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RECORDS OF MOSQUITO-PARASITIC MERMITHID NEMATODES IN THE NORTHCENTRAL UNITED STATES

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ABSTRACT. Mermithid parasites (Nematoda: Mermithidae) were observed in 11 mosquito species in 22 counties of Indiana, Michigan, Minnesota, Ohio and Wisconsin. Natural hosts included adult *Aedes vexans, Ae. canadensis, Ae. cinereus, Ae. diantaeus, Ae. punctor, Anopheles punctipennis* and *Coquillettidia perturbans* and larvae of *Ae. abserratus, Ae. canadensis, Ae. cinereus, Ae. communis, Ae. diantaeus, Ae. provocans, Ae. punctor, Ae. stimulans* and *Cq. perturbans*. These are the first records of such parasites in Indiana, Minnesota, Ohio and Wisconsin.

Mermithid parasites of mosquitoes occur throughout the Holarctic region, but relatively few populations of these nematodes have been reported. Published distributional records include 14 states and 3 provinces in North America ranging from Alaska to Florida (Fig. 1). Infected mosquitoes have been found in such disparate habitats as snow pools, tree holes, ponds and roadside ditches (Petersen et al. 1968, Tsai and Grundmann 1969, Poinar and Sanders 1974, Ross and Smith 1976, Harlos et al. 1980, Gaugler et al. 1984, Olds et al. 1989). At least 8 genera of Culicidae have natural mermithid parasites, but populations of these nematodes appear to be rare and patchily distributed. The extent to which the known distribution of mermithids reflects the actual occurrence and importance of these parasites in mosquito populations is questionable.

Ten mermithid species have been described from North American mosquitoes: *Perutilimermis culicis* (Stiles), *Paramermis canadensis* Steiner, *Hydromermis churchillensis* Welch, *Romanomermis nielseni* (Tsai and Grundmann), *Strelkovimermis peterseni* (Nickle), *Octomyomermis troglodytis* Poinar and Sanders, *Romanomermis culicivorax* Ross and Smith, *Romanomermis hermaphrodita* Ross and Smith, *Romanomermis kiktoreak* Ross and Smith, and *Romanomermis communensis* Galloway and Brust. However, most mermithid parasites found in Nearctic mosquitoes have not been identified to species, and the extent to which allopatric populations are related is not known.

Only 6 populations of mosquito-parasitic mermithids have been reported in the northcentral United States and adjoining areas of southern Canada. These populations are located in Michigan (Hagan 1966[6], Olds et al. 1989), Iowa (Reardon and Lunt 1989) and southeastern Manitoba (Harlos et al. 1980). In the following account, we report the discovery of additional populations of mosquito-parasitic mermithids in the Great Lakes region. The collection localities, host species and host stage at postparasite emergence for these nematodes are summarized in Table 1.

All mermithid parasites of mosquitoes infect the larval stages of their hosts and develop in the hemocoel, but mermithid species differ with regard to whether development is completed in the larval or adult stages of the host. *Aedes vexans* (Meigen) is the most commonly reported host of mermithids that emerge from adult mosquitoes in North America. Parasitized adults of this species have been observed in British Columbia (Steiner 1924, Trpiš et al. 1968), Manitoba (Harlos et al. 1980), Oklahoma (Ewing et al. 1989) and Iowa (Reardon and Lunt 1989).

Parasitized *Ae. vexans* adults were collected in New Jersey light traps at 2 locations in Midland Co., MI, in 1992. Parasite prevalence ranged from 11% ($n = 9$) (Larkin Township, July 10) to 18% ($n = 142$) (Homer Township, August 24–25). Mosquitoes collected in a CDC light trap at the Homer Township site on August 25 had similar infection rates (19%, $n = 36$). Because parasitism was determined only by visual inspection, these values represent minimum infection rates. Parasites were not observed in any other species (*Anopheles punctipennis* (Say), *An. quadrimaculatus* Say, *Coquillettidia perturbans* (Walker), *Culex pipiens* Linn.) in these adult collections.

