	-	26.8
S. vittatum	-	211	-	9	19	1	13.7

* Total pupae 1356
**Total pupae 2113

invertebrates have suggested that an alternative method is possible.

Elliott (1971) demonstrated that larval simuliids moved distances of 50 cm. upstream over a 24 hour period; movement occurred only during the night, with no migration upstream during the day. Elliott's study supports that of Ball *et al.*, (1963) who found that significant amounts of ^{32}P, incorporated into *Escherichia coli*, when introduced into a Michigan stream, were found one week later, 100 yards upstream in *Simulium*, *Physa* and *Isoperla;* two weeks later and 200 yards upstream in *Nigronia*, *Pteronarcys* and *Baetidae*, and five weeks after introduction in *Nigronia* and *Isoperla* at a distance of 500 yards upstream. The studies indicate that upstream migration of *Simulium* does occur, and it is also conceivable that mermithid-infected simuliids could also migrate upstream, and hence be maintained within the stream; this hypothesis, however, remains to be demonstrated.

Anderson and DeFoliart (1962) recorded 16 species of simuliids infected with mermithids in Wisconsin. *Gastromermis viridis* was found in 8 species, *I. wisconsinensis* in 10 and an unidentified mermithid in 10 blackfly species. Phelps and DeFoliart (1964) recorded *G. viridis* and *I. wisconsinensis* only from *S. vittatum*, but also recovered *N. flumenalis* from *P. magnum*, *C. mutata* and *S. venustum*. Abdelnur (1968) reported *S. vittatum* infected with *G. viridis* and *S. venustum* with *N. flumenalis*.

Of the 20 blackfly species previously mentioned in the distribution section, only 7 were found to be infected with mermithids. *Neomesomermis flumenalis* was found in 5 simuliid species, *G. viridis* and *I. wisconsinensis* each in two species. The remaining simuliid

species appeared to be refractile to infection in the wild state. It is possible that mermithid host specificity is a result of true physiological host specificity, but it would appear more logical, in light of the data above, that host specificity may be more closely related to the asynchronous development of the host/parasite life cycles. For example, *Cnephia mutata* co-exists in Long Pond Tributary with *P. fuscum/mixtum*, but was never infected with *N. flumenalis*. *Cnephia mutata* does not hatch until the middle-end of November, approximately one month after the *Prosimuliums*; this difference in hatching may explain why *C. mutata*, or the summer simuliids (viz. *S. gouldingi*, *S. aureum*, *S. verecundum* and others) which have later egg hatching times than *S. venustum*, do not harbour mermithid infections in Newfoundland, since the timing of their susceptible stages are probably not synchronized with the occurrence of the infective pre-parasites. Another possible explanation of host specificity may be related to the age of the host, which if too small or large when the pre-parasites are present in the stream may present physical barriers to the initiation of infection as 1) their mouthparts may be too small to enable ingestion of the pre-parasites; 2) or the intestine wall may be too thick or resilient in older larvae thereby preventing the pre-parasites from penetrating into the hemocoele. It is only by laboratory experimentation that the true host specificity of a given mermithid species can be determined for a wide range of simuliids.

Sex Ratio

The sex ratio of Mermithidae is generally accepted to be at least partially influenced by environmental factors. Many workers (Caullery and Comas, 1928; Christie, 1929; Kaburaki and Imamura, 1932; Kaburaki and Iyatomi, 1933; Parenti, 1962a, b; Phelps and DeFoliart, 1964; Petersen *et al.*, 1968; Petersen and Chapman, 1970; Petersen and Willis, 1970; Willis, 1971; Petersen, 1972) have demonstrated that as the number of mermithid parasites increased per host, the ratio of males to females also increased, and it was concluded that multiple infections tended to produce more males than females.

Johnson (1955) concluded that only 18.4% of sex determination in *Hydromermis contorta* was genetically fixed, and that the sex of the remaining 81.6% mermithids was determined by environmental factors. The actual physiological mechanism by which mermithid sex is determined has not as yet been discovered, but Johnson (*op. cit.*) suggested that increased parasite crowding in the host, decreases in the available food supply per parasite and an increase in the amount of excretory products accumulated in the host could be important factors in sex determination. Strelkov (1964) reported that the sex of *Filipjevimermis singularis* correlated with that of its host, that is, females were most often produced in female hosts and males in male hosts. Petersen (1972) demonstrated that nutrition had a noticeable effect on the sex ratio of *Reesimermis nielseni*, in that singly infected, starved hosts produced 92% males compared with 13% males from normally fed hosts. Similar results were obtained with 2 parasites per host; 97% males were produced from starved hosts as opposed to 83% in normally fed hosts. No starved

larvae with more than three parasites survived.

Sex ratios in *N. flumenalis* were determined in 1972 from emerged post-parasitic nematodes, and nematodes dissected from small to medium-large larvae of *P. fuscum/mixtum* and *S. venustum* from the two regular collection sites. Accurate sex ratios cannot be obtained from isolated observations based on one or two samples, as there are often extreme fluctuations from one collection day to another, and therefore, sex ratios were based on results of seasonal collections. Multiple infections were frequently recorded in the simuliids from Half Moon Brook and Long Pond Tributary, as well as in other Newfoundland streams, but no attempt was made to study in detail multiple infections and their effects on the sex ratio, since blackfly larvae were not separately reared. However, isolated observations, based on dissections and the occasional correlation or worms emerged from single hosts, gave some indication of the degree of multiple infection.

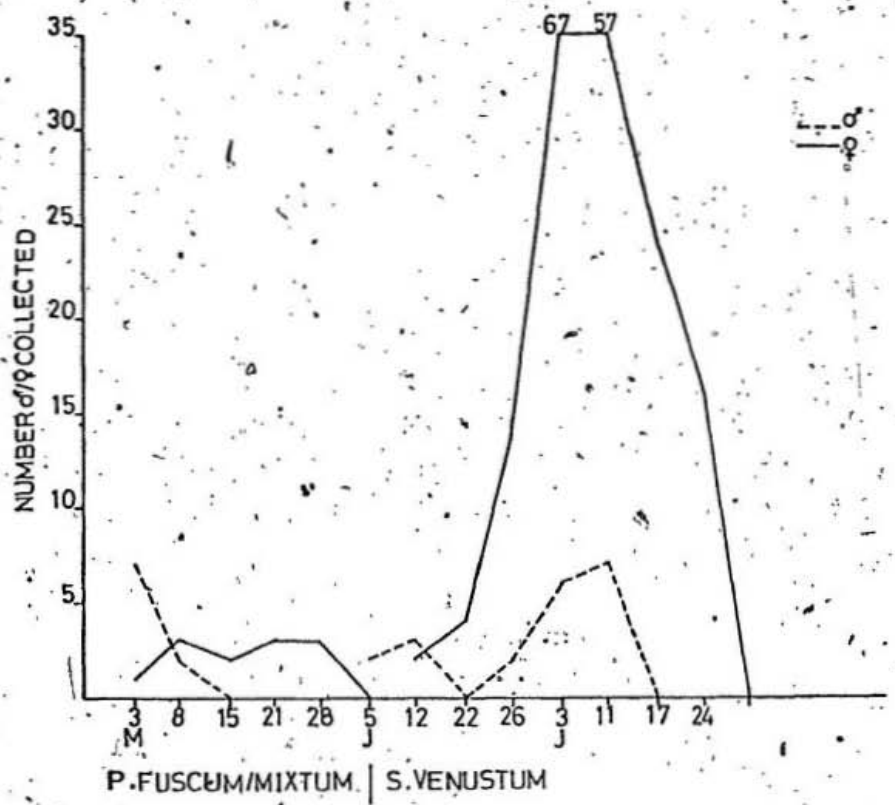
The seasonal sex ratio data, based on the total number of male and female mermithids recovered per collection (Fig. 17a, b), indicate that the Half Moon Brook *Prosimulium* mermithid population maintained a large number of males throughout the life cycle of the host, this being reflected in the overall sex ratio, where a male to female predominance (1.4:1) was shown. All other sex ratios had a female to male predominance. The *Prosimulium* and *S. venustum* generations in Long Pond Tributary had 1.33:1 and 9.2:1 ratios respectively, while

