Lang, J. T. 1978. Relationship of fecundity to the nutritional quality of larval and adult diets of *Wyeomyia smithii.* Mosq. News 38:396–403.

Lea, A. O. 1964. Studies on the dietary and endocrine regulation of autogenous reproduction in *Aedes taeniorhynchus.* J. Med. Entomol. 1:40–44.

Lillie, T. H., J. M. Campbell, C. E. Thalken and J. T. Lang. 1980. The pitcher plant mosquito, *Wyeomyia smithii,* a recent introduction to the bioassay laboratory. Proc. 14th Ann. Conf. Trace Subs. in Environ. Hlth. 14:383–389.

O'Meara, G. F., L. P. Lounibos and R. A. Brust. 1981. Repeated egg clutches without blood in the pitcher plant mosquito. Ann. Entomol. Soc. Am. 74:68–72.

Price, R. D. 1958. Notes on the biology and laboratory colonization of *Wyeomyia smithii* (Coquillett) (Diptera: Culicidae). Can. Entomol. 90:473–478.

Smith, S.M. and R. A. Brust. 1971. Photoperiodic control of maintenance and termination of larval diapause in *Wyeomyia smithii* (Coq.) (Diptera: Culicidae) with notes on oogenesis in the adult female. Can. J. Zool. 49:1065–1073.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and procedures of statistics, with special reference to the biological sciences. McGraw-Hill, N.Y. pp. 107–109.

Wallis, R. C. and J. Frempong-Boadu. 1967. Colonization of *Wyeomyia smithii* (Coq.) from Connecticut. Mosq. News 27:9–11.

MERMITHID PARASITISM IN *CULICOIDES VARIIPENNIS* (DIPTERA: CERATOPOGONIDAE) IN NEW YORK STATE

BRADLEY A. MULLENS AND DONALD A. RUTZ
Department of Entomology, Cornell University, Ithaca, NY 14853

ABSTRACT. Parasitism of late instar *Culicoides variipennis* larvae by the mermithid nematode, *Heleidomermis vivipara,* is reported. Parasites were found at 4 geographically distinct sites in central New York State. The nematodes emerged from the host as adults, mated, and the females gave birth to live preparasites. The sex ratio was 41:59 (male:female), with generally either 1 female or 1 or 2 males emerging/host. During the 7-month study at 2 of the sites, average parasitism was 9.8% and 7.1%, but individual collections ranged from 0–54%.

Mermithid parasitism in ceratopogonids has been reported on numerous occasions, although proper parasite identifications are often lacking (see Wirth 1977 for review). The first report of mermithids attacking midges of the subgenus *Monoculicoides* was by Glukhova (1967), who found parasitized larvae of *Culicoides stigma* (Meigen), *C. nubeculosus* (Meigen) and *C. puncticollis* (Becker) in a silty, manure-contaminated habitat near a cattle watering trough in Karelia, USSR. The nematodes were later described by Rubtsov (1970, 1972) as *Heleidomermis vivipara.* Another species, *H. ovipara* (Rubtsov 1974a) was found developing primarily in late instar larvae (rarely pupae) of *C. helveticus* Callot, Kremer and Deduit, though the nematode also parasitized *C. pulicaris* L., *C. circumscriptus* Kieffer and *C. manchuriensis* Tokunaga. Very little is known of their biologies.

MATERIALS AND METHODS

We first discovered mermithid parasites emerging from 4th instar larvae of *Culicoides v. variipennis* (Coquillett) collected from Fanton Farm, near Belvidere, Allegheny Co., NY in May 1980. Parasitized midge larvae were subsequently found at 3 additional sites: (1) House Farm, near Weedsport in Cayuga Co., (2) Pearce Farm, near Auburn in Cayuga Co., and (3) Yenei Farm, near Newfield in Tompkins Co. All 4 sites had open, silty mud contaminated with cattle manure, which served as substrate for the midge larvae. The Pearce Farm site was a slow creekbed with highly organic muck, received some milk parlor and cowyard drainage, and had no direct cattle access to the area. The Yenei Farm site was a spring-fed pasture stock pond with moderate cattle access. Mermithids were identified by Dr. W. R. Nickle (Nematology Laboratory, Plant Protection Institute, USDA, Beltsville, MD 20705).

Two sites, Pearce Farm and Yenei Farm, were sampled at 1–3 week intervals, when possible, to estimate the seasonal incidence of parasitism. Due to host voltinism patterns, however, late instar midges were not always available. From 9 to 18 samples were taken from the top cm of mud just below the waterline. Larval midges (3rd and 4th instars) were separated with a 50-mesh sieve and held in 8.8 cm petri dishes with 20 ml of tap water at 23°C and a 14:10 (L:D) photoperiod. The larvae were checked at 3–5 day intervals for at least 1 month for parasite emergence. Several cohorts of midge larvae also were held individually in vials to determine the number of parasites emerging/host. Parasites were held in darkness in 5 cm Syracuse dishes with 10 ml of tap water at 8°C for observations on their biology.

RESULTS AND DISCUSSION

The mermithids were determined to be *Heleidomermis vivipara* Rubtsov. Parasite emergence was observed only from 4th instar hosts and occurred primarily through the anus. Hosts died shortly before or at parasite exit (Figs. 1a, 1b). A few nematodes unsuccessfully attempted to emerge through the oral cavity, but apparently were caught in the heavily sclerotized pharyngeal armature and died. Single female parasites emerged from 19 of 26 individually held, parasitized larvae. Single males emerged from 2 hosts. Two males emerged per host from 4 hosts and a male and a very small female emerged from 1 host. Early season parasites were not identified to sex, but the sex ratio for those emerging from late June to early October was 41:59 (male:female, n = 119). Parasite sex may be influenced by the number of preparasites attacking a host (which affects the nutrients available/parasite), as has been noted in other mermithid species (Welch 1965).

Mating of the nematodes occurred in loose clumps, with the posterior end of the male curled around the midsection (vaginal region) of the female, a common method in mermithids (Rubtsov 1974b) (Fig. 2). Eggs of *H. vivipara* hatch within the female (Fig. 3), which gives birth to live preparasites (Fig. 4). The preparasites measured 288.5 ± 9.7 μm long and 25.5 ± 3.2 μm wide (maximum width, n = 20. Preparasite emergence from individual females occurred over a 1–2 day interval, and the young nematodes lived 1–2 days (some as long as 4 days) in tap water. Relevant aspects of their biology (e.g. mode of entry, preferred host stage) remain to be determined.

Heleidomermis vivipara emerged from the host as adults, rather than postparasitic juveniles as do many other mermithids (Welch 1965, Rubtsov 1974b). Both the host larvae and their parasites appeared to be slightly larger in the overwintered generation. For parasites obtained primarily in September, females averaged 10.2 ± 2.2 mm long (range = 4.9 – 14.6 mm, n = 21), while males were significantly (t = 7.19, $P < .01$) smaller, averaging 6.0 ± 1.1 mm in length (range = 4.1 – 7.9 mm, n = 18). *Heleidomermis vivipara* described by Rubtsov (1972) were considerably smaller, with 5 females ranging from 5.2 – 6.8 mm and a single male measuring 5.5 mm. This may reflect size differences in the host species. Judging from Rubstov's illustration, the Russian host larvae are slightly less than 6

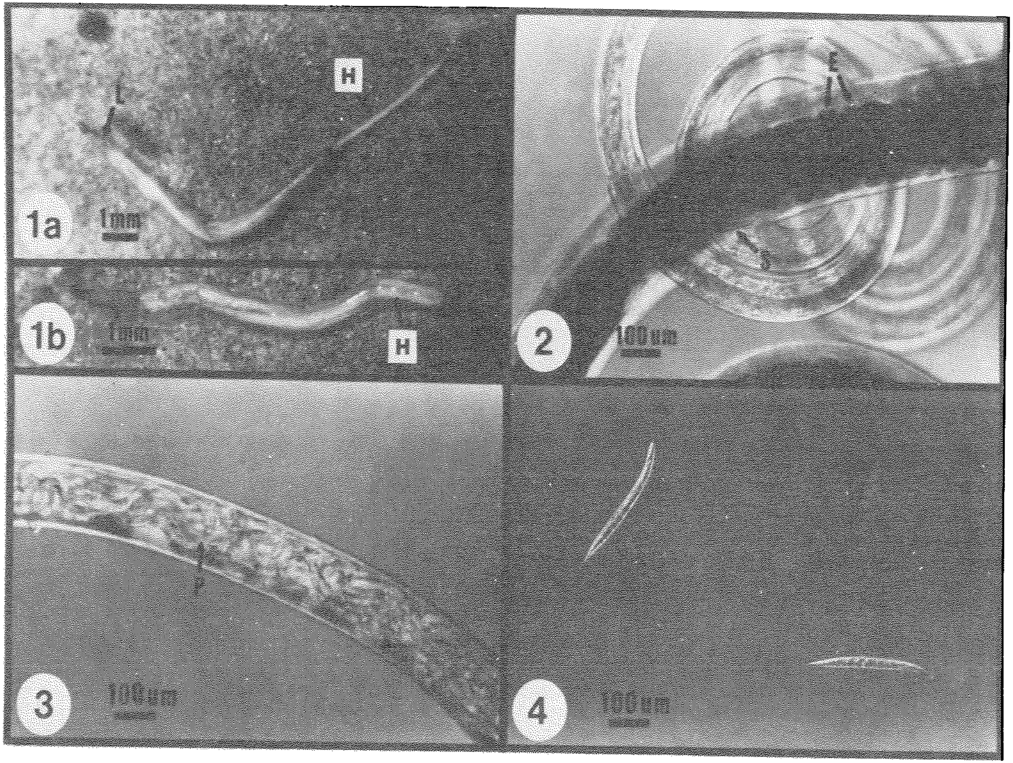

Fig. 1a. *Heleidomermis vivipara* (H) emerging from the anus of a 4th instar larva (L) of *Culicoides variipennis.* 1b. *H. vivipara* prior to emergence.

Fig. 2. Posterior end of male *H. vivipara* coiled around midsection (vaginal region) of female (approximate mating position). S = spicule, E = eggs.

Fig. 3. Section of female body cavity of *H. vivipara* filled with preparasites (P).

Fig. 4. Preparasites of *H. vivipara.*

mm long, while September *C. variipennis* larvae are about 8 mm in length. Voucher specimens are deposited in the Entomology Collection at Cornell University.

Point prevalence of parasitism in 4th instars at the 2 sites is presented in Table 1. Wide variation occurred at both sites, with the highest rates of parasitism in August at Yenei Farm (17%) and in September at Pearce Farm (32–54%). These higher parasitism rates occurred near the end of summer host emergence and could be due to several factors. First, it is possible that the parasites delayed host development, with unparasitized midges emerging normally and the remaining larvae showing an artificially high parasitism rate. Second, holding the larvae in water allowed easy detection of parasite emergence, but retarded or stopped host development due to lack of food. Therefore, parasite emergence might have been inhibited from younger 4th instar larvae, and truly high rates of parasitism would be more readily seen in host larvae collected at a more advanced age. Third, parasitism possibly increased through the season, perhaps as a response to increasing host density. The average incidence of parasitism was 9.8% at Pearce Farm and 7.1% at Yenei Farm.

Parasite emergence was never observed from pupae. Limited collections of newly emerged adults at both locations yielded one mermithid from an adult midge collected at Yenei Farm in May, but the parasite was lost before positive identification could be made. Mullens and Schmidtmann (1982) reported mermithid parasitism in an adult female of *C. variipennis* from a different site in central New York, but the identification of this parasite is also uncertain. It seems plausible, however, that *H. vivipara* could persist and emerge from the adult midge. This has been noted in other aquatic mermithids and would have obvious advantages for dispersal (Welch 1965).

We have found *H. vivipara* in 4 geographically distinct New York sites. Ad-

Table 1. Seasonal parasitism of 4th instar *Culicoides variipennis* by *Heleidomermis vivipara* at 2 sites in central New York State, 1981.

Farm	Date larvae collected	No. held	Mermithid emergence Male	Female	Total	% Parasitism (95% CI)*
Pearce	4/6	113	—	—	5	≤4.4
	4/20, 4/28	14	—	—	1	≤7.1
	6/26, 7/3	234	4	5	9	3.0 (1 –6)
	7/30	171	5	10	15	7.6 (4 –13)
	8/20	82	1	1	2	2.4 (0 –10)
	9/4	95	18	21	39	31.6 (21 –40)
	9/17	35	7	11	18	42.9 (29 –62)
	9/24	13	4	5	9	53.8 (27 –79)
	10/1	56	0	4	4	7.1 (2 –18)
	10/7	113	5	5	10	7.1 (4 –15)
	Total	926	44	62	112	9.8 (8 –12)
Yenei	5/13	107	—	—	10	≤9.3
	6/27, 7/3	79	0	3	3	3.8 (1 –11)
	8/6, 8/12	42	6	4	10	16.7 (8 –33)
	10/8	25	0	0	0	0.0 (0 –13)
	Total	253	6	7	23	7.1 (4 –11)

* % Parasitism $= \dfrac{\frac{m}{2} + f \times 100}{L}$, where m = male *Heleidomermis*, f = female *Heleidomermis*, and L = total larvae held. Unsexed parasites assumed to be 40% males.

ditionally, R. H. Zimmerman and E. C. Turner (Department of Entomology, VPI and SU, Blacksburg, VA 24061, personal communication) have recently found *Heleidomermis* in *C. variipennis* larval populations in Saltville, Virginia, and have observed several mermithid-parasitized adult midges as well. Therefore it appears that this parasite may be fairly widespread. The finding of *H. vivipara* in *Culicoides variipennis* is not unexpected considering the phylogenetic and ecological similarities with its counterparts in the old-world *Monoculicoides*. Wirth (1977), in fact, suggested that *H. vivipara* should be explored as a potential biological control agent for *C. variipennis*. Additional studies on this mermithid and its potential impact on *C. variipennis* populations are needed.

ACKNOWLEDGMENTS

We thank Dr. W. R. Nickle for encouragement and assistance in identifying the *Heleidomermis*. We also thank Dr. Nickle, Dr. W. F. Mai (Department of Plant Pathology, Cornell University), and Dr. J. J. Petersen (USDA-ARS and Department of Entomology, University of Nebraska) for their valuable comments on the manuscript.

References Cited

Glukhova, V. M. 1967. On parasitism in blood-sucking midges (Diptera: Ceratopogonidae) by nematodes of the superfamily Mermithoidea. Parasitologiia 1:519–520.

Mullens, B. A. and E. T. Schmidtmann. 1982. The gonotrophic cycle of *Culicoides variipennis* (Diptera: Ceratopogonidae) and its implications in age-grading field populations in New York State, USA. J. Med. Entomol. 19 (in press).

Rubtsov, I. A. 1970. New species and genera of mermithids from biting midges. New and poorly known species of the fauna of Siberia. 3(CO) Nauka Novosibersk, pp. 94–101. (*In* Wirth 1977).

Rubtsov, I. A. 1972. Aquatic Mermithidae of the fauna of the USSR. Akad. Nauk. SSSR. Zool. Inst. Vol. 1. 280 p. Amerind Publ. Co., New Delhi. (*Heleidomermis vivipara* redescribed).

Rubtsov, I. A. 1974a. New species of mermithids from midges. Parasitologiia 8:212–219.

Rubtsov, I. A. 1974b. Aquatic Mermithidae of the fauna of the USSR. Akad. Nauk. SSSR. Zool. Inst. Vol. 2, 274 p. Amerind Publ. Co., New Delhi.

Welch, H. E. 1965. Entomophilic nematodes. Annu. Rev. Entomol. 10:275–302.

Wirth, W. W. 1977. A review of the pathogens and parasites of the biting midges (Diptera: Ceratopogonidae). J. Wash. Acad. Sci. 67:60–75.