Two *Ae. vexans* females captured in light traps in Saginaw Co., MI, contained partially emerged mermithid postparasites (R. G. Knepper, un-

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[6] Hagan, N. K. B. 1966. Mermithid nematode parasitism of *Aedes stimulans* (Walker) (Diptera: Culicidae) from Ingham County, Michigan. Unpublished M.S. thesis. Michigan State University, East Lansing, MI.

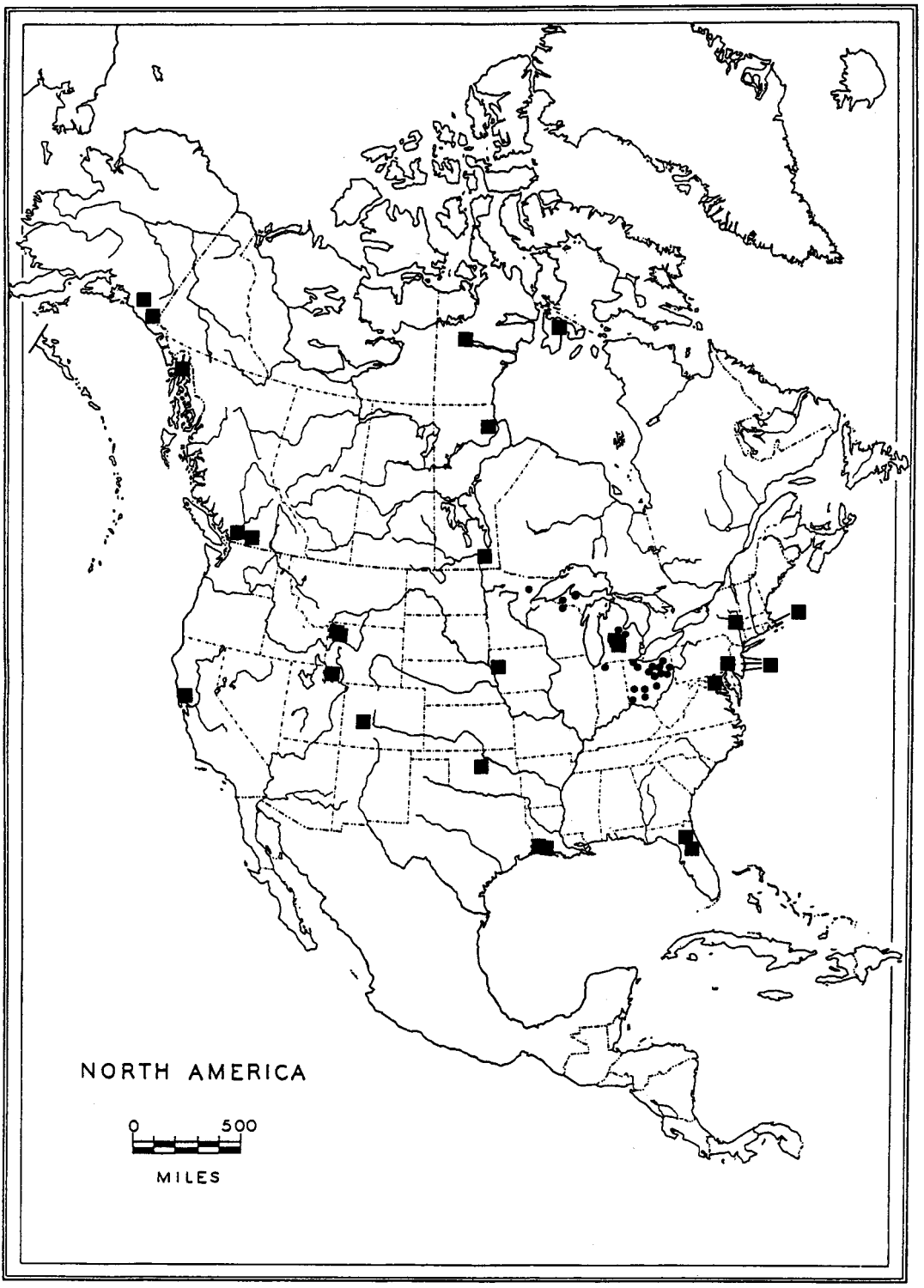

Fig. 1. Distribution of sites in North America where mosquito-parasitic mermithid nematodes have been reported. ■, literature records; ●, observations reported here.

Table 1. New geographic records of mosquito-parasitic mermithid nematodes in the northcentral United States.

State County	Host species[1]	Host stage at emergence	Collector
Indiana			
St. Joseph	*Ae. vexans*	Adult	M. Blackmore
	Cq. perturbans	Larva	E. Walker
Michigan			
Gogebic	*Ae. punctor* *Ae. cinereus* *Ae. canadensis* *Ae. abserratus* *Ae. provocans* *Ae. diantaeus* *Ae. communis*	Larva	G. Craig, Jr.
Marquette	*Ae. punctor* *Ae. canadensis* *Ae. diantaeus*	Adult	M. Blackmore
Midland	*Ae. vexans*	Adult	T. Wilmot
	Cq. perturbans	Larva	T. Wilmot
Saginaw	*Ae. vexans*	Adult	R. Knepper
Minnesota			
St. Louis	*Ae. canadensis* *Ae. cinereus* *Ae. punctor*	Larva	R. Price
Ohio			
Franklin	*Ae. vexans*	Adult	R. Berry and W. Foster
	Cq. perturbans	Adult	W. Foster
Ashland	*Ae. vexans*	Adult	R. Berry
Columbiana	*Ae. vexans*	Adult	R. Berry
Hamilton	*Ae. vexans*	Adult	R. Berry
Holmes	*An. punctipennis*	Adult	R. Berry
Knox	*Ae. vexans*	Adult	R. Berry
Lucas	*Ae. vexans*	Adult	R. Berry
Miami	*Ae. vexans*	Adult	R. Berry
Muskingum	*Ae. vexans*	Adult	R. Berry
Richland	*Ae. vexans*	Adult	R. Berry
Ross	*Ae. vexans*	Adult	R. Berry
Summit	*Ae. vexans*	Adult	R. Berry
Tuscarawas	*Ae. vexans*	Adult	R. Berry
Wayne	*Ae. vexans*	Adult	R. Berry
Wood	*Ae. vexans*	Adult	R. Berry
Wisconsin			
Vilas	*Ae. punctor* *Ae. provocans* *Ae. abserratus* *Ae. cinereus* *Ae. communis* *Ae. diantaeus* *Ae. stimulans*	Larva	G. Craig, Jr.

[1] Multiple hosts listed in order of decreasing importance.

published data). These were collected during July 1992, but the specific time and place of collection were not recorded.

Aedes vexans larvae collected from a rural drainage ditch near Lakeville, IN (St. Joseph Co.), on July 19, 1992, were dissected and found to be infected by juvenile mermithids. All of the parasites were located in the head capsules of these 4th instar larvae and appeared to be in an early stage of development. To study the life cycle of these parasites, mosquito larvae were reared to the adult stage in the laboratory. Individual mosquitoes were dissected after death and examined for parasites. Mermithid parasites were present in 72% (n = 293) of these mosquitoes. Prevalence did not differ between host stages, suggesting that parasitism caused little mortality before postparasite emergence (1–2 wk after host eclosion). Parasites were situated in the thoracic or abdominal hemocoels of pupae and adults and grew rapidly after host eclosion. Infected females that took blood meals produced larger postparasites than either males or non-biting females. Additional adult mosquitoes were collected with battery-powered aspirators between July 27 and August 13. Parasite prevalence ranged from 79 to 19% in these collections, declining sharply after August 4. Although *Ae. vexans* was the only species present in the larval sample, *Ae. trivittatus* (Coq.), *Psorophora ciliata* (Fabr.) and *Ps. confinnis* (Lynch Arribalzaga) adults also were collected in the vicinity of the larval habitat. Mermithids were found in 3 of 110 (3%) *Ae. trivittatus* and 1 of 3 *Ps. confinnis,* but all of the parasites in these species were encapsulated. Living parasites were found only in *Ae. vexans.*