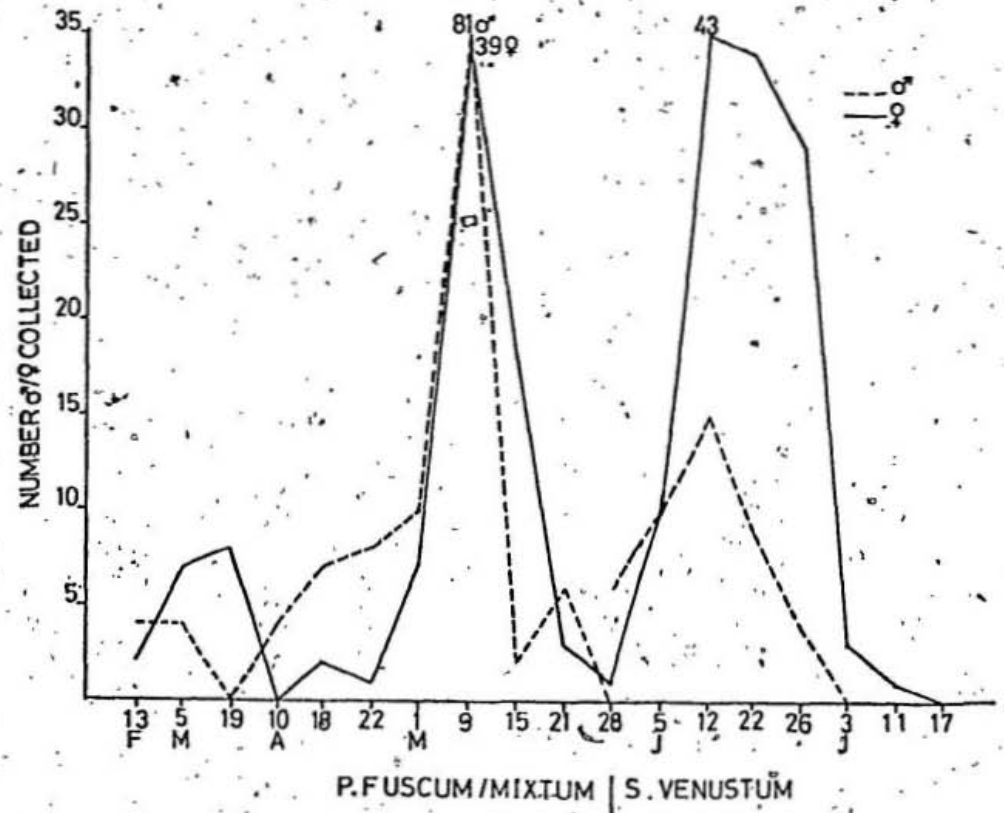
Figure 17a

Seasonal sex ratios in the simuliids from Long Pond Tributary in 1972.

Figure 17b

Seasonal sex ratios in the simuliids from Half Moon Brook in 1972.


NUMBER ♂/♀ COLLECTED
35
30
25
20
15
10
5
67
57
♂
♀
3 8 15 21 28 5 12 22 26 3 11 17 24
M
J
J
P.FUSCUM/MIXTUM | S.VENUSTUM


NUMBER ♂/♀ COLLECTED
35
30
25
20
15
10
5
81♂
39♀
43
♂
♀
13 5 19 10 18 22 1 9 15 21 28 5 12 22 26 3 11 17
F
M
A
M
J
J
P.FUSCUM/MIXTUM | S.VENUSTUM

the *S. venustum* generation in Half Moon Brook had a 2.7:1 ratio.

The seasonal change in average numbers of male and female mermithids is shown in Fig. 18a, b. The results indicate that the infected simuliids from both streams tended to be predominantly male during the early stages of the host life cycle, but later, females were primarily produced.

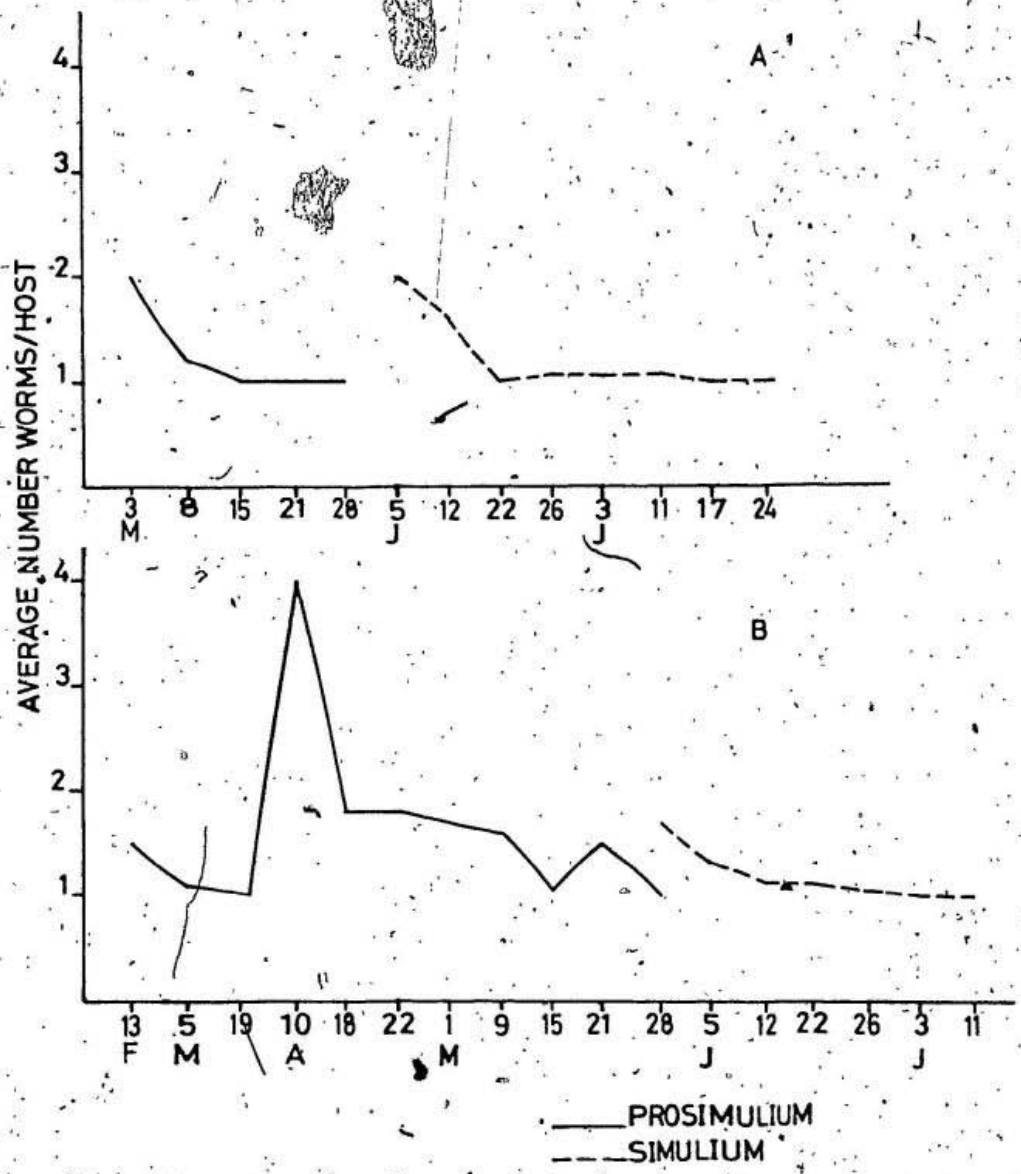
The limited multiple infection data indicate that the number of worms harboured per host ranged from 1 - 4. Only female mermithids were found in simuliid larvae with single infections, but it was not possible to tell whether additional worms, either male or female, had also entered the host but subsequently died; no indication of melanization, encapsulation or dead worms were noted within the hosts' hemocoele. When two or more worms were recorded per host, they were always male. Multiple infections probably occur during the periods of heaviest egg hatching, and hence are reflected in the sex ratio by producing males. Based on the data at hand, it would appear that only females are produced from single infections, while males only result from multiple infections. However, other workers (Christie, 1929; Kaburaki and Imamura, 1932; Kaburaki and Iyatomi, 1933; Petersen, 1972, and others) found that males may also be produced from single infections and both females and males in multiple infections. It would seem therefore, that either *N. flumenalis* in Newfoundland is influenced more drastically by the internal environmental conditions of the host species than for other mermithids elsewhere, or the data are too meagre, giving a false indication

Figure 18a

Seasonal changes in average numbers of simuliid mermithids in Long Pond Tributary in 1972.

Figure 18b

Seasonal changes in average numbers of simuliid mermithids in Half Moon Brook in 1972.


A
B
AVERAGE NUMBER WORMS/HOST
4
3
2
1
3 8 15 21 28 5 12 22 26 3 11 17 24
M J J
13 5 19 10 18 22 1 9 15 21 28 5 12 22 26 3 11
F M A M J J
PROSIMULIUM
SIMULIUM

that females and males are only produced as a result of single and multiple infections respectively. Perhaps with larger samples and individual rearing of infected simulids, the relationships between multiple infections and the sex ratio may be more precisely determined.

SUMMARY

1. A total of 198 streams in insular Newfoundland were examined for blackfly endoparasites in 1971 and 1972. One or more species of microsporida-- *Thelohania bracteata, T. fibrata, Plistophora simulii, Caudospora simulii* and *C. brevicauda*-- were recovered from 40 (20.2%) of the streams.

2. *Coelomycidium simulii* was recorded from 14 streams in Newfoundland.

3. Three species of blackfly mermithid-- *Gastromermis viridis, Isomermis wisconsinensis* and *Neomesomermis flumenalis*-- were recovered from 59 of 198 (29.7%) of the streams examined. The interior regions of Newfoundland had higher frequencies (47.3-75.0%) of mermithids than the more coastal areas (11.7-36.3%). The reasons for these distribution patterns were discussed.

4. The longitudinal distribution of mermithid infected blackflies within the stream environment was examined. The upper 400 m. of the streams examined were devoid of mermithid parasites, while the lower reaches of the streams harboured mermithids.

5. Current, depth and chemical parameters in the stream water were examined from streams with and without mermithids. Mermithid parasitism in a stream did not appear to be directly dependent on these factors.

6. *Neomesomermis flumenalis* was re-described; the eggs and pre-parasites being described for the first time. *Gastromermis viridis* and *Isomermis wisconsinensis* adult males were also re-described.

7. The life cycle of *N. flumenalis* was described. Male and female post-parasites molted to adults in 9-15 days at 12°C. after emergence from the host; 10-13 days at 18°C., 37-40 days at 6°C., and failed to molt at 22-24°C. Three molts were recorded, one during parasitic development, and a double pre-adult molt. Mating usually followed molting within a few hours, and continued for 12-24 hours. Eggs were laid 36-59 days post-mating. Females lay 600-650 eggs over a 3 day period. Eggs incubate for 35-55 days at 12°C., with heaviest egg hatching occuring 4-11 days after the onset of hatching. No eggs were laid at 3°, 7°, 18°, or 22-24°C. The pre-parasite life span was 2-3 days. Total elapsed time from host-emergence to egg laying was 45-74 days, and from emergence to egg hatching, 80-129 days. Parasitic development takes approximately seven months in the *Prosimulium* and 4-8 weeks in the *Simulium* generations.

8. Mixed infections between microsporidan species, microsporida and *N. flumenalis*, microsporida and *Coelomycidium simulii*, and *Coelomycidium simulii* and *N. flumenalis* were recorded on 15 occasions.

9. Seasonal fluctuations of host simuliid/ *N. flumenalis* parasite populations in Half Moon Brook and Long Pond Tributary were

detailed. *Neomesomermis flumenalis* is a univoltine species infecting the *P. fuscum/mixtum* generations in October, and only the first generations of the early summer simuliids, primarily *S. venustum*, near the end of May to early June. Initiation of infection occurred between 7-12°C.

10. Adult simuliids were not examined in this study, but data extrapolated from maturing and mature larvae and pupae infected with *N. flumenalis* showed that only .026 and .062% of the *P. fuscum/mixtum* and *S. venustum* adults respectively were probably infected. *Gastromermis viridis* and *I. wisconsinensis* probably infect a larger proportion (1.3-26.8%) of adult simuliids than does *N. flumenalis*.

11. Host specificity was discussed, and it appeared to be due to the asynchronous development of the host/parasite life cycles. True physiological host specificity was not, however, entirely ruled out.

12. Sex ratios were discussed. A male to female predominance of 1.4:1 was noted for the mermithids from *P. fuscum/mixtum* in Half Moon Brook. Other ratios, but with a female to male predominance of 1.33:1 and 9.2:1 for the *Prosimulium and Simulium* generations in Long Pond Tributary, and 2.7:1 for the *S. venustum* generations in Half Moon Brook were noted in 1972.

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References in Appendices 1 - 4 to Pickavance Creek, A, B, C, etc., refer to a series of streams within a generalized study area on the TCH approximately 1.1 km. east of the Cochrane Pond Provincial Park access. Figure 18, depicts the stream locations within the Pickavance study area.

Symbols immediately following the stream name refer to the stream type; P - permanent, I - intermittent, T - temporary (not shown on the topographic maps). The numerical data refer to the stream width (in meters) and depth (in cms.) respectively.

APPENDIX 1

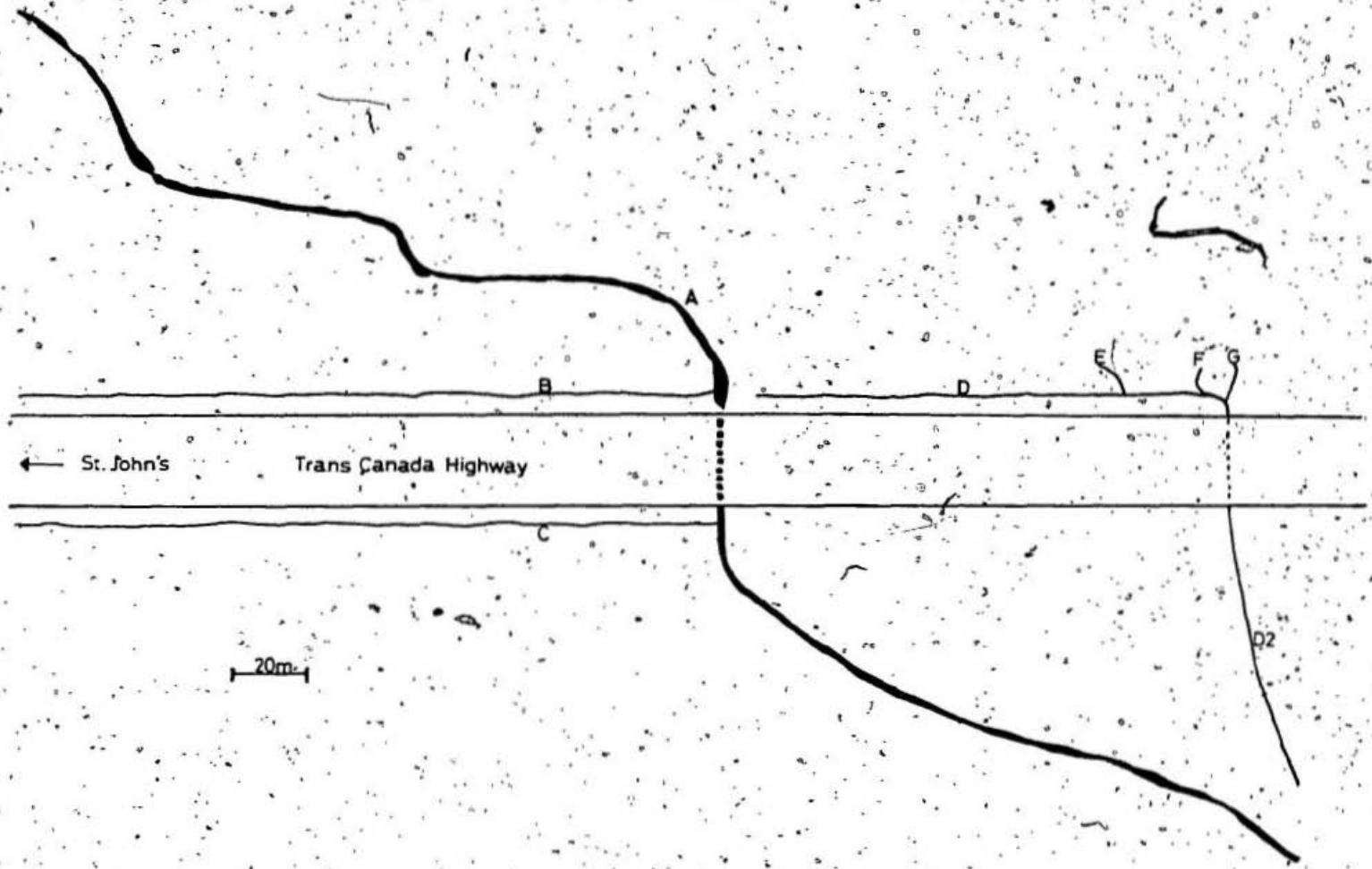
LOCATIONS OF NEWFOUNDLAND STREAMS YIELDING MERMITHID, MICROSPORIDAN OR *COELOMYCIDIUM SIMULII* INFECTED BLACKFLIES

A.

1. 1N/7 591604 Pickavance Creek A; P, 2.0, 15.
2. 1N/7 592605 Pickavance Creek B; T, 1.0, 10.
3. 1N/7 591605 Pickavance Creek C; T, 1.0, 10.
4. 1N/7 590602 Pickavance Creek D; T, 1.0, 10.
5. 1N/7 591602 Pickavance Creek D2; T, 1.0, 10.
6. 1N/7 591602 Pickavance Creek F; T, .5, 10.
7. 1N/7 591601 Pickavance Creek G; T, .5, 10.
8. 1N/7 586598 Phipps Trickle; T, 2.0, 5.
9. 1N/7 578587 1.4 km. west of Cochrane Pond Provincial Park; T, 2.0, 10.
10. 1N/7 551584 Manuels River; P, 8.0, 10.
11. 1N/7 526566 .96 km. east of Foxtrap access; I, 1.0, 10.
12. 1N/7 508555 .96 km. west of Foxtrap access; T, 2.0, 10.
13. 1N/7 502547 1.9 km. west of Foxtrap access; P, 1.0, 20.

Figure 19

Stream locations within the Pickavance Creek study area.


A
B
C
D
E
F
G
D2
St. John's
Trans Canada Highway
20m

14.	IN/6	474519	Round Pond outflow; P; 5.0, 20.
15.	IN/6	457489	Butterpot Provincial Park entrance; P, 4.0, 10.
16.	IN/6	351448	Louis Pond outflow; P, 4.0, 15.
17.	IN/6	323472	Southwest Pond outflow; P, 6.0, 10.
18.	IN/6	299485	Lockyers Waters; P, 2.0, 10.
19.	IN/6	271523	.5 km. west of Gushues Pond Provincial Park; P, 2.0, 10.
20.	IN/5E	021599	4.8 km. west of Argentia access; I, 1.0, 10.
21.	IN/5E	006608	6.4 km. west of Argentia access; P, 4.0, 20.
22.	IN/12	961653	1.1 km. west of Long Harbour access; P; 5.0, 10.
23.	IN/12	922713	6.8 km. west of Long Harbour access; P, 3.0, 10.
24.	IN/12	916735	5.4 km. east of Bellevue east access; P, 4.0, 15.
25.	IN/12	911750	3.2 km. east of Bellevue east access; P, 6.0, 20.
26.	IN/12	909758	1.6 km. east of Bellevue east access; P, 3.0, 15.
27.	IN/13	797113	Goobies east access; P, 3.0, 15.
28.	2C/4W	805311	Deep Bight River; P, 4.0, 15.
29.	2D/1	209424	Shoal Harbour River; P, 12.0, 15.
30.	2D/8	134500	Thorburn Lake Tributary; P, 3.0, 15.
31.	2D/8	095543	7.3 km. west of Thorburn Lake Tributary; P, 7.0,15.
32.	2C/12W	813847	3.2 km. west of Terra Nova Park Headquarters access; P, 4.0, 15.
33.	2C/12W	807884	6.5 km. west of Terra Nova Park Headquarters access; P, 5.0, 15.
34.	2D/9	125981	5.2 km. west of Glovertown access; P, 1.0, 15.
35.	2D/9	116984	6.5 km. west of Glovertown access; P, 3.0, 10.
36.	2D/16	862181	2.5 km. west of Benton access; I, 2.0, 12.
37.	2D/15	585256	.9 km. west of Glenwood Provincial Park; P, 2.0, 6.
38.	12A/16E	720245	7.6 km. west of Aspen Brook; P, 4.0, 12.

39. 12A/16E 716248 Junction Brook; P, 6.0, 15.

40. 12H/1E 697278 3.0 km. west of Badger west entry; I, 4.0, 10.

41. 12H/1E 667335 Catamaran Brook; P, 6.0, 15.

42. 12H/1E 657471 7.0 km. west of Powderhorn Brook; P, 3.0, 12.

43. 12H/1E 641552 Gull Brook; P, 2.0, 10.

44. 12H/8W 502784 7.3 km. west of Indian River Provincial Park access; P, 1.0, 8.

45. 12H/7E 343732 6.5 km. west of Baie Verte access; P, 5.0, 20.

46. 12H/7E 291691 13.2 km. west of Baie Verte access; T. 3.0, 15.

47. 12H/7W 179617 7.8 km. west of river joining Birchy and Sheffield Lakes; P, 1.0, 15.

48. 12H/6E 925569 Boot Brook; P, 5.0, 20.

49. 12H/3E 823517 Crooked Feeder; P, 6.0, 20.

50. 12H/3W 727501 5.6 km. west of Junction Brook; T, 2.0, 15.

51. 12H/4E 604370 13.2 km. west of Bonne Bay access; P, 5.0, 25.

52. 12A/13W 319142 Whale Back Brook; P, 3.0, 20.

53. 12B/9E 154952 Island Pond outflow; P, 3.0, 15.

54. 12B/8W 935630 Dribble Brook; P, 10.0, 20.

55. 12B/7E 854520 Barry Brook; P, 4.0, 15.

56. 12B/7E 767479 4.0 km. west of Fischels Brook; T, 3.0, 15.

57. 110/14E 317937 2.8 km. west of St. Andrews access; P, 4.0, 25.

58. 110/11E 318797 1.4 km. west of Cheeseman Provincial Park access; P, 4.0, 15.

59. 12H/5E 612603 Rocky Pond outflow; P, 2.0, 25.

60. 12H/5E 574695 .8 km. north of Jacks Pond; I, 3.0, 20.

61. 12H/12W 329093 Sally Cove; P, 5.0, 20.

62. IN/7 641478 Middle Pond Tributary; T, 1.0, 10.

63. IN/7 633454 Long Pond Tributary; P, 1.0, 10.

64. IN/7 613393 Pierres Brook; P, 5.0, 15.

65. IN/2W 512171 Cape Broyle River; P, 10.0, 20.

66. IN/10G 699305 Piccos Brook; P, 8.0, 15.

67. IN/10G 699874 Half Moon Brook; P, 2.0, 10.

68. IN/10G 746756 Logy Bay; P, 2.0, 10.

69. IN/10 589735 Goat Cove Brook; P, 3.0, 10.

70. IN/10 594702 Broad Cove River; P, 2.0, 10.

71. IN/10 605704 Healeys Pond outflow; P, 4.0, 10.

72. IN/10 623702 Powers Pond outflow; P, 3.0, 15.

73. IN/10d 524643 Long Pond tributary; P, 1.0, 10.

74. IN/6 478623 Kellegrews Playground River; P, 3.0, 15.

75. IN/6 458607 Lawrence Pond outflow; P, 2.0, 10.

76. IN/6 322620 Three Island Pond outflow; P, 2.0, 15.

77. IN/14 297951 Victoria; I, 1.0, 15.

78. 2C/11 473789 Catalina; P, 2.0, 20.

79. IN/3 204304 Back River; P, 5.0, 10.

80. IN/3 179278 4.0 km. south of Back River; P, 2.0, 10.

LOCATIONS OF NEWFOUNDLAND STREAMS EXAMINED FOR BLACKFLY ENDOPARASITES BUT NOT YIELDING PARASITES

B.

81. IN/7 591603 Pickavance Creek E; T

82. IN/5E 051584 1.9 km. west of Argentia access; T,

83. IN/5E 047586 2.4 km. west of Argentia access; I.

84. IN/5E 039589 2.7 km. west of Argentia access; P.

85. IN/5E 997612 7.5 km. west of Argentia access; P.

86. IN/12 971641 11.2 km. west of Argentia access; P.

87.	IN/12	956660	1.9 km. west of Long Harbour access; P.
88.	IN/12	940695	4.1 km. west of Long Harbour access; P.
89.	IN/12	802898	20.2 km. west of Bellevue east access; P.
90.	IN/12	709907	21.2 km. west of Bellevue east access; P.
91.	IN/13	784946	1.7 km. west of Jack's Pond Provincial Park access;P.
92.	IN/13	796144	3.5 km. west of Goobies east access; P.
93.	IN/13	789165	Come By Chance River; P.
94.	2C/4W	784369	Lower Shoal Harbour River; P.
95.	2D/16.	797092	Middle Brook; P.
96.	2E/3	431389	Neyles Brook; P.
97.	2E/3	398422	Notre Dame Provincial Park; P.
98.	2E/3	317412	Eel Brook; P.
99.	2E/3	169311	Jumpers Brook; P.
100.	2D/13	857217	Leech Brook; P.
101.	2D/13	796225	Aspen Brook; P.
102.	2D/13	796225	60 M. west of Aspen Brook; T.
103.	12H/8E	653674	5.6 km. west of Gull Brook; I.
104.	12H/8E	605780	Burnt Berry Brook; P.
105.	12H/8W	450793	13.7 km. west of Indian River Provincial Park; P.
106.	12H/8W	388766	1.1 km. west of Baie Verte access; P.
107.	12H/7E	359744	4.8 km. west of Baie Verte access; I.
108.	12H/7W	048625	7.3 km. west of Birchy Narrows; P.
109.	12H/7W	011696	White Spruce Brook; P.
110.	12H/6E	988661	Flights Brook; P.
111.	12H/6E	987654	McIsaac's Brook; P.
112.	12H/3W	649425	5.2 km. west of Bonne Bay access; P.

113.	12H/4E	578322	18.5 km. west of Bonne Bay access; I.
114.	12H/4E	552288	South Brook; P.
115.	12A/13E	480268	Matthews Brook; P.
116.	12A/13W	397220	Steady Brook; P.
117.	12B/16E	219052	Pinchgut Brook; P.
118.	12B/9E	142929	Grand Lake Brook; P.
119.	12B/9W	064762	Wheeler Brook; P.
120.	12B/8W	895566	Journois Brook; P.
121.	12B/2E	709440	Robinson's River; P.
122.	12B/2W	681389	Crabbes Brook; P.
123.	12B/2W	680350	1.1 km. west of Crabbes Brook; I.
124.	12B/2W	673316	3.8 km. west of Crabbes Brook; I.
125.	12B/2W	649226	7.6 km. west of Crabbes Brook; I.
126.	12B/2W	559189	North Branch; P.
127.	110/15W	509103	Coal Brook; P.
128.	110/14E	470069	1.7 km. west of South Branch access; P.
129.	110/14E	439062	Mollychignie Brook; P.
130.	110/14W	302924	5.1 km. west of St. Andrews access; I.
131.	12H/3W	666513	Nichols Brooks; I.
132.	12H/3W	643547	2.7 km. north of the Cormack access; P.
133.	12H/5E	615639	White Hill Brook; P.
134.	12H/5E	554722	East Branch River; P.
135.	12H/5E	511786	South East Brook; P.
136.	12H/5E	482799	Dicks Brook; P.
137.	12H/5W	431828	20.1 km. north of Wiltondale; P.
138.	12H/12W	309979	1.7 km. north of Norris Point south access; P.

139.	12H/12W	309005	Bakers Brook; P.
140.	12H/13W	432249	11.1 km. north of Western Brook; P.
141.	12I/4E	539544	10.5 km. north of Three Mile Rock access; P.
142.	12J/5E	594678	Bowring Brook; P.
143.	IN/6	396445	Near Four Mile Pond; T.
144.	2C/11	457758	Lookout Pond outflow; P.
145.	IN/14	312939	Victoria; I.
146.	2C/11	405854	Birchy Cove; P.
147.	2C/5	040625	Sweet Bay.
148.	2C/6W	250673	Lockston Path Provincial Park; T.
149.	IN/6	445504	Butterpot Provincial Park; P.
150.	IN/6	446503	Butterpot Provincial Park; P.
151.	2C/11	447866	Bonavista; P.
152.	2C/11	415842	Birchy Cove; P.
153.	2C/12W	577943	Sandy Cove; I.
154.	2C/11	371790	Catalina; P.
155.	1K/15W	493898	Cappahayden; P.
156.	IN/10E	771641	Spear Bay Brook; P.
157.	2C/6W	252673	Lockston; P.
158.	IN/10E	716795	North Pond Brook; P.
159.	2C/11	424865	Bonavista; P.
160.	IN/10d	520641	Long Pond; P.
161.	2C/11	269786	Stock Cove; P.
162.	IN/6	441575	Seal Cove; P.
163.	2C/11	440894	Bonavista; T.
164.	IN/6	400508	Holyrood; P.

165.	IN/10E	699833	Near Piccos Brook; T.
166.	2C/11	350758	Upper Amherst Cove; P.
167.	IN/10E	699832	Near Piccos Brook; T.
168.	IN/10E	745757	Logy Bay; P.
169.	IN/15	677192	Pouch Cove; P.
170.	2C/11	452859	Bonavista; P.
171.	2C/11	456759	Catalina; T.
172.	2C/11	475781	Catalina; P.
173.	IN/15	677925	Cape St. Francis; P.
174.	IN/15	670936	Cape St. Francis; P.
175.	IN/15	667942	Cape St. Francis; P.
176.	IN/15	659953	Cape St. Francis; P.
177.	IN/15	661959	Cape St. Francis; P.
178.	IN/10E	694889	Shoe Cove; P.
179.	IN/10E	718791	Middle Cove; P.
180.	IN/10E	731768	Outer Cove; P.
181.	IN/10E	749756	Logy Bay; P.
182.	IN/7	627440	Long Pond; P.
183.	IN/7	492534	Soldiers Pond; I.
184.	IN/7	587596	Paddys Pond; T.
185.	IN/6	203564	Grand Pond outflow; P.
186.	IN/6	280516	Gushues Pond outflow; P.
187.	10N/10W	595752	Beachy Cove Brook; P.
188.	1K/13E	651059	Near Colinet, Placentia access; P.
189.	1K/13E	635045	4 km. south of Colinet, Placentia access; P.
190.	IN/2	543259	1.3 km. north of LaManche Provincial Park Entrance; P.

191.	IN/2	535133	4.8 km. north of Ferryland; P.
192.	IN/2	566108	1.3 km. north of Ferryland; P.
193.	IN/11W	290766	Northern Cove Pond outflow; P.
194.	IN/11W	289675	South River; P.
195.	IN/7	613375	Witless Bay Brook; P.
196.	IN/2	557090	South of Ferryland; P.
197.	IN/6	181560	Ocean Pond; P.
198.	IN/6	138502	Ocean Pond; P.

APPENDIX 2

DATA ON MICROSPORIDA COLLECTED IN NEWFOUNDLAND IN 1971 AND 1972

Stream Number	Date	Blackfly Species	Microsporidan Species	Number Examined		Percent Infection
				Host	Parasite	
11	5/ V /71	*P. fuscum/mixtum*	*C. simulii*	2	1	50.0*
12	5/ V /71	"	"	1	1	100.0*
9	10/ V /71	"	"	20	6	30.0
10	17/ V /71	"	"	2	2	100.0*
10	21/ V /72	"	"	158	1	.6
72	8/ V /72	"	"	126	6	4.8
71	8/ V /72	"	"	62	4	6.5
9	16/ V /72	"	"	110	2	1.8
11	16/ V /72	"	"	48	3	6.3
12	16/ V /72	"	"	73	9	12.3
15	16/ V /72	"	"	49	1	2.0
17	16/ V /72	"	"	38	1	2.6
27	23/ V /72	"	"	14	1	7.1
30	23/ V /72	"	"	2	1	50.0
31	23/ V /72	"	"	25	1	4.0
33	23/ V /72	"	"	26	1	3.8
39	24/ V /72	"	"	10	1	10.0
42	24/ V /72	"	"	21	1	4.8

APPENDIX 2 (CONTINUED)

Stream Number	Date	Blackfly Species	Microsporidan Species	Number Examined		Percent Infection
				Host	Parasite	
50	25/ V /72	*P. fuscum/mixtum*	*C. simulii*	4	1	25.0
54	26/ V /72	"	"	9	1	11.1
56	26/ V /72	"	"	6	2	33.3
58	26/ V /72	"	"	26	1	3.8
60	26/ V /72	"	"	24	2	8.3
10	10/ V /71	*C. mutata*	*C. brevicauda*	4	3	75.0*
10	17/ V /71	"	"	6	6	100.0*
10	21/IV /72	"	"	200	20	10.0
65	12/VI /72	*S. corbis*	*T. bracteata*	93	2	2.2
14	1/VI /71	*S. latipes*	*P. simulii*	6	1	16.7
62	7/VI /71	"	"	16	1	6.3
9	10/VI /71	"	*T. bracteata*	2	1	50.0
7	9/VII /71	"	*T. fibrata*	8	1	12.5
63	4/VIII/71	"	*T. bracteata*	12	1	8.3
1	2/VI /71	*S. tuberosum*	*P. simulii*	21	1	4.8
24	2/VIII/71	"	"	26	1	3.8
24	2/VIII/71	"	*T. fibrata*	26	1	3.8
69	24/V /71	*S. venustum*	*P. simulii*	79	1	1.3
12	1/VI /71	"	*T. fibrata*	60	1	1.7

APPENDIX 2 (CONTINUED)

Stream Number	Date	Blackfly Species	Microsporidan Species	Number Examined		Percent Infection
				Host	Parasite	
12	1/VI /71	*S. venustum*	*T. bracteata*	60	1	1.7
12	1/VI /71	"	*P. simulii*	60	1	1.7
14	1/VI /71	"	*T. fibrata*	80	1	1.3
10	2/VI /71	"	*T. bracteata*	63	1	1.6
67	3/VI /71	"	*T. fibrata*	90	1	1.1
63	7/VI /71	"	*T. fibrata*	353	2	.6
63	7/VI /71	"	*T. bracteata*	353	1	.3
67	15/VI /71	"	*T. fibrata*	152	1	.7
63	16/V /71	"	*T. bracteata*	171	1	.6
7	17/VI /71	"	"	31	2	6.5
6	17/VI /71	"	"	12	2	16.7
5	17/VI /71	"	*P. simulii*	30	1	3.3
62	22/VI /71	"	*T. bracteata*	52	2	3.8
6	25/VI /71	"	"	9	1	11.1
7	25/VI /71	"	"	9	1	11.1
4	25/VI /71	"	"	32	4	12.5
1	25/VI /71	"	"	64	1	1.6
62	30/VI /71	"	*P. simulii*	82	1	1.2
62	30/VI /71	"	*T. bracteata*	82	16	19.5

APPENDIX 2 (CONTINUED)

Stream Number	Date	Blackfly Species	Microsporidan Species	Number Examined		Percent Infection
				Host	Parasite	
63	30/VI /71	*S. venustum*	*T. bracteata*	255	4	1.6
63	30/VI /71	"	*T. fibrata*	255	1	.4
1	2/VII /71	"	*T. bracteata*	39	1	2.6
1	2/VII /71	"	*T. fibrata*	8	1	12.5
6	2/VII /71	"	*T. bracteata*	5	1	20.0
4	2/VII /71	"	"	29	3	10.3
4	2/VII /71	"				
13	3/VII /71	"	*P. simulii*	34	1	2.9
10	4/VII /71	"	*T. fibrata*	4	1	25.0
74	4/VII /71	"	"	17	1	5.9
62	7/VII /71	"	*P. simulii*	38	1	2.6
62	7/VII /71	"	*T. bracteata*	38	1	2.6
63	7/VII /71	"	"	248	2	.8
4	9/VII /71	"	*T. fibrata*	9	1	11.1
63	14/VII /71	"	"	137	1	.7
67	15/VII /71	"	"	45	1	2.2
16	16/VII /71	"	*T. bracteata*	6	1	16.7
63	21/VII /71	"	*P. simulii*	39	1	2.6
63	21/VII /71	"	*T. fibrata*	39	1	2.6

APPENDIX 2 (CONTINUED)

Stream Number	Date	Blackfly Species	Microsporidan Species	Number Examined		Percent Infection
				Host	Parasite	
63	21/VII /71	*S. venustum*	*T. bracteata*	39	1	2.6
67	22/VII /71	"	"	36	1	2.8
4	23/VII /71	"	"	15	1	6.7
4	23/VII /71	"	*T. fibrata*	15	1	6.7
62	28/VII /71	"	"	4	1	25.0
63	28/VII /71	"	"	59	1	1.7
63	28/VII /71	"	*T. bracteata*	59	1	1.7
67	29/VII /71	"	*P. simulii*	28	1	3.6
67	29/VII /71	"	*T. bracteata*	28	1	3.6
67	29/VII /71	"	*T. fibrata*	28	1	3.6
1	30/VII /71	"	*T. bracteata*	25	1	4.0
26	2/VIII/71	"	"	50	1	2.0
25	2/VIII/71	"	*T. fibrata*	6	1	16.7
22	2/VIII/71	"	"	98	1	1.0
22	2/VIII/71	"	*T. bracteata*	98	1	1.0
10	2/VIII/71	"	"	53	1	1.9
63	4/VIII/71	"	"	57	2	3.5
63	11/VIII/71	"	"	45	1	2.2
63	11/VIII/71	"	*P. simulii*	45	2	4.4

APPENDIX 2 (CONTINUED)

Stream Number	Date	Blackfly Species	Microsporidan Species	Number Examined		Percent Infection
				Host	Parasite	
63	18/VIII/71	*S. venustum*	*T. fibrata*	50	1	2.0
62	18/VIII/71	"	*T. bracteata*	5	1	20.0
63	14/IX /71	"	*T. fibrata*	79	1	1.3
63	14/IX /71	"	*T. bracteata*	79	1	1.3
20	8/VI /72	"	"	13	1	7.7
18	8/VI /72	"	*T. fibrata*	241	2	.8
18	8/VI /72	"	*T. bracteata*	241	1	.4
16	8/VI /72	"	"	134	2	1.5
67	12/VI /72	"	"	338	8	2.4
67	12/VI /72	"	*T. fibrata*	338	1	.3
67	12/VI /72	"	*P. simulii*	338	5	1.5
63	22/VI /72	"	*T. bracteata*	315	2	.6
63	22/VI /72	"	*T. fibrata*	315	3	.9
63	22/VI /72	"	*P. simulii*	315	1	.3
67	22/VI /72	"	*P. simulii*	420	1	.2
67	26/VI /72	"	*T. bracteata*	593	1	.2
67	26/VI /72	"	*T. fibrata*	593	1	.2
63	26/VI /72	"	*T. bracteata*	332	3	.9
63	26/VI /72	"	*T. fibrata*	332	1	.3

APPENDIX 2 (CONTINUED)

Stream Number	Date	Blackfly Species	Microsporidan Species	Number Examined		Percent Infection
				Host	Parasite	
63	3/VII /72	*S. venustum*	*T. fibrata*	333	1	.3
63	11/VII /72	"	*T. bracteata*	663	1	.2
63	11/VII /72	"	*P. simulii*	663	1	.2
63	11/VII /72	"	*T. fibrata*	663	1	.2
63	17/VII /72	"	"	245	1	.4
67	17/VII /72	"	"	146	1	.7
63	24/VII /72	"	"	232	4	1.7
63	24/VII /72	"	*T. bracteata*	232	2	.9
67	29/IV /71	*S. vittatum*	*T. fibrata*	3	1	33.3
10	25/VI /71	"	"	54	2	3.7
10	2/VII /71	"	"	60	3	5.0
10	9/VII /71	"	*P. simulii*	36	1	2.8
10	23/VII /71	"	*T. fibrata*	72	1	1.4
24	2/VIII/71	"	"	31	1	3.2
76	29/VI /72	"	"	211	1	.5

* biased samples; larvae not collected randomly..

APPENDIX 3

DATA ON *COELOMYCIDIUM SIMULII* COLLECTED IN NEWFOUNDLAND IN 1971 AND 1972

Stream Number	Date	Blackfly Species	Number Examined		Percent Infection
			Uninfected	Infected	
10	2/VI /71	*S. venustum*	63	2	3.2
63	7/VI /71	"	142	1	.7
67	15/VI /71	"	152	1	.7
6	25/VI /71	"	9	1	11.1
1	25/VI /71	"	64	1	1.6
10	16/VII /71	"	52	2	3.8
19	2/VIII/71	"	68	1	1.5
38	24/V /72	*P. fuscum/mixtum*	43	9	20.9
40	24/V /72	"	131	1	.8
48	25/V /72	"	15	1	6.7
61	27/V /72	"	74	2	2.7
21	8/VI /72	*S. venustum*	227	1	.4
16	8/VI /72	"	134	8	5.9
29	8/VI /72	*S. corbis*	113	5	4.4
80	11/VI /72	"	12	1	8.3
67	12/VI /72	*S. venustum*	338	4	1.2
67	22/VI /72	"	420	1	.2
1	27/VI /72	*S. vittatum*	275	2	.7

APPENDIX 4

NEWFOUNDLAND BLACKFLY MERMITHID DISTRIBUTION DATA FOR 1971 AND 1972

Stream Number	Date	Blackfly Species	Mermithid Species	Number Examined		Percent Infection
				Uninfected	Infected	
68	20/II /71	*P. fuscum/mixtum*	*N. flumenalis*	16	1	6.3
78	12/IV /71	"	"	21	14	66.7
9	26/IV /71	"	"	117	1	.9
3	30/IV /71	"	"	15	1	6.7
69	30/IV /71	"	"	84	7	8.3
62	6/V /71	"	"	95	12	12.6
73	11/V /71	"	"	16	1	6.3
75	11/V /71	"	"	28	3	10.7
62	26/V /71	"	"	8	2	25.0
66	18/IV /72	"	"	21	1	4.8
10	21/IV /72	"	"	158	3	1.9
69	8/V /72	"	"	125	5	4.0
70	8/V /72	"	"	151	6	3.9
72	8/V /72	"	"	126	3	2.4
9	16/V /72	"	"	110	1	.9
15	16/V /72	"	"	49	1	2.0
23	23/V /72	"	"	15	2	13.3
27	23/V /72	"	"	14	2	14.3

APPENDIX 4 (CONTINUED)

Stream Number	Date	Blackfly Species	Mermithid Species	Number Examined		Percent Infection
				Uninfected	Infected	
28	23/V /72	*P. fuscum/mixtum*	*N. flumenalis*	37	1	2.7
31	23/V /72	"	"	25	2	8.0
32	23/V /72	"	"	15	1	6.7
33	23/V /72	"	"	26	1	3.8
34	23/V /72	"	"	34	3	8.8
35	24/V /72	"	"	236	3	1.3
36	24/V /72	"	"	37	3	8.1
37	24/V /72	"	"	55	1	1.8
38	24/V /72	"	"	43	6	14.0
40	24/V /72	"	"	131	4	3.1
41	24/V /72	"	"	2	1	50.0
42	24/V /72	"	"	21	1	4.8
43	24/V /72	"	"	17	4	23.5
44	25/V /72	"	"	4	1	25.0
45	25/V /72	"	"	56	3	5.4
46	25/V /72	"	"	34	1	2.9
47	25/V /72	"	"	29	4	13.8
48	25/V /72	"	"	15	1	6.6
49	25/V /72	"	"	116	3	2.6

APPENDIX 4 (CONTINUED)

Stream Number	Date	Blackfly Species	Mermithid Species	Number Examined		Percent Infection
				Uninfected	Infected	
51	25/V /72	*P. fuscum/mixtum*	*N. flumenalis*	19	1	5.3
52	25/V /72	"	"	35	3	8.6
53	25/V /72	"	"	11	1	9.1
55	26/V /72	"	"	34	1	2.9
57	26/V /72	"	"	12	1	8.3
59	27/V /72	"	"	15	1	6.7
60	27/V /72	"	"	24	5	20.8
61	27/V /72	"	"	74	1	1.4
65	12/V /72	*S. corbis*	*G. viridis*	93	50	53.8
6	13/V /72	*S. latipes*	*N. flumenalis*	6	1	16.7
4	25/V /72	"	"	15	7	46.7
7	25/V /71	"	"	43	31	72.1
6	26/V /71	"	"	90	10	11.1
7	2/VI /71	"	"	18	6	33.3
6	2/VI /71	"	"	4	1	25.0
62	7/VI /71	"	"	16	3	18.8
7	10/VI /71	"	"	10	3	30.0
4	17/VI /71	"	"	10	1	10.0
7	17/VI /71	"	"	4	1	25.0

APPENDIX 4 (CONTINUED)

Stream Number	Date	Blackfly Species	Mermithid Species	Number Examined		Percent Infection
				Uninfected	Infected	
6	17/VI /71	*S. latipes*	*N. flumenalis*	10	1	10.0
7	25/VI /71	"	"	7	6	85.7
4	2/VII /71	"	"	4	1	25.0
5	10/VII /71	"	"	1	1	100.0
6	25/V /71	*S. venustum*	*N. flumenalis*	75	6	8.0
62	26/V /71	"	"	129	5	3.9
8	28/V /71	"	"	29	1	3.4
14	1/VI /71	"	"	80	1	1.3
1	2/VI /71	"	"	314	6	1.9
5	2/VI /71	"	"	87	4	4.6
10	2/VI /71	"	"	63	3	4.8
62	7/VI /71	"	"	173	4	2.3
4	10/VI /71	"	"	112	12	10.7
5	10/VI /71	"	"	73	20	27.4
1	10/VI /71	"	"	65	7	10.8
10	10/VI /71	"	"	18	2	11.1
62	16/VI /71	"	"	113	1	.9
1	17/VI /71	"	"	74	29	39.2
5	17/VI /71	"	"	30	15	50.0

APPENDIX 4 (CONTINUED)

Stream Number	Date	Blackfly Species	Mermithid Species	Number Examined		Percent Infection
				Uninfected	Infected	
10	17/VI /71	*S. venustum*	*N. flumenalis*	11	1	9.1
62	22/VI /71	"	"	52	1	1.9
5	25/VI /71	"	"	10	2	20.0
4	25/VI /71	"	"	32	2	6.3
1	25/VI /71	"	"	64	7	10.9
62	30/VI /71	"	"	82	1	1.2
5	2/VII /71	"	"	18	2	11.1
15	3/VII /71	"	"	59	8	13.6
70	4/VII /71	"	"	53	1	1.9
69	4/VII /71	"	"	64	2	3.1
62	7/VII /71	"	"	38	2	5.3
2	16/VII /71	"	"	36	4	11.1
5	16/VII /71	"	"	6	1	16.7
4	23/VII /71	"	"	15	1	6.7
5	30/VII /71	"	"	10	2	20.0
21	8/VI /72	"	*I. wisconsinensis*	227	8	3.5
23	8/VI /72	"	"	145	5	3.4
18	8/VI /72	"	*N. flumenalis*	241	4	1.7
79	11/VI /72	"	"	152	17	11.2

APPENDIX 4 (CONTINUED)

Stream Number	Date	Blackfly Species	Mermithid Species	Number Examined		Percent Infection
				Uninfected	Infected	
65	12/VI /72	*S. venustum*	*N. flumenalis*	22	2	9.1
77	24/VI /72	"	"	78	4	5.1
76	29/VI /72	*S. vittatum*	*G. viridis*	211	36	17.1
76	29/VI /72	"	*I. wisconsinensis*	211	5	2.4

APPENDIX 5

RESULTS OF WATER ANALYSES FROM STREAMS WITH AND WITHOUT BLACKFLY MERMITHIDS

HALF MOON BROOK*

Date	Carbon dioxide	Dissolved oxygen	Chlorides	Total Hardness	pH	Silicon dioxide
23/ VI /71	4.0	7.0	25	25	6.5	2.0
1/VII /71	4.0	7.0	20	25	6.0	2.0
15/VII /71	2.5	8.6	20	30	6.5	1.5
29/VII /71	2.5	8.8	25	35	5.5	1.5
12/VIII/71	3.5	8.6	30	20	6.5	1.0
26/VIII/71	3.0	7.6	25	25	6.0	1.5
14/IX /71	2.5	8.4	20	20	6.0	1.0
28/IX /71	2.0	8.8	20	25	5.5	1.5
14/ X /71	2.0	7.6	25	20	4.5	2.0
29/ X /71	3.5	7.2	25	20	6.0	1.0
5/XII /71	3.5	6.2	20	25	6.0	1.5
19/XII /71	5.0	6.4	20	25	6.0	1.5
23/I /72	4.5	6.6	20	20	6.0	2.0
13/II /72	5.0	6.4	25	30	5.5	2.5
5/III /72	4.5	6.0	20	20	6.0	1.5

APPENDIX 5 (CONTINUED)

HALF MOON BROOK*

Date	Carbon dioxide	Dissolved oxygen	Chlorides	Total hardness	pH	Silicon dioxide
10/IV /72	4.0	7.6	25	25	6.5	2.0
15/ V /72	3.5	9.0	20	30	6.5	1.5
22/VI /72	3.5	7.8	30	20	6.0	2.5
17/VII /72	4.0	8.6	25	25	6.0	2.0
Range	2.0 - 5.0	6.0 - 9.0	20 - 30	20 - 30	4.5 - 6.5	1.0 - 2.5

*Harbours mermithid infected simuliids.

APPENDIX 5 (CONTINUED)

LONG POND TRIBUTARY*

Date	Carbon dioxide	Dissolved oxygen	Chlorides	Total hardness	pH	Silicon dioxide
30/VI /71	3.5	6.8	20	60	6.0	1.5
14/VII /71	2.0	9.0	25	70	6.0	1.5
28/VII /71	3.0	9.2	20	65	6.0	2.5
11/VIII/71	5.0	8.0	15	50	6.0	1.5
23/VIII/71	7.0	7.6	25	60	4.5	2.0
14/IX /71	6.0	8.8	20	45	6.0	1.5
28/IX /71	3.0	9.2	20	50	6.0	2.0
14/ X /71	3.5	8.4	20	55	5.5	2.0
29/ X /71	4.5	8.8	25	45	6.0	2.0
28/XI /71	5.0	7.4	25	50	5.5	2.0
29/XII /71	6.0	7.0	20	60	5.5	2.5
26/ I /72	6.5	7.2	20	45	6.0	1.5
28/ II /72	5.5	6.8	20	55	5.5	2.0
2/III /72	6.0	7.0	25	50	6.0	2.5
5/ IV /72	6.5	6.8	20	50	6.0	2.5

APPENDIX 5 (CONTINUED)

LONG POND TRIBUTARY*

Date	Carbon dioxide	Dissolved oxygen	Chlorides	Total hardness	pH	Silicon dioxide
3/ V /72	4.0	7.8	25	55	6.0	2.0
12/ VI /72	3.5	8.6	20	50	6.0	2.0
14/VII /72	3.5	9.4	25	60	6.0	2.5
Range	2.0 - 7.0	6.8 - 9.4	15 - 25	45 - 70	4.5 - 6.0	1.5 - 2.5

*Harbours mermithid infected simuliids.

APPENDIX 5 (CONTINUED)

PICCOS BROOK

Date	Carbon dioxide	Dissolved oxygen	Chlorides	Total hardness	pH	Silicon dioxide
23/VI /71	3.5	6.8	25	25	6.5	2.5
1/VII /71	3.5	7.2	15	20	6.0	1.0
15/VII /71	3.0	8.2	20	25	6.5	2.0
29/VII /71	3.5	8.6	25	25	6.5	1.5
12/VIII/71	4.0	7.8	20	20	6.0	2.0
26/VIII/71	3.5	7.2	25	30	5.5	1.5
14/IX /71	3.0	8.2	25	20	5.5	2.0
28/IX /71	2.5	7.6	25	25	6.0	2.5
14/ X /71	3.5	6.4	20	20	6.0	2.0
29/ X /71	4.0	6.0	20	25	6.0	1.5
5/XII /71	4.0	6.2	25	30	6.5	2.0
19/XII /71	5.0	5.8	20	25	5.5	1.5
23/ I /72	4.0	6.0	20	20	6.0	2.0
13/II /72	5.5	6.2	20	25	6.0	2.5
5/III /72	4.0	6.6	25	20	6.0	1.0
10/IV /72	4.5	7.4	25	20	6.0	2.0

APPENDIX 5 (CONTINUED)

PICCOS BROOK

Date	Carbon dioxide	Dissolved Oxygen	Chlorides	Total hardness	pH	Silicon dioxide
15/ V /72	4.0	8.2	20	30	6.5	1.5
22/ VI /72	3.0	7.8	25	25	6.0	2.0
17/VII /72	4.5	8.2	20	25	6.5	1.0
Range	2.0 - 5.5	6.0 - 8.8	15 - 25	20 - 30	5.5 - 6.5	1.0 - 2.5

APPENDIX 6

COMPARISON OF NEWFOUNDLAND ADULT MERMITHID DATA WITH THAT OF WELCH (1962a), PHELPS AND DEFOLIART (1964) AND NICKLE (1972).

Neomesomermis flumenalis: female	Welch (1962a)	Phelps and DeFoliart (1964)	Nickle (1972)	Newfoundland Data
Length	18 mm	-	-	13.4 mm
Width at head	52.0μ	66.4μ	72.0μ	87.5μ
Width at vulva	150.0μ	174.0μ	231.2μ	255.6μ
Width at tail	102.5μ	-	183.6μ	146.2μ
Amphid pouch	20-23 x 13-17μ	14.4 x 12.8μ	17.6 x 10.0μ	12.5 x 10.0μ
Amphid pore	9-13μ	7.2 x 4.8μ	11.0 x 7.3μ	7.5 x 6.25μ
Vagina length	80-100μ	75.4μ	74.8μ	88.3μ
N. flumenalis: male				
Length	9.5mm	-	-	9.6 mm
Width at head	57.0μ	-	66.1μ	73.4μ
Width at mid-body	97.0μ	-	-	138.6μ
Width at spicule opening	110.0μ	92.8μ	125.8μ	122.0μ
Amphid pouch	26-28 x 17-19μ	-	29 x 20μ	28.1 x 20.0μ
Amphid pore	21-26 x 6-8μ	-	27 x 10μ	27.5 x 12.5μ
Spicule length	230.0μ	185.6μ	210.8μ	222.5μ
Spicule width (tip)	10.0μ	11.8μ	10.2 μ	10.25μ

APPENDIX 6 (Continued)

Gastromermis viridis: male	Welch (1962a)	Phelps and DeFoliart (1964)	Nickle (1972)	Newfoundland Date
Length	11.5mm	-	-	15.0 mm
Width at head	52.0μ	-	62.8μ	70.0 μ
Width at spicule opening	150.0μ	172.0μ	150.0μ	150.5 μ
Spicule length	0.8 - 1.0 mm	1.08 mm	1.33 mm	1.35 mm
Spicule width (base)	21.0μ	38.0μ	34.0μ	39.0 μ
Spicule width (midpoint)	15-16μ	33.0μ	26.0μ	18.6 μ
Isomermis wisconsinensis:male				
Length	11.5 mm	-	-	15.0 mm
Width at head	61.0 μ	-	-	75.2 μ
Width at spicule opening	140.0 μ	145.0μ	-	136.2 μ
Spicule length	180.0 μ	162.0μ	-	210.0 μ
Spicule width (midpoint)	13.0 μ	16.0μ	-	10.0 μ