

## The *Neoechinorhynchus* of Turtles: Specimen Base, Distribution, and Host Use

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**ABSTRACT:** Distribution and host use of the 9 species of *Neoechinorhynchus* (Acanthocephala: Neoechinorhynchidae) described from turtles are summarized from a comprehensive evaluation of the specimen base in the major parasitology museums of the United States. Each specimen in each lot was examined and its identity verified, if possible. Verified specimens were used to construct a specimen-based known distribution and list of definitive hosts for each species. Five species (*Neoechinorhynchus chrysemydis*, *Neoechinorhynchus emydis*, *Neoechinorhynchus emyditoides*, *Neoechinorhynchus pseudemydis*, and *Neoechinorhynchus stunkardi*) have broad distributions in North America, whereas *Neoechinorhynchus chelonos* and *Neoechinorhynchus lingulatus* are currently known only from eastern states, and *Neoechinorhynchus magnapapillatus* is known from the eastern Atlantic seaboard, Florida, and the coast of the Gulf of Mexico. *Neoechinorhynchus schmidti* is known only from Mexico. Host use is confined largely to emydid turtles; reports from turtles in other families are sporadic, and most of the turtle species of North America have not been surveyed adequately for acanthocephalans. The specimen base for the species of *Neoechinorhynchus* of turtles is unsuitable for most taxonomic purposes; it is composed of small lots of specimens with few identifiable worms that are, on average, in poor physical condition. Future biodiversity studies of this group will require significant new specimen collections to answer questions of host use, evolutionary relationships, and biogeography.

**KEY WORDS:** Acanthocephala, museum specimens, taxonomy, distribution, host use, *Neoechinorhynchus emydis*, *Neoechinorhynchus pseudemydis*, *Neoechinorhynchus chrysemydis*, *Neoechinorhynchus emyditoides*, *Neoechinorhynchus stunkardi*, *Neoechinorhynchus constrictus*, *Neoechinorhynchus magnapapillatus*, *Neoechinorhynchus chelonos*, *Neoechinorhynchus lingulatus*, *Neoechinorhynchus schmidti*.

Acanthocephalans of the genus *Neoechinorhynchus* occurring in turtles were presumed (Van Cleave and Bullock, 1950) to constitute a single species, *Neoechinorhynchus emydis* (Leidy, 1851) Van Cleave, 1916, until the description of *Neoechinorhynchus pseudemydis* Cable and Hopp, 1954 and *Neoechinorhynchus chrysemydis* Cable and Hopp, 1954. Subsequently, 7 other species of *Neoechinorhynchus* have been described from turtles, *Neoechinorhynchus emyditoides* Fisher, 1960; *Neoechinorhynchus stunkardi* Cable and Fisher, 1961; *Neoechinorhynchus constrictus* Little and Hopkins, 1968; *Neoechinorhynchus magnapapillatus* Johnson, 1969; *Neoechinorhynchus chelonos* Schmidt, Esch and Gibbons, 1970 (q.v. Schmidt et al., [1970]); *Neoechinorhynchus lingulatus* Nickol and Ernst, 1987; and *Neoechinorhynchus schmidti* Barger, Thatcher and Nickol, 2004 (q.v. Barger et al., [2004]). Schmidt et al. (1970) argued that *N. constrictus* is a junior synonym of *N. pseudemydis*, a position adopted by Nickol and Ernst (1987) and Barger et al. (2004), leaving 9 species of acanthocephalans described from turtles. Golvan (1994) and Amin (2002) rejected the synonymy proposed by Schmidt et al. (1970), although neither examined specimens.

Recently, Amin (2002) grouped all species of *Neoechinorhynchus* into 2 subgenera. Members of

the nominal subgenus are characterized by concentric egg membranes, whereas members of the subgenus *Hebesoma* are characterized by polar elongations of the egg membranes. Two species from turtles, *N. chrysemydis* and *N. lingulatus*, are therefore classified in the subgenus *Hebesoma*. Barger and Nickol (2004) constructed a dichotomous key to the 9 species of *Neoechinorhynchus* from turtles, clarifying the interpretation of diagnostic structural features for each species. Currently, only fully gravid female worms can be identified, and the males of the 9 species are presumed to be indistinguishable from each other. Frequent infection of turtles with more than 1 species of *Neoechinorhynchus* has precluded association of male worms with their female counterparts, and, currently, the male worm is known for only 2 species.

Barger and Nickol (2004) noted that most of the specimens of *Neoechinorhynchus* from turtles that are housed in the major parasitology museums of North America are of limited utility to taxonomists, systematists, or those wishing to verify an identification by reference to an existing specimen. Therefore, a full evaluation of the specimen base was conducted to clarify the specimen–taxon relationships available and to evaluate specimens for their taxonomic utility, making the museum specimen base for this group more accessible. The goal of this study was to

provide a lot-by-lot, specimen-by-specimen evaluation of the existing material in the United States National Parasite Collection (USNPC), Beltsville, Maryland, U.S.A., and the Harold W. Manter Laboratory of Parasitology, University of Nebraska State Museum, Lincoln, Nebraska, U.S.A. (HWML). Those lots containing specimens whose identification could be verified independently are distinguished from those lots containing inadequate specimens. Each specimen in each lot is categorized according to its degree of utility for future taxonomic work, new specimens have been deposited to supplement existing collections, and excellent specimens stored in liquid in the USNPC and HWML were mounted permanently on microscope slides for the first time. In addition, host use and distributional information for each species were summarized based on verified specimens in the museums.

## MATERIALS AND METHODS

Specimens available for species of *Neoechinorhynchus* reported from turtles were examined from the USNPC and the HWML. Each permanently mounted specimen was evaluated on 2 categorical scales. First, each was compared with the original species descriptions and the key to species provided by Barger and Nickol (2004). If the specimen could be unambiguously identified, it was coded as "verified"; if not, it was coded as "unverified." Second, the overall state of the specimen was evaluated using 4 categories: "excellent" specimens are those from which all morphometric and categorical data could be gathered, e.g., specimen fully extended, proboscis everted; "good" specimens are those in which 1 or 2 features of the specimen are obscured, e.g., a partially inverted proboscis or copulatory bursa; "fair" specimens are those in which the majority of features are obscured, e.g., fully inverted proboscis, contorted, poorly stained; "poor" specimens are those for which measurement of morphometric features or evaluation of categorical features would be misleading.

The males of *Neoechinorhynchus* from turtles cannot currently be assigned to species, nor can most immature females (Barger and Nickol, 2004). Thus, all male and many female specimens are classified herein as unverified, although they range from poor to excellent in condition. Because diagnosis of female worms is based on so few characters (those of the egg and the shape of the posterior end), it is possible that a specimen categorized as poor could nevertheless be verified.

Most lots of specimens in the USNPC and HWML include several to many specimens, and quality can vary substantially within a lot. For brevity, a coding system was used. An entry has the following format: accession number (# females [# verified]; #excellent, #good, #fair, #poor; # males: #excellent, #good, #fair, #poor). For example, "USNPC XXXXX (12 [8]: 0, 4, 8, 0; 10: 7, 1, 1, 1)" reads 12 female worms, of which 8 can be verified, 4 are good, 8 are fair, and 10 male worms, of which 7 are excellent, 1 is good, 1 is fair, and 1 is poor. Although no effort is made here to identify specific slides or specimens within a lot that

fall into each category, a spreadsheet that includes all the data collected, including notes on individual specimens within lots and a coding system that allows association of every specimen examined with its evaluation, is available from the author.

Specimens stored in fluid in the USNPC and HWML also were examined and verified. Specimens were sorted by sex and counted, and eggs were withdrawn from females for examination as wet mounts. Fully gravid females were removed, stained, mounted permanently on microscope slides, evaluated using the criteria outlined above, and deposited. In a few cases, no slides were made despite excellent material. The coding system for specimens stored in fluid notes whether the identification was verified, whether slides were made and deposited as part of this study, and the number of male and female specimens remaining in fluid.

Those lots for which the original species determination was incorrect are noted under the heading of the species originally designated, and the reader is directed to the correct species designation where full information is given. In a few cases, multiple species were present in a single lot. Each entry in these cases summarizes only those specimens of that species; readers are directed to other species headings.

Specimens from the author's collections were collected as part of a survey of the turtle parasites throughout the Mississippi river valley and other locales during the summers of 2002 and 2003. Turtles were collected from Reelfoot Lake, Lake and Obion counties, Tennessee, U.S.A.; Sherburne Wildlife Management Area within the Atchafalaya National Wildlife Refuge (NWR), Pointe Coupee Parish, Louisiana, U.S.A.; Chotard Lake, Issaquena County, Mississippi, U.S.A.; Big Chute Island, White river NWR, Arkansas County, Arkansas, U.S.A.; St. Joseph river, St. Joseph County, Indiana, U.S.A.; near Gainesville, Alachua County, Florida, U.S.A.; and near Villahermosa, Tabasco, Mexico. Specimens obtained were evaluated using the system outlined above and deposited in the HWML.

The highest ranking verified specimens for each species were compared with the type material, original species descriptions, and the key to species in Barger and Nickol (2004). Those lots containing the most representative specimens are identified herein as specimens to use in lieu of the holotype for routine verification of species identifications of new specimens.

Host use and geographic distributions for each species could be assembled from literature reports, deposited specimens, or both. Because many reports on acanthocephalans from turtles were made before a complete understanding of the diversity of the group, it is likely that the literature base is tainted to some degree by misidentifications. In many cases, voucher specimens were not deposited, and, in some cases, those deposited cannot be verified as the species reported in the literature. Thus, a conservative approach is taken herein in summarizing host use and geographic distribution. Only those reports of hosts and localities supported by an identifiable specimen in the USNPC or HWML are included as valid reports. Although this undoubtedly underestimates host use and geographical distribution for some of the more commonly encountered species of *Neoechinorhynchus* in turtles, it nonetheless is the only verifiable way to document host use and geographical distribution.

***Neoechinorhynchus chelonos*  
Schmidt, Esch and Gibbons, 1970**

*Definitive hosts:* Slider, *Trachemys scripta*.

*Life cycle:* Unknown.

*Distribution:* Figure 1.

*Holotype:* USNPC 70708 (in good condition).

*Paratypes:* USNPC 70709 (7 females in good condition).

*Specimens (slides):* HWML 34623 (18 [10]: 0, 11, 2, 5; 0: 0, 0, 0, 0).

*Specimens (vials):* None.

*Specimens to use in lieu of holotype:* USNPC 70709; HWML 34623.

*Remarks:* I am unaware of any report on *N. chelonos* since the original species description. The specimens in HWML 34623 are from the type locality and were deposited by Gerald Schmidt. The available lots of specimens all contain easily identifiable specimens; some are twisted, and some have an inverted proboscis, but both the eggs and the contour of the posterior end are in good condition.



**Figure 1.** Distribution of *Neoechinorhynchus chelonos* based on verified specimens in the USNPC and the HWML. Inset cross marks the type locality; open squares represent collection locales of voucher specimens; open circles are collection locales of specimens deposited as a part of this study.

***Neoechinorhynchus chrysemydis*  
Cable and Hopp, 1954**

*Definitive hosts:* Slider, *T. scripta*; painted turtle, *Chrysemys picta*; common map turtle, *Graptemys geographica*; river cooter, *Pseudemys concinna*.

*Life cycle:* Unknown.

*Distribution:* Figure 2.

*Holotype:* USNPC 49099 (in excellent condition).

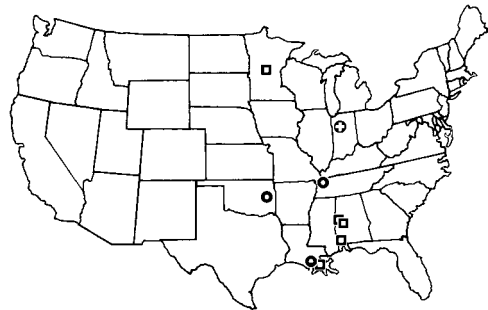
*Paratypes:* USNPC 49099 (1 male in poor condition).

*Specimens (slides):* USNPC 34536 (2 [2]: 1, 1, 0, 0; 0: 0, 0, 0, 0); USNPC 61822 (1 [1]: 0, 0, 0, 1; 0: 0, 0, 0, 0); USNPC 82348 (1 [1]: 0, 1, 0, 0; 1: 0, 0, 1, 0); USNPC 82349 (4 [1]: 0, 0, 2, 2; 4: 0, 0, 3, 1); USNPC 82350 (4 [2]: 0, 1, 2, 1; 4: 0, 2, 0, 2); USNPC 82351 (5 [1]: 0, 2, 1, 2; 7: 0, 2, 2, 3); USNPC 88658 (1 [0]: 0, 0, 0, 1; 0: 0, 0, 0, 0); HWML 33883 (0 [0]: 0, 0, 0, 0; 1: 0, 1, 0, 0); HWML 39334 (0 [0]: 0, 0, 0, 0; 1: 0, 0, 0, 1); HWML 45563 (1 [1]: 0, 1, 0, 0; 0: 0, 0, 0, 0); HWML 45564 (1 [1]: 0, 1, 0, 0; 0: 0, 0, 0, 0); HWML 45573 (1 [1]: 0, 0, 1, 0; 0: 0, 0, 0, 0).

*Specimens (vials):* USNPC 34536 (3 females, 3 males; verified, 2 slides deposited); USNPC 61822 (27 females, 24 males; verified, 1 slide deposited).

*Specimens to use in lieu of holotype:* HWML 45564; USNPC 82348.

*Remarks:* Surprisingly, only 36 permanently mounted specimens of *N. chrysemydis* were available, of which half were females (8 of which could be verified). Three lots (USNPC 88658, 33883, and 39334) contain no identifiable specimen, and the overall condition of the specimens is inadequate (12 of 18 female specimens categorized as fair or poor). Overall, 2.8% of specimens were excellent, 27.8% were good, 30.5% were fair, and 38.9% were poor. Three lots (each containing 1 specimen) were added as a part of this study (HWML 45563, 45564, and 45573) from Reelfoot Lake, Lake and Obion counties, Tennessee,



**Figure 2.** Distribution of *Neoechinorhynchus chrysemydis* based on verified specimens in the USNPC and the HWML. No detailed collection locality available for Minnesota. Inset cross marks the type locality; open squares represent collection locales of voucher specimens; open circles are collection locales of specimens deposited as a part of this study.

U.S.A.; McIntosh County, Oklahoma, U.S.A.; and Atchafalaya NWR, Pointe Coupee Parish, Louisiana, U.S.A., respectively. *Neoechinorhynchus chrysemydis* has a broad distribution in North America. However, it has not been found with the frequency or intensity of the other common acanthocephalans of turtles, *N. emyditoides* and *N. pseudemydis*.

***Neoechinorhynchus constrictus*  
Little and Hopkins, 1968**

(Junior synonym of *Neoechinorhynchus pseudemydis* Cable and Hopp, 1954.)

*Holotype*: USNPC 62972 (see Remarks).

*Paratypes*: USNPC 62973; USNPC 62974 (see Remarks).

*Remarks*: Little and Hopkins (1968) described *N. constrictus* from *T. scripta* collected in Brazos County, Texas, U.S.A. Schmidt et al. (1970) compared paratypes of *N. constrictus* with specimens of *N. pseudemydis* and convincingly argued that *N. constrictus* is a junior synonym of *N. pseudemydis*. Little and Hopkins (1968) distinguished *N. constrictus* from *N. pseudemydis* based on the smaller eggs, more constricted posterior extremity of the female worm, and smaller trunk size characterizing *N. constrictus*. I have examined the type material of *N. constrictus* and agree with Schmidt et al. (1970) that it is a junior synonym of *N. pseudemydis*. All the diagnostic characters used by Little and Hopkins (1968) are characteristic of worms that are immature (Schmidt et al., 1970). Examination of the type material revealed that the shape of the posterior end is well within the range exhibited by *N. pseudemydis*, and that the few fully developed eggs present were not distinguishable from those of *N. pseudemydis* in size, shape, or membrane structure. However, Amin (2002) did not accept the synonymy in a revision of the genus *Neoechinorhynchus*, stating that the position of the female gonopore and egg size differ. The interpretation of the position of the female gonopore by Amin (2002) appears mistaken. In the original description of *N. pseudemydis*, the posterior of the female was drawn from a dorsolateral view (Cable and Hopp 1954, fig. 2), giving the impression that the gonopore is terminal. The position of the gonopore in the description of *N. constrictus* is decidedly ventro-subterminal, and the figure is a lateral view. When examined from a lateral view, the gonopore of *N. pseudemydis* is clearly revealed as ventrosubterminal, as well. Thus, the characters suggested by Amin

(2002) do not distinguish putative individuals of *N. constrictus* from those of *N. pseudemydis*.

***Neoechinorhynchus emydis*  
(Leidy, 1851) Van Cleave, 1916**

*Definitive hosts*: Common map turtle, *G. geographica*; false map turtle, *Graptemys pseudogeographica*; Texas map turtle, *Graptemys versa*.

*Life cycle*: *Cypria maculata* (Ostracoda) reported as intermediate host by Hopp (1954) in Tippecanoe river near Lafayette, Indiana, U.S.A.; Hopp (1954) found juveniles (presumed to be *N. emydis*) embedded in foot of *Campeloma rufum*, a viviparid snail, as did Lincicome and Whitt (1947) and Lincicome (1948) near Lexington, Kentucky, U.S.A., along with *Ceriphasia semicarinata*. Developmental details in Hopp (1954).

*Distribution*: Figure 3.

*Holotype*: USNPC 6506 (in excellent condition).

*Paratypes*: USNPC 6506 (1 female in poor condition; 3 males in fair to good condition).

*Specimens (slides)*: USNPC 27255 (see *N. emyditoides*); USNPC 37406 (0 [0]: 0, 0, 0, 0; 1: 0, 1, 0, 0); USNPC 37407 (1 [1]: 0, 1, 0, 0; 0: 0, 0, 0, 0); USNPC 38680 (see *N. pseudemydis*); USNPC 43489 (see *N. emyditoides*); USNPC 50953 (see *N. emyditoides*); USNPC 51922 (3 [1]: 1, 0, 1, 1; 1: 0, 0, 1, 0); USNPC 61822 (see *N. chrysemydis*); USNPC 66144 (see *N. emyditoides* and *N. pseudemydis*); USNPC 82345 (11 [4]: 1, 2, 4, 4; 9: 0, 5, 2, 2); USNPC 82346 (3 [2]: 0, 0, 0, 3; 0: 0, 0, 0, 0); USNPC 82347 (see *N. pseudemydis*); USNPC 82348 (see *N. chrysemydis*); USNPC 82349 (see *N. chrysemydis*); USNPC 82350 (see *N. chrysemydis*); USNPC 82351 (see *N. chrysemydis*); USNPC 82352 (see *N. emyditoides*); USNPC 82353 (5 [2]: 0, 1, 2, 2; 5: 0, 4, 0, 1); USNPC 82354 (see *N. emyditoides*); USNPC 82355 (10 [0]: 0, 1, 1, 8; 2: 0, 0, 0, 2); USNPC 82356 (5 [3]: 4, 1, 0, 0; 2: 0, 2, 0, 0); USNPC 82357 (4 [1]: 0, 1, 2, 1; 0: 0, 0, 0, 0); USNPC 82358 (0 [0]: 0, 0, 0, 0; 1: 0, 0, 0, 1); USNPC 82359 (1 [1]: 0, 0, 0, 1; 0: 0, 0, 0, 0); USNPC 82360 (see *N. emyditoides*); USNPC 82361 (see *N. pseudemydis*); USNPC 82362 (2 [2]: 0, 0, 0, 2; 0: 0, 0, 0, 0); USNPC 82363 (2 [2]: 0, 0, 2, 0; 2: 0, 0, 1, 1); USNPC 82364 (see *N. emyditoides*); USNPC 82365 (0 [0]: 0, 0, 0, 0; 1: 0, 0, 1, 0); USNPC 82366 (0 [0]: 0, 0, 0, 0; 7: 0, 4, 3, 0); USNPC 82367 (0 [0]: 0, 0, 0, 0; 18: 0, 18, 0, 0); USNPC 82368 (0 [0]: 0, 0, 0, 1; 0, 1, 0, 0); USNPC 83610 (see *N. emyditoides* and *N. stunkardi*); USNPC 88659 (0 [0]: 0, 0, 0, 0; 1: 0, 0, 0,

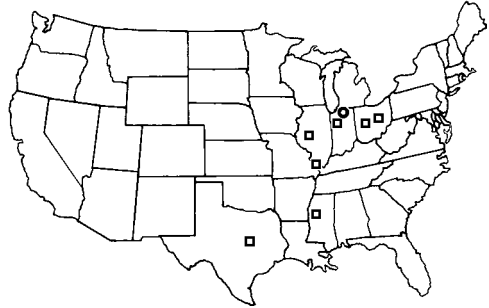
1); USNPC 90151 (see *N. emyditoides*); HWML 17000 (4 [4]: 0, 2, 2, 0; 4: 0, 1, 3, 0); HWML 45565 (2 [2]: 2, 0, 0, 0; 0: 0, 0, 0, 0).

*Specimens (vials)*: USNPC 27243 (9 fragments of 1 worm; cannot be verified); USNPC 27254 (12 fragments of female worms, 1 female; cannot be verified, see also *N. emyditoides* and *N. pseudemydis*); USNPC 27255 (see *N. emyditoides*); USNPC 34511 (21 females; verified as *N. emydis*, no slides made); USNPC 42739 (see *N. pseudemydis*); USNPC 42742 (2 females, 2 males; cannot be verified); USNPC 43489 (see *N. emyditoides*); USNPC 44210 (see *N. emyditoides*); USNPC 47043 (see *N. emyditoides*); USNPC 50945 (see *N. emyditoides* and *N. pseudemydis*); USNPC 50946 (see *N. stunkardi*); USNPC 50947 (see *N. emyditoides* and *N. pseudemydis*); USNPC 50951 (see *N. pseudemydis*); USNPC 50952 (2 females; cannot be verified); USNPC 50953 (see *N. emyditoides*); USNPC 50954 (5 females, 4 males; cannot be verified); USNPC 61822 (see *N. chrysemydis*); USNPC 66144 (see *N. emyditoides* and *N. pseudemydis*); USNPC 83610 (see *N. emyditoides* and *N. stunkardi*); USNPC 90151 (see *N. emyditoides*); HWML 10356 (98 females, 82 males; verified as *N. emydis*); HWML 10433 (21 females, 23 males; verified as *N. emydis*); HWML 15375 (4 females; verified as *N. emydis*); HWML 40174 (see *N. emyditoides*).

*Specimens to use in lieu of holotype*: USNPC 82356; HWML 45565.

*Remarks*: Acanthocephalans of turtles accumulated in the USNPC for over 100 yr were assumed to be *N. emydis* until Cable and Hopp (1954) described 2 new species from turtles. Thus, the association of specimens and lots with this species is the most convoluted. Many lots originally deposited under *N. emydis* contain 1 or more other species; some of these problems have been solved in the past, but many persisted until the present investigation. Overall, of 37 lots originally deposited as *N. emydis*, 19 contain identifiable specimens of other species of *Neoechinorhynchus* from turtles. Of the remaining 18 lots, 11 contain at least 1 specimen that can be verified as *N. emydis*. Overall, 24 of 52 female specimens are verifiable, and 5.6% of all specimens on slides (107) are excellent, 42.1% are good, 23.4% are fair, and 28.9% are poor. Only 5 of the lots consisting of whole worms in vials contained specimens of *N. emydis*. One lot containing 2 specimens (HWML 45565) from the Saint Joseph River, St. Joseph County, Indiana, U.S.A., was deposited as part of this

study. *Neoechinorhynchus emydis* has been found most frequently from the eastern half of the upper Mississippi river drainage, but the distribution of this species is not well known. *Neoechinorhynchus emydis* has been reported (Ernst and Ernst, 1977) from *Chelydra serpentina*, *P. concinna*, *T. scripta*, *Clemmys guttata*, *Clemmys insculpta*, and *Emydoidea blandingii*, in addition to the turtles listed above. However, verifiable specimens exist only from map turtles (*Graptemys* spp.)



**Figure 3.** Distribution of *Neoechinorhynchus emydis* based on verified specimens in the USNPC and the HWML. Inset cross marks the type locality; open squares represent collection locales of voucher specimens; open circles are collection locales of specimens deposited as a part of this study.

### ***Neoechinorhynchus emyditoides* Fisher, 1960**

*Definitive hosts*: Slider, *T. scripta*; painted turtle, *C. picta*; common map turtle, *G. geographica*; false map turtle, *G. pseudogeographica*; Blanding's turtle, *E. blandingii*; mud turtle, probably *Kinosternon* sp.

*Life cycle*: Unknown.

*Distribution*: Figure 4.

*Holotype*: USNPC 39025 (in fair condition).

*Paratypes*: USNPC 39025 (1 male in fair condition).

*Specimens (slides)*: USNPC 27255 (2 [2]: 0, 0, 2, 0; 0: 0, 0, 0, 0); USNPC 29459 (3 [3]: 0, 3, 0, 0; 0: 0, 0, 0, 0); USNPC 94793 (2 [2]: 0, 0, 2, 0; 0: 0, 0, 0, 0); USNPC 36626 (2 [1]: 0, 0, 1, 1; 1: 0, 0, 0, 1); USNPC 42739 (see *N. pseudemydis*); USNPC 43489 (1 [1]: 0, 0, 0, 1; 0: 0, 0, 0, 0); USNPC 44210 (2 [2]: 0, 2, 0, 0; 0: 0, 0, 0, 0); USNPC 47043 (1 [1]: 1, 0, 0, 0; 0: 0, 0, 0, 0); USNPC 94795 (1 [1]: 0, 1, 0, 0; 0: 0, 0, 0, 0); USNPC 94796 (2 [2]: 0, 0, 2, 0; 0: 0, 0, 0, 0); USNPC 50953 (2 [2]: 0, 1, 1, 0; 0: 0, 0, 0, 0); USNPC 66144 (1 [1]: 1, 0, 0, 0; 0: 0, 0, 0, 0); USNPC 82352 (3 [2]: 0, 2, 1, 0; 4: 0, 0, 2, 2); USNPC 94792 (1 [1]: 0, 0, 1,

0; 5: 0, 4, 0, 1); USNPC 82354 (18 [12]: 0, 0, 0, 18; 2: 0, 0, 0, 2); USNPC 82360 (2 [2]: 0, 0, 0, 2; 2: 0, 0, 0, 2); USNPC 82364 (5 [3]: 0, 2, 3, 0; 6: 0, 1, 0, 5); USNPC 83610 (1 [1]: 0, 1, 0, 0; 0: 0, 0, 0, 0); USNPC 90151 (2 [2]: 0, 2, 0, 0; 0: 0, 0, 0, 0); HWML 30556 (1 [0]: 0, 0, 0, 1; 0: 0, 0, 0, 0); HWML 34122 (2 [1]: 0, 1, 0, 1; 1: 0, 0, 0, 1); HWML 45557 (2 [2]: 2, 0, 0, 0; 0: 0, 0, 0, 0); HWML 45558 (2 [2]: 2, 0, 0, 0; 0: 0, 0, 0, 0); HWML 45559 (2 [2]: 0, 1, 1, 0; 0: 0, 0, 0, 0); HWML 45560 (3 [3]: 3, 0, 0, 0; 0: 0, 0, 0, 0); HWML 45562 (2 [2]: 0, 2, 0, 0; 0: 0, 0, 0, 0); HWML 45570 (2 [2]: 2, 0, 0, 0; 0: 0, 0, 0, 0); HWML 45571 (1 [1]: 1, 0, 0, 0; 0: 0, 0, 0, 0); HWML 45572 (1 [1]: 0, 1, 0, 0; 0: 0, 0, 0, 0).

*Specimens (vials)*: USNPC 27254 (12 fragments of female worms, 1 whole female; cannot be verified, see also *N. emydis* and *N. pseudemydis*); USNPC 27255 (8 female fragments, 5 females, 3 males; verified as *N. emyditoides*, 2 slides made); USNPC 29459 (16 females, 24 males; verified as *N. emyditoides*, 3 slides made); USNPC 34570 (11 females, 2 males; verified as *N. emyditoides*, 2 slides made); USNPC 42739 (see *N. pseudemydis*); USNPC 43489 (13 females; verified as *N. emyditoides*, 1 slide made); USNPC 44210 (7 females, 15 males; verified as *N. emyditoides*, 2 slides made); USNPC 47043 (1 male; verified as *N. emyditoides*, 1 slide made); USNPC 50945 (38 females, 35 males; verified as *N. emyditoides*, 1 slide made, see also *N. pseudemydis*); USNPC 50947 (138 juveniles, 19 males; verified as *N. emyditoides*, 2 slides made, see also *N. pseudemydis*); USNPC 50953 (1 female; verified as *N. emyditoides*, 2 slides made); USNPC 66144 (13 females, 11 males; verified as *N. emyditoides*, 1 slide made, see also *N. pseudemydis*); USNPC 83610 (86 females, 132 males; verified as *N. emyditoides*, 1 slide made, see also *N. stunkardi*); USNPC 90151 (9 females, 8 males; verified as *N. emyditoides*, 2 slides made).

*Specimens to use in lieu of holotype*: HWML 45560; HWML 45557; HWML 45558; USNPC 47043.

*Remarks*: The specimen base of *N. emyditoides* is in relatively good condition. Only 2 of the 21 lots of slides in the USNPC and HWML contain no identifiable specimen of this species (USNPC 42739; HWML 30556), including specimens from 11 lots of unmounted specimens that were mounted for the first time as a part of this study. Overall, 42 of 54 female specimens could be verified as *N. emyditoides*, and 2.7% of all specimens were excellent, 26.7%

were good, 20% were fair, and 50.6% were poor. Fifteen specimens in 8 lots were deposited as a part of this study: HWML 45557 (Villahermosa, Tabasco, Mexico), HWML 45558 (Chotard Lake, Issaquena County, Mississippi, U.S.A.), HWML 45559 and 45560 (Reelfoot Lake, Lake and Obion counties, Tennessee, U.S.A.), HWML 45562 (McIntosh County, Oklahoma, U.S.A.), HWML 45570 (White river NWR, Arkansas County, Arkansas, U.S.A.), HWML 45571 (Lake Talawanda, Oklahoma, U.S.A.), and HWML 45572 (St. Joseph river, St. Joseph County, Indiana, U.S.A.). Currently, the distribution of *N. emyditoides* is the best known of all the *Neoechinorhynchus* species infecting turtles, although most of the verified records are confined to the Mississippi river floodplain. The specimens from California, U.S.A., were reported from a turtle, and so it is difficult to know whether the host was introduced, held in a zoo, etc. The specimens from New York, U.S.A., were reported from *T. scripta* from an aquarium and from a turtle from Brooklyn College. All 3 reports are outside the native range of the most common host of *N. emyditoides*, the slider (*T. scripta*), although the common map turtle extends into New York, U.S.A., and the painted turtle occurs along the western coast of North America.



**Figure 4.** Distribution of *Neoechinorhynchus emyditoides* based on verified specimens in the USNPC and the HWML. No detailed collection locale for Virginia; record from New York is from a zoological park; record from California might be from introduced turtle. Inset cross marks the type locality; open squares represent collection locales of voucher specimens; open circles are collection locales of specimens deposited as a part of this study.

***Neoechinorhynchus lingulatus*  
Nickol and Ernst, 1987**

*Definitive hosts:* Florida red-bellied turtle, *Pseudemys nelsoni*.

*Life cycle:* Unknown.

*Distribution:* Figure 5.

*Holotype:* USNPC 79261 (in excellent condition).

*Paratypes:* USNPC 79262 (occluded); USNPC 79263 (2 females and 4 males in poor to excellent condition); HWML 23106 (1 female and 1 male in excellent condition).

*Specimens (slides):* None other than type series.

*Specimens (vials):* None.

*Specimens to use in lieu of holotype:* HWML 23106.

*Remarks:* Members of this species have not been collected since the original species description. Some of the specimens in the type series have taken up air since being deposited. However, the material is still in mostly excellent condition. No new material was deposited as a part of this study. The known distribution is limