Comp. Parasitol.
76(1), 2009, pp. 44–50

Redescription of *Neoechinorhynchus tenellus* (Acanthocephala: Neoechinorhynchidae) from Esox *lucius* (Esocidae) and Sander *vitreus* (Percidae), among other Percid and Centrarchid fish, in Michigan, U.S.A.

OMAR M. AMIN[1,3] AND PATRICK M. MUZZALL[2]

[1] Institute of Parasitic Diseases, P.O. Box 28372, Tempe, Arizona 85285-8372, U.S.A. (e-mail: omaramin@aol.com),
[2] 203 Natural Science Building, Department of Zoology, Michigan State University, East Lansing, MI 48824, U.S.A. (email; muzzal@msu.edu)

ABSTRACT: The only 2 published taxonomic accounts of *Neoechinorhynchus tenellus* are those of Van Cleave (1913) and Van Cleave (1919) from *Esox lucius* Linnaeus and *Sander vitreus* (Mitchill) (=*Stizostedion vitreus* (Mitchill)). While Van Cleave's original description is adequate to identify *N. tenellus*, his description of proboscis armature, lemnisci, reproductive system in both sexes, and eggs was either not complete or in error. We studied the original type material and found their present state to be of little use for elucidating characters that were not already illustrated and described by Van Cleave. For that reason we studied newly collected, conspecific specimens to better document key morphological features of this species. Our description of the Michigan material from the same 2 fish species was compared with the original description and with Van Cleave's cotypes (designated syntypes). Our revised description includes the following: (1) trunk of males and females is widest in anterior third tapering gradually at both ends. (2) Lateral anterior hooks are markedly larger than and set more posterior to the other 4 hooks of the same circle. Middle hooks not in perfect circle but alternate. (3) Middle and posterior hooks with discoidal bases. (4) Lemnisci are subequal. (5) Eggs have distinct polar prolongation of fertilization membrane, which places the species in the subgenus *Hebesoma* Van Cleave, 1928. New observations address sexual dimorphism, the larger size of specimens from *S. vitreus* than from *E. lucius*, the apical organ, giant nuclei, sensory pits on the proboscis, and details of the reproductive system in both sexes.

KEY WORDS: *Neoechinorhynchus tenellus* (Acanthocephala), redescription, *Esox lucius*, *Sander vitreus*, Michigan, distribution.

Neoechinorhynchus tenellus (Van Cleave, 1913) Van Cleave, 1919, is readily recognizable despite its incomplete description from relatively uninformative specimens. The availability of specimens of *N. tenellus* from northern pike *Esox lucius* Linnaeus and walleye *Sander vitreus* (Mitchill) (=*Stizostedion vitreus* (Mitchill); the same hosts from which the species was originally described), smallmouth bass *Micropterus dolomieui* (Lacépède), rock bass *Ambloplites rupestris* (Rafinesque), and yellow perch *Perca flavescens* (Mitchill) from Michigan allowed us to redescribe the species and account for variability in worm size in relation to host species and geographical distribution.

The species was originally described from *E. lucius* in Lake Marquette, Bemidgi, Minnesota (Van Cleave, 1913). The description was subsequently briefly updated based on additional specimens from *S. vitreus* in the Illinois River (Van Cleave, 1919). No other descriptive account has been published, but a few fish parasite surveys have reported it in these and other fish species in other geographical locations. Dechtiar (1972a, b), Dechtiar and Christie (1988), Dechtiar and Nepszy (1988), Dechtiar and Lawrie (1988), and Dechtiar et al. (1988) reported it in various Canadian waters. Canadian fish hosts additionally included sauger, *Sander canadensis* (Griffith and Smith). The present study includes new observations of *N. tenellus* derived from more recently collected specimens from fishes of the St. Marys River, Michigan.

MATERIAL AND METHODS

Three sources of information were studied. The first is the published descriptions based on an indeterminate number of specimens collected by Herman Douthitt from 2 specimens of *E. lucius* in Lake Marquette, Bemidji, Minnesota (near 47°25′39″N, 94°54′28″W) on 8 September 1911 (Van Cleave, 1913) and another set of specimens presumably collected by Harley Jones Van Cleave from *E. lucius* and *S. vitreus* in 3 locations of the Illinois River, mostly at Havana (near 40°18′0″N, 90°3′39″W) during unspecified summer months of 1910 (Van Cleave, 1919).