Between 1969 and 1972, mermithid parasites were noted in 40 pools of adult mosquitoes collected in 15 counties by the Vector-borne Disease Unit of the Ohio Department of Health (Table 1). A single infected *An. punctipennis* was collected in Holmes Co. in 1969; all other infected mosquitoes were *Ae. vexans.* These individuals were captured in CDC miniature light traps supplemented with dry ice, and infection rates (determined by visual inspection) as high as 25% were observed.

More extensive observations of infected *Ae. vexans* in Franklin Co. were made in the summers of 1975 and 1976 in conjunction with studies of adult feeding. Adult mosquitoes were collected at 2 locations near Columbus: Carruthers Field and Don Scott Field. The former site is well drained, and mosquitoes were collected after dark while nectar feeding or biting. At Don Scott Field, samples were taken by sweep net and biting catch in the afternoon in a woods 400 m from a meadow where *Ae. vexans* and *Ae. trivittatus* sometimes developed in large numbers. The meadow was used for collections of nectar-feeding mosquitoes and biting catches made after dark. Males were not dissected; infections were noted during dissection to determine parity. Many infected females were scored as parous (Detinova tracheal skein method), though it is possible that the nematodes had altered the ovaries to make their tracheae appear that way. A few blooded/gravid females collected in the woods were infected, but these were rare. Infections were observed principally in the early summer, in the vanguard of the first brood of *Ae. vexans.* Older populations and subsequent summer broods were less likely to be infected. Infected females were found mainly close to the larval habitats. The highest infection rate in a single-day collection of *Ae. vexans* was 93% (n = 60). This was on July 1, 1976, in a biting collection at the meadow with oviposition sites. Parasite prevalence in the simultaneous collection of nectar-feeding adults at the same site was 15% (n = 39). On most occasions infected individuals were more common among nectar-feeding mosquitoes than among biting mosquitoes at the same sites.

Aedes trivittatus and other common biting mosquitoes were never infected, with one exception: *Cq. perturbans.* Two of 8 females of this species collected while biting at Carruthers Field on July 16, 1975, and a single biting female collected at Don Scott Field on July 13, 1976, were infected.

Parasitism of adult mosquitoes in the Great Lakes region is not limited to *Ae. vexans.* In addition to the *Anopheles* and *Coquillettidia* noted above, infections also have been observed in adults of spring *Aedes* species. Hagan (1966)[6] reported mermithid parasites in *Ae. stimulans* collected at 2 snow pool sites in Ingham Co., Michigan. These nematodes were present in mosquito larvae, pupae and adults, but postparasites emerged only from adult hosts. Collections of infected adult *Ae. stimulans* in June 1992 confirmed that this parasite population remains extant. Similar parasites were found in mosquito larvae collected from 2 snow pools in Marquette Co., MI, on May 14, 1992. Again, parasites were confined to the head capsules of larval hosts and migrated posteriorly after host pupation. *Aedes punctor* (Kirby) appeared to be the principal host species, but *Ae. canadensis* (Theobald) and *Ae. diantaeus* Howard, Dyar and Knab also were infected. The parasite prevalences for all mosquitoes collected in the 2 pools were 17% (n = 43) and 43% (n = 35), but too few individuals were collected to compare infection rates in different species.

Most of the mermithid parasites that have been reported from early spring *Aedes* species complete their development in larval hosts (Frohne

1953, Tsai and Grundmann 1969, Galloway and Brust 1979, Blackmore and Nielsen 1990). These appear to infect a broader range of mosquito species than parasites that emerge from adult hosts. Parasites with this life history were found in 8 *Aedes* species in snowmelt pools at the University of Notre Dame Environmental Research Center (UNDERC) near Land O'Lakes, Wisconsin. This property straddles the border between Gogebic Co., MI, and Vilas Co., WI, and infested sites were found in both states (Table 1). Thirty-five sites at UNDERC are sampled annually in early May, and the mosquito fauna of these disjunct pools has remained stable since 1968. Infected mosquito larvae have been collected at 14 of these sites, and parasite prevalence varied from 10 to 79% depending on sampling date and local climatic conditions. Hosts included *Ae. abserratus* (Felt and Young), *Ae. canadensis, Ae. cinereus* Meigen, *Ae. communis* (De Geer), *Ae. diantaeus, Ae. punctor, Ae. provocans* (Walker) and *Ae. stimulans* (Walker).

Infected 4th instar *Ae. canadensis, Ae. cinereus* and *Ae. punctor* larvae also were collected at 2 sites in St. Louis Co., MN, on May 29, 1956 (R. D. Price, unpublished data). *Aedes punctor* collected at these sites on May 20, 1988, were not parasitized; whether or not these mermithid populations have persisted has not been determined.

Mermithids that emerge from larval stage hosts also were found in *Cq. perturbans* in central Michigan and northern Indiana during September 1992. Parasitism of *Cq. perturbans* was first reported by Olds et al. (1989) from collections at 2 sites in southcentral Michigan and has since been observed in eastern Massachusetts (Kenny and Ruber 1991). Twenty-six percent (n = 57) of larvae collected from a cattail marsh in Midland Co., MI (Lincoln Township), on September 16 and 24, 1992, were parasitized. Parasites with a similar infection pattern were collected in *Cq. perturbans* from a site in Granger, IN (St. Joseph Co.), on September 17, 1992. Twenty-eight larvae were collected, most of which were in the 3rd instar. Fourteen of these individuals were held at 8°C to allow parasite development to proceed; the remaining individuals were immediately dissected and examined for parasites. Eight of the larvae were infected, but only 2 of the infected individuals had viable nematodes; all other parasites were encapsulated. All parasites (viable and encapsulated) were situated in the thorax or abdomen of the hosts. None of the larvae survived long enough for postparasites to emerge.

There were no published records of mosquito-parasitic mermithids in the northcentral United States before 1989 even though such parasites had been observed at several different locations before that time. Our data substantially increase the number of mermithid populations reported in this region and extend their known geographic distribution to 4 additional states. Many other populations undoubtedly exist but remain undetected.

Mermithid parasitism often is not apparent during casual examination of mosquitoes. Parasites that develop in larvae are most obvious 1–2 days before they emerge. Earlier stages are easily overlooked unless the host is dissected. Parasites of *Cq. perturbans* are still more difficult to detect because of the gray-white appearance of the hosts. Furthermore, the difficulties in collecting and rearing larvae of *Cq. perturbans* probably have limited opportunities for discovering populations of this species with parasites.

Mermithid parasites that emerge from adult mosquitoes are virtually impossible to detect in host larvae and pupae without careful dissection under a microscope. Even when fully developed, parasites in the abdominal cavities of adult mosquitoes are easily mistaken for eggs or nectar meals, and specimens collected in light traps are often so dried or distorted that the presence of parasites is obscured.

All of the mermithid populations reported here were discovered serendipitously rather than by systematic surveys of mosquito populations. A better understanding of the natural distribution of these nematodes is necessary to fully appreciate their role in the biology of mosquito populations. It appears that *Ae. vexans* adults and *Cq. perturbans* larvae may offer the best opportunities for discovering new mermithid populations. Although many more populations probably occur in spring *Aedes* species, the ephemeral nature of these populations and the nearly ubiquitous distribution of potentially infested habitats present greater obstacles to finding mermithids in these mosquitoes. Nonetheless, our observations suggest that mermithid parasitism of mosquitoes is more common than previously suspected. Surveys specifically directed toward locating parasite populations and better reporting of accidentally discovered populations would add much to our understanding of the biogeography of these mosquito parasites.

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REFERENCES CITED

Blackmore, M. S. and L. T. Nielsen. 1990. Observations on the biology of *Romanomermis* sp. (Nem-

atoda: Mermithidae) parasites of *Aedes* in western Wyoming. J. Am. Mosq. Control Assoc. 6:229–234.

Ewing, S. A., J. J. Petersen and J. S. Afolabi. 1989. Prevalence of parasitism of adult *Aedes vexans* by a mermithid (Nematoda: Mermithidae) in Oklahoma. J. Am. Mosq. Control Assoc. 5:106–108.

Frohne, W. C. 1953. Mosquito breeding in Alaskan salt marshes, with especial reference to *Aedes punctodes* Dyar. Mosq. News 13:96–103.

Galloway, T. D. and R. A. Brust. 1979. Review of the genus *Romanomermis* (Nematoda: Mermithidae) with a description of *R. communensis* sp. n. from Canada. Can. J. Zool. 57:281–289.

Gaugler, R., S. Wraight and D. Molloy. 1984. Bionomics of a mermithid parasitizing snow-pool *Aedes* spp. mosquitoes. Can. J. Zool. 62:670–674.

Harlos, J., R. A. Brust and T. D. Galloway. 1980. Observations on a nematode parasite of *Aedes vexans* (Diptera: Culicidae) in Manitoba. Can. J. Zool. 58:215–220.

Kenny, E. A. and E. Ruber. 1991. Mermithid nematode parasites of *Coquillettidia perturbans* in Massachusetts. J. Am. Mosq. Control Assoc. 7:663–664.

Olds, E. J., R. W. Merritt and E. D. Walker. 1989. Sampling, seasonal abundance, and mermithid parasitism of larval *Coquillettidia perturbans* in south-central Michigan. J. Am. Mosq. Control Assoc. 5:586–592.

Petersen, J. J., H. C. Chapman and D. B. Woodard. 1968. The bionomics of a mermithid nematode of larval mosquitoes in southwestern Louisiana. Mosq. News 28:346–352.

Poinar, G. O., Jr. and R. D. Sanders. 1974. Description and bionomics of *Octomyomermis troglodytis* sp. n. (Nematoda: Mermithidae) parasitizing the western treehole mosquito *Aedes sierrensis* (Ludlow) (Diptera: Culicidae). Proc. Helminthol. Soc. Wash. 41:37–41.

Reardon, T. P. and S. R. Lunt. 1989. Parasitism of adult *Aedes vexans* by a mermithid (Nematoda: Mermithidae) in Iowa. J. Am. Mosq. Control Assoc. 5:446–447.

Ross, J. F. and S. M. Smith. 1976. A review of the mermithid parasites (Nematoda: Mermithidae) described from North American mosquitoes (Diptera: Culicidae) with descriptions of three new species. Can. J. Zool. 54:1084–1102.

Steiner, G. 1924. Remarks on a mermithid found parasitic in the adult mosquito (*Aedes vexans* Meigen) in B. C. Can. Entomol. 56:161–164.

Trpiš, M., W. O. Haufe and J. A. Shemanchuk. 1968. Mermithid parasites of the mosquito *Aedes vexans* Meigen in British Columbia. Can. J. Zool. 46:1077–1079.

Tsai, Y.-H. and A. W. Grundmann. 1969. *Reesimermis nielseni* gen. et sp. n. (Nematoda: Mermithidae) parasitizing mosquitoes in Wyoming. Proc. Helminthol. Soc. Wash. 36:61–67.