[3] Corresponding author.

The second source of information is Van Cleave's 17 syntypes (11 males, 6 females; named and marked on the slides as cotypes by Van Cleave) on 17 slides collected from Lake Marquette on 8 September 1911 and on which his original 1913 description was apparently based. These specimens were obtained from the U.S. National Parasite Collection (USNPC), Beltsville, Maryland. The log of the USNPC, however, indicates that these syntypes were collected by Van Cleave himself on 10 August 1910. Van Cleave did not designate a holotype, allotype, or paratype, nor did he assign a type host. Ten specimens, 5 males and 5 females mostly with everted proboscides, were made available for the present study.

The third source of materials is the 1981 Michigan collection at Neebish Island (46°17′0″N, 84°9′30″W), St. Marys River, an outflow of Lake Superior draining into the lower Great Lakes. Liston et al. (1980) described the physical, chemical, and biological features of the St. Marys River. Fishes (*A. rupestris*, *E. lucius*, *M. dolomieui*, *P. flavescens*, *S. vitreus*) were sampled with gill nets, trap nets, or bag seine mostly during June, July, and August. The digestive tracts of fishes were examined within 36 hr of collection. Worms were kept in tap water for up to 1 day until the proboscis was extended then fixed in 70% ethanol, pricked, stained in Grenacher's borax carmine, and mounted in Canada balsam.

Measurements are reported in micrometers, unless otherwise stated. The length is followed by the mean (in parentheses). Length measurements are given before the width; the latter refers to maximum width. Trunk length does not include neck, proboscis, or bursa. The length of the proboscis is based on the posterior extension (continuity) of its prominent tegument and its clear separation from that of the trunk, which extends slightly behind the posterior circle of hooks. Measurements of Saefftigen's pouch do not include its posterior 2 branches. Eggs refer to fully developed mature eggs available only from the 6 longest females collected from *S. vitreus*. The Michigan specimens are deposited in the USNPC, Beltsville, Maryland.

RESULTS

Specimens of *N. tenellus* described in this study include specimens collected from 5 fish species in Michigan during the summer of 1981, namely, *A. rupestris* (1 male, 1 female), *E. lucius* (7, 22), *M. dolomieui* (2, 7), *P. flavescens* (2, 1), and *S. vitreus* (10, 22). The prevalence of infection from each of these host species was 13% of 16, 60% of 25, 50% of 6, 16% of 73, and 46% of 28, in the same order (Muzzall, 1984). Of these specimens, 6 males and 14 females from *E. lucius* and 7 males and 11 females from *S. vitreus* were measured. Of Van Cleave's (1913) 17 syntypes (11 males, 6 females) collected from *E. lucius* in Minnesota in 1910, the best 5 males and 5 females were studied and measured. These specimens were compared with Van Cleave's description of 1913 and his updated description of 1919, which included specimens from *S. vitreus* (Table 1). We have not been able to locate any of Van Cleave's specimens from *S. vitreus*. Van Cleave's (1919) very brief update only increased the reported maximum length of male and female trunk and provided a new measurement of what may have been an immature egg lacking polar prolongation of the fertilization membrane.

REDESCRIPTION

Neoechinorhynchus (*Hebesoma*) *tenellus* (Figs. 1–8)

General

Neoechinorhynchidae, with characters of the genus. All shared structures proportionally larger in females. Trunk cylindrical, widest in anterior one third, attenuating posteriorly, and tapering anteriorly (Figs. 1, 2, 8), occasionally with cuticular plaques at both ends (Fig. 1). Body wall with reticular lacunar system, 5 dorsal and 1 ventral giant nuclei (Fig. 2). Proboscis nearly cylindrical, slightly longer than wide, rounded anteriorly, and with 2 sensory pits at level of middle hooks, a well-defined tegument that extends distal to posterior hooks, and a prominent apical organ containing 3 anterior giant nuclei and 2 small posterior nucleated cells (Fig. 3). Apical organ apparently contractile occasionally extending to full length of proboscis. All hooks rooted. Anterior hooks large with lateral hooks markedly larger than and set more posterior to other 4 smaller hooks of same circle. Middle hooks not in a perfect circle but alternate, much smaller than anterior hooks. Posterior hooks slightly smaller than middle hooks. Roots of anterior hooks prominent, shorter than hooks, simple and directed posteriorly. Middle and posterior hooks with discoid bases (Figs. 3, 4). Proboscis receptacle single-walled; cephalic ganglion at its posterior end. Lemnisci elongate, longer than receptacle, subequal, with 2 adjacent and 1 giant nuclei in longer and shorter lemniscus, respectively; nuclei opposite each other in anterior half of each lemniscus (Figs. 1, 2, 8).

Table 1. Comparative measurements of male and female specimens of *Neoechinorhynchus tenellus* from *Esox lucius* and *Sander vitreus*.

Character	Van Cleave, 1913	Van Cleave, 1919	Syntypes (USNPC no. 37633)	This paper	This paper
	Esox lucius	*Esox lucius*, *Sander vitreus*	*Esox lucius*	*Esox lucius*	*Sander vitreus*
Males (*n*)	—*	—	(5)	(7)	(7)
Trunk LXW (mean) (mm)	2.0 × 0.28	2.0 × 8.0 × –	2.29–2.60 (2.45) × 0.25–0.35 (0.29)	2.87–4.70 (3.90) × 0.30–0.47 (0.40)	4.00–8.87 (6.87) × 0.37–0.67 (0.52)
Proboscis LXW (mean)	150 × 135	150 × 135	102–142 (127) × 102–127 (115)	150–180 (170) × 120–150 (136)	162–187 (172) × 127–152 (137)
Hook L (mean) no. 1 (lateral)	90 × 110	90–110	77–92 (85)	80–100 (93)	87–92 (90)
No. 1 (other)	90 × 110	90–110	62–77 (70)	72–80 (75)	70–80 (76)
No. 2	38	38	40–42 (41)	32–47 (43)	40–45 (43)
No. 3	27	27	30–32 (31)	29–35 (31)	30–32 (31)
Receptacle LXW (mean)	260 × –	—	332–395 (363) × 93–135 (109)	302–489 (412) × 135–208 (172)	395–645 (537) × 135–208 (171)
Shorter lemiscus LXW (mean)	870 × –	—	645–884 (738) × 55–87 (66)	749–1,258 (1,061) × 85–125 (101)	1,092–1,675 (1433) × 95–176 (130)
Longer lemniscus LXW (mean)	870 × –	—	676–967 (790) × 52–75 (64)	822–1,300 (1,167) × 80–135 (106)	1,227–1,800 (1587) × 102–198 (135)
Anterior testis LXW (mean)	210 × 120	—	208–302 (247) × 114–187 (145)	364–509 (444) × 198–270 (245)	600–1,125 (850) × 198–450 (328)
Posterior testis LXW (mean)	210 × 120	—	177–270 (214) × 104–198 (148)	270–510 (354) × 198–270 (239)	400–1,150 (807) × 218–350 (288)
Cement gland LXW (mean)	260 × 70	—	229–312 (273) × 87–135 (117)	530–967 (740) × 177–260 (220)	655–2,050 (1454) × 198–325 (260)
Saefftigen's pouch LXW (mean)	—	—	229–300 (280) × 32–50 (42)	426–749 (558) × 52–87 (64)	468–1,040 (812) × 75–166 (106)
Cement reservoir LXW (mean)	—	—	105–135 (115) × 57–104 (77)	177–281 (235) × 104–166 (142)	218–603 (432) × 94–280 (214)
Cement reservoir duct LXW (mean)	—	—	250–275 (258) × 12–15 (14)	354–645 (481) × 15–27 (22)	468–1,040 (759) × 23–42 (33)
Common sperm duct LXW (mean)	—	—	250–287 (266) × 35–47 (40)	385–624 (494) × 45–62 (52)	520–988 (764) × 58–104 (81)
Penis LXW (mean)	—	—	50–87 (65) × 32–45 (40)	87–120 (100) × 50–62 (54)	97–137 (123) × 42–75 (63)
Females (*n*)	—	—	(5)	(14)	(11)
Trunk LXW (mean) (mm)	3.5–5.0 × 0.28	3.5–13.0 × 0.60	2.50–4.20 (2.93) × 0.25–0.32 (0.28)	4.00–7.05 (5.28) × 0.40–0.55 (0.47)	6.37–13.50 (10.14) × 0.47–0.72 (0.60)
Proboscis LXW (mean)	150 × 135	150 × 135	150–162 (156) × 125–130 (127)	157–192 (175) × 127–162 (146)	162–200 (185) × 135–175 (155)
Hook L. (mean) no. 1 (lateral)	90 × 110	90–110	95–100 (97)	92–107 (100)	95–112 (102)
No. 1 (other)	90 × 110	90–110	80–90 (85)	72–95 (82)	77–90 (85)
No. 2	38	38	35–45 (40)	37–45 (41)	40–47 (43)
No. 3	27	27	30–35 (32)	27–37 (32)	30–37 (32)
Receptacle LXW (mean)	260 × –	—	312–395 (351) × 104–146 (124)	395–468 (424) × 156–187 (181)	416–780 (555) × 125–218 (185)
Shorter lemiscus LXW (mean)	870 × –	—	634–728 (681) × 47–62 (54)	1,125–1,425 (1,305) × 60–125 (96)	1,196–1,976 (1,605) × 65–187 (122)
Longer lemniscus LXW (mean)	870 × –	—	759–800 (779) × 52–75 (63)	1,250–1,477 (1,367) × 70–125 (108)	1,300–2,184 (1,807) × 75–180 (131)
Eggs LXW (mean)	—	37–45 × 12–16	Ovarian balls only	Ovarian balls, unripe eggs	37–50 (44× 12–17 (15)
Reproductive system L (mean)	—	—	395	520–905 (615)	832–1,070 (969)
% of trunk length	—	—	16%	10–15 (12%)	7–12 (9%)

* Information not given or unavailable.

Male

Measurements provided in Table 1. Testes oblong, contiguous or slightly overlapping, pre-equatorial, just behind anterior trunk swelling; anterior testis relatively longer than posterior testis. Cement gland elongate, contiguous with and about twice as long as posterior testis, with 8 anteriorly clustered rounded giant nuclei (Fig. 1). Giant nuclei not clustered anteriorly in short cement glands of Van Cleaves's material. Prominent rounded-ovoid cement gland reservoir with 2 lateral ducts inserting posteriorly into penis. Saefftigen's pouch dorsal, elongate, beginning at level of anterior end of cement reservoir duct and extending posteriorly to level of conical penis where it forks into 2 branches; shorter branch ending at penis and longer branch extending more posteriorly. Common sperm duct emerging at level of cement reservoir ventrally where it is widest and extending posteriorly to penis (Fig. 5).

Female

Measurements provided in Table 1; see also Figure 8. Reproductive system with undulating walls, long uterus, prominent uterine bell pouches, muscular vaginal wall around sphincters, 1 pair of muscular processes at base of vagina and subventral gonopore (Fig. 6). Reproductive system relatively longer in shorter worms compared to body length, being 7–12 (9%) in longest specimens from *S. vitreus*, 10–15 (12%) in shorter specimens from *E. lucius*, and 16% in Van Cleave's shortest specimen from the same host (Table 1). Fully developed eggs only in longest females from *S. vitreus;* fusiform with rounded ends and polar prolongation of fertilization membrane (Fig. 7).

Note

Van Cleave (1913, 1919) did not assign a holotype, allotype, or paratype specimens, nor did he designate type host or type locality. *Esox lucius* is herein designated as the type host and Lake Marquette, Bemidji, Minnesota, as the type locality based on Van Cleave's (1913) original description. The only type materials available are the syntypes (named cotypes by Van Cleave) collected from *E. lucius* in Lake Marquette.

Taxonomic summary

Type host: Esox lucius Linnaeus.

Other hosts: Ambloplitis rupestris (Rafinesque), E*sox americanus* Gmelin, *Esox masquinongy* Mitchill, *Micropterus dolomieui* (Lacépède), *Perca flavescens* (Mitchill), *Sander canadensis* (Smith), and *Sander vitreus* (Mitchill).

Type locality: Lake Marquette, Bemidji, Minnesota (near 47°25′39″N, 94°54′28″W).

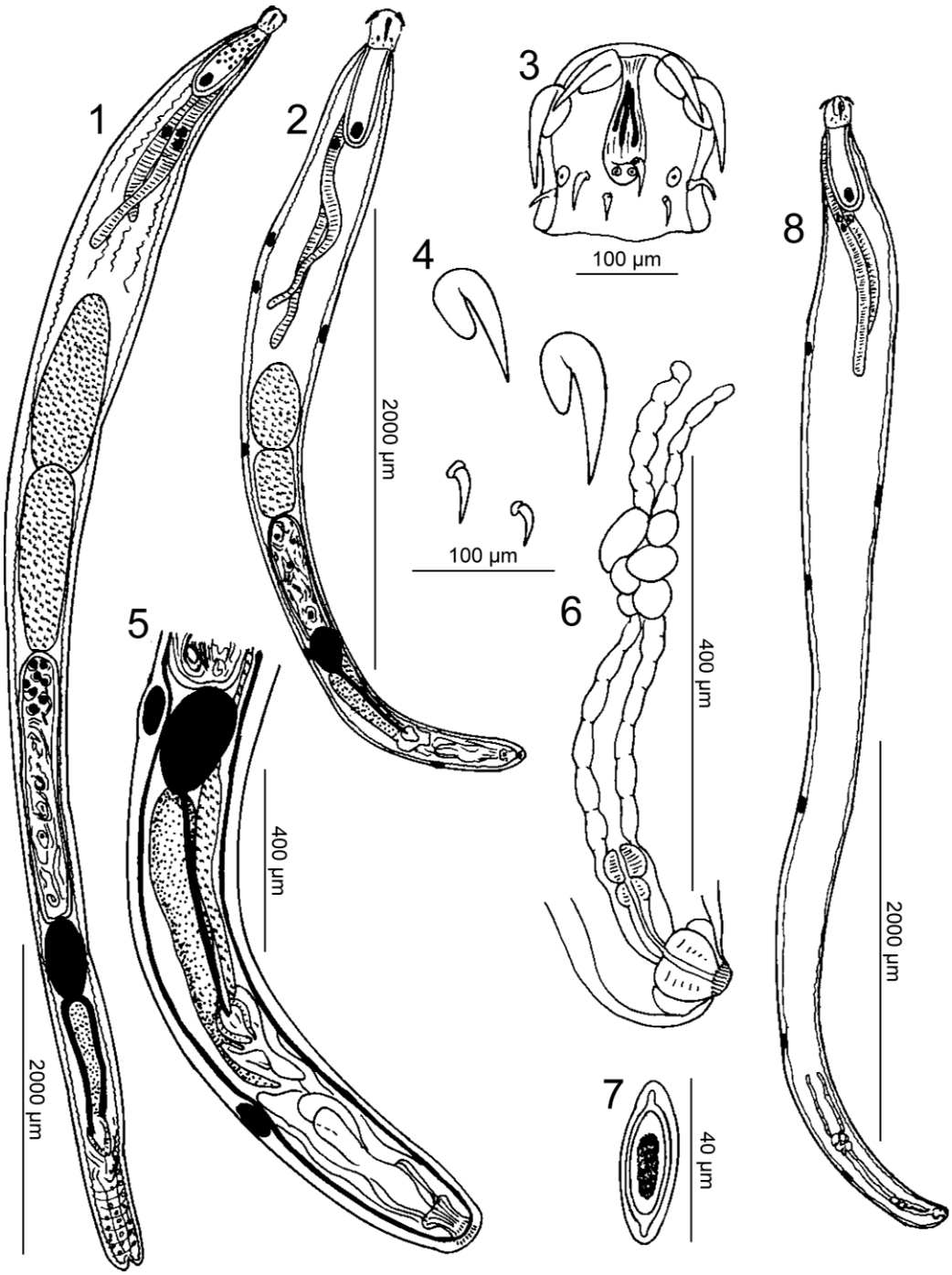
Other localities: The Illinois River probably near Havana, Illinois (near 40°18′0″N, 90°3′39″W), St. Marys River, at Neebish Island, Michigan (46°17′0″N, 84°9′30″W), Lake of the Woods, Ontario (Dechtiar, 1972a), Lake Ontario (Dechtiar and Christie, 1988), Lake Superior (Dechtiar and Lawrie, 1988), Lake Erie (Bangham and Hunter, 1939, Dechtiar, 1972b, Dechtiar and Nepszy, 1988), Lake Huron (Dechtiar et al., 1988), Lake Nipissing, Ontario (Anthony, 1978), Mid Lake, Bear Lake, Casey Lake, Cyclone Lake, Mathew Lake, Birch Lake, and other Wisconsin lakes (Bangham, 1944; Fischthal, 1947, 1950, 1952), and Bear Creek and Yellow River, Wisconsin (Fischthal, 1947), as well as the Susquehanna River, Pennsylvania (Deutsch, 1947), and Paxon Lake, Alaska (Dunagan, 1957).

Type specimens examined: Syntypes USNPC No. 037633.

Other specimens examined: Voucher specimens: USNPC Nos. 100593–100595 from *Esox lucius;* Nos. 100596–100601 from *Sander vitreus;* No. 100590 from *Perca flavescens;* No. 100591 from *Ambloplitis rupestris;* No. 100592 from *Micropterus dolomieui*.

Taxonomic remarks

Neoechinorhynchus tenellus is herein redescribed because the proboscis armature, lemnisci, reproductive system in both sexes, and egg structure were incompletely described. Initially Van Cleave (1913) showed anterior proboscis hooks of comparable length (90–110 μm) in one circle and middle and posterior hooks without roots or basal discs, and he gave 1 measurement for lemnisci (870 μm long) in both sexes, suggesting equal length. Later Van Cleave (1919) illustrated eggs with concentric shells, which would place the species in the subgenus *Neoechinorhynchus*, according to Amin (2002). He did not recognize sexual dimorphism in shared structures or the alternating middle hooks in 2 close tiers and made no reference to the apical organ, the giant nuclei in the subcuticula, apical organ or cement gland, sensory pits in the proboscis, and male or female reproductive system, which were not illustrated. He did, however, give measurements of one testis (implying that testes



Figures 1–8. *Neoechinorhynchus* (*Hebesoma*) *tenellus* from Michigan. **1.** Ventral view of a long male specimen from *Sander vitreus*. (Note dermal plaques at both extremities, anterior position of the giant nuclei of the long cement gland and lateral position of the paired cement reservoir ducts.) **2.** Lateral view of a smaller male specimen from *Esox lucius*. (Note subequal lemnisci.) **3.** Proboscis of a male specimen from *E. lucius*. (Note prominent apical organ with 3 elongate giant nuclei and 2 posterior cells, 2 sensory cells, and 2 larger lateral hooks.) **4.** Hooks from the proboscis in Figure 3, detail. **5.** Posterior reproductive system from Figure 2, detail. (Note insertion of cement reservoir duct in penis, ventral position of

are of equal size) and of the cement gland, showing it to be of similar size to testis.

Despite the noted discrepancies, *N. tenellus* remains recognizable and distinguishable from other species of *Neoechinorhynchus* using Amin's (2002) key. It can readily be separated from the only 2 other species of the subgenus *Hebesoma* Van Cleave, 1928, namely, *Neoechinorhynchus* (*H.*) *doryphorus* Van Cleave and Bangham, 1949, and *Neoechinorhynchus* (*H.*) *carinatus* Buckner and Buckner, 1993, that also have the 2 anterior lateral proboscis hooks markedly larger than the other 4 hooks in the same circle, as follows. In these 2 latter species, the lateral anterior hooks are at the same level as the other 4 anterior hooks of the same circle and measure 105–132 μm in length compared to 61–72 μm in the other 4 anterior hooks, and 31–50 μm compared to 24–43 μm, respectively. In *N. tenellus* the lateral hooks are set more posteriorly and measure 80–92 μm compared to 70–80 μm in length.

Van Cleave's (1913) specimens from *E. lucius* in Minnesota were very small. His subsequent account of specimens, from *S. vitreus*, only updated the larger size of worms and provided illustrations of the outline of a proboscis, a gravid female from *S. vitreus*, and of one oblong egg with concentric shells (Figs. 16, 19, and 20 of Van Cleave, 1919). The legend to his figure 19 stated that the specimen was "Hematoxylin-stained whole-mount in dammar." We failed to locate his specimens from *S. vitreus* for comparison.

Host factors

Measurements of worms from our collection from the St. Marys River in Michigan during the summer of 1981 clearly demonstrate that *N. tenellus* attains a markedly larger size in *S. vitreus* than in *E. lucius*. Characters demonstrating this size difference include trunk, receptacle, and lemnisci in both sexes, length of female reproductive system, and testes, cement glands, Saefftigen's pouch, cement reservoir, and penis (Table 1). Worms were collected from these 2 fish species during the same time period and processed using the same method. Only fully developed adults were compared. Measurements of worms from the other fish species from Michigan were intermediate between those of *E. lucius* and *S. vitreus*. Van Cleave's limited observations also showed the same relationship between the smaller worms only from *E. lucius* in Minnesota (Van Cleave, 1913) and the larger worms from *E. lucius* and *S. vitreus* in the Illinois River combined (Van Cleave, 1919) (Table 1). The latter comparison, however, involves 2 different geographical locations, and the possible involvement of geographical factors cannot be totally excluded in this case because Van Cleave's specimens only from *E. lucius* in Minnesota are considerably smaller than ours from the same host in Michigan. Also note the ratio between the size of the cement gland to that of the posterior testis being almost 1:1 in Minnesota compared to about 2:1 in our specimens from Michigan. It is not known whether host intestinal environment alone can account for such differential size of worms in different fish species. Similar observations, however, have been reported for other species of acanthocephalans. For instance, the size of trunk, proboscis, proboscis hooks, receptacle, lemnnisci, testes, and cement glands of male and female specimens of *Echinorhynchus salmonis* Müller, 1784, was markedly larger in worms from bloater *Coregonus hoyi* (Gill) (Salmonidae) than from smelt *Osmerus mordax* (Mitchill) (Osmeridae) collected from Lake Michigan. Larger worms from bloater invariably showed higher regression coefficient compared to those from smelt in all characters (Amin and Redlin, 1980). It was suggested that these size differences result from differential growth rates in the "various host intestinal environments and are probably mediated by host specific factors" (Amin, 1975).

Host and geographical distribution

Esox lucius and *S. vitreus* are probably the primary principal hosts of *N. tenellus*. Amin (1987) defined fish hosts as principal, accessory, and occasional. Principal hosts are those that "assume the major role of supporting the adult ... population [where] infections are usually prevalent and heavy and worms readily grow, develop, and mature ...; gravid females are common." Females gravid with ripe eggs were collected from all fish species from Michigan except for females from *E. lucius* where the eggs were not ripe. *Neoechinorhynchus tenellus* is probably more of an open water/lake rather than a riverine species.

←

common sperm duct, and dorsal position of Saefftigen's pouch and its 2 unequal posterior branches.) **6.** Reproductive system from Figure 8, detail. (Note undulating walls and 2 muscular processes surrounding terminal vaginal sphincter.) **7.** Egg from the body cavity of a long female specimen from *S. vitreus*. **8.** Female specimen from *E. lucius*. (Ovarian balls and immature eggs omitted.).

It was initially reported from *E. lucius* in Marquette Lake, Minnesota (Van Cleave, 1913), then from *E. lucuis* and *S. vitreus* in the Illinois River basin, which drains in the south end of Lake Michigan (Van Cleave, 1919). It was subsequently reported from the same and other hosts from the St. Marys River, which is the only outflow of Lake Superior to the lower Great Lakes, then from these and additional hosts in lakes Erie, Huron, Ontario, and Superior and Lake of the Woods by Dechtiar (1972a, b) and Dechtiar and coworkers (1988). It was also reported from other lakes in Ontario (Anthony, 1978) and Wisconsin (Bangham, 1944; Fischthal, 1947, 1950, 1952) as well as from Lake Erie by Bangham and Hunter (1939) from *E. lucius*, *E. americanus*, and *E. masquinongy*. It thus appears that *N. tenellus* habitats are primarily in open waters of the Great Lakes region and associated waters, where it infects fishes of the families Esocidae, Percidae, and Centrarchidae. The range of distribution, however, extends beyond this region with the reports of *N. tenellus* in Pennsylvania (Deutsch, 1977) and Alaska (Dunagan, 1957). The possible introduction of this acanthocephalan to these 2 latter locations with the introduction of infected fishes could not be confirmed.

LITERATURE CITED

Amin, O. M. 1975. Variability in *Acanthocephalus parksidei* Amin, 1974 (Acanthocephala: Echinorhynchidae). Journal of Parasitology 61:307–317.

Amin, O. M. 1987. Acanthocephala from lake fishes in Wisconsin: ecology and host relationships of *Pomphorhynchus bulbocolli* (Pomphorhynchidae). Journal of Parasitology 73:278–289.

Amin, O. M. 2002. Revision of *Neoechinorhynchus* Stiles and Hassall, 1905 (Acanthocephala: Neoechinorhynchidae) with keys to 88 species in two subgenera. Systematic Parasitology 53:1–18.

Amin, O. M., and M. J. Redlin. 1980. The effect of host species on growth and variability of *Echinorhynchus salmonis* Müller, 1784 (Acanthocephala: Echinorhynchidae), with special reference to the status of the genus. Systematic Parasitology 2:9–20.

Anthony, D. D. 1978. Metazoan parasites of percids from Lake Nipissing, Ontario, Canada. Short Communication Section H, pages 39–40 in Fourth International Congress of Parasitology, August 19–26, Warsaw, Poland.

Bangham, R. V. 1944. Parasites of northern Wisconsin fish. Transactions of Wisconsin Academy of Sciences, Arts, and Letters 36:291–325.

Bangham, R. V., and G. W. Hanter III. 1939. Studies on fish parasites of Lake Erie. Distribution studies. Zoologica (NY) 24:385–448.

Dechtiar, A. O. 1972a. Parasites of fish from Lake of the Woods, Ontario. Journal of the Fisheries Research Board of Canada 29:275–283.

Dechtiar, A. O. 1972b. New parasite records for Lake Erie fish. Great Lakes Fisheries Commission, Technical Report 17:1–20.

Dechtiar, A. O., and W. J. Christie. 1988. Survey of the parasite fauna of Lake Ontario fishes, 1961 to 1971. Great Lakes Fisheries Commission, Technical Report 51:66–95.

Dechtiar, A. O., J. J. Collins, and J. A. Reckahn. 1988. Survey of the parasite fauna of Lake Huron fishes, 1961 to 1971. Great Lakes Fisheries Commission, Technical Report 51:19–48.

Dechtiar, A. O., and A. H. Lawrie. 1988. Survey of the parasite fauna of Lake Superior fishes, 1969 to 1975. Great Lakes Fisheries Commission, Technical Report 51:1–18.

Dechtiar, A. O., and S. J. Nepszy. 1988. Survey of the parasite fauna of selected fish species from Lake Erie, 1970 to 1975. Great Lakes Fisheries Commission, Technical Report 51:49–65.

Deutsch, W. G. 1977. Fish parasites from the Susquehanna River in Pennsylvania, with new host records. Proceedings of the Pennsylvania Academy of Science 51:122–124.

Dunagan, T. T. 1957. Studies on the parasites of edible animals in Alaska. Alaska Air Command, Arctic Aeromedical Laboratory, Technical Note AAL-TN-56-12. 9 pp.

Fischthal, J. H. 1947. Parasites of northwest Wisconsin fishes I. The 1944 survey. Transactions of Wisconsin Academy of Sciences, Arts, and Letters 37:157–220.

Fischthal, J. H. 1950. Parasites of northwest Wisconsin fishes II. The 1945 survey. Transactions of Wisconsin Academy of Sciences, Arts, and Letters 40:87–113.

Fischthal, J. H. 1952. Parasites of northwest Wisconsin fishes III. The 1946 survey. Transactions of Wisconsin Academy of Sciences, Arts, and Letters 41:17–58.

Liston, C. R., W. G. Duffy, D. E. Ashton, C. D. Mcnabb, and F. E. Koehler. 1980. Environmental baseline and evaluation of the St. Marys River dredging. U. S. Fish and Wildlife Service Report/FWS/OBS-80/ 62.

Muzzall, P. M. 1984. Helminths of fishes from the St. Marys River, Michigan. Canadian Journal of Zoology 62:516–519.

Van Cleave, H. J. 1913. The genus *Neorhynchus* in North America. Zoologischer Anzeiger 43:177–190.

Van Cleave, H. J. 1919. Acanthocephala from the Illinois River, with descriptions of species and a synopsis of the family Neoechinorhynchidae. Illinois Natural History Survey Bulletin 13:225–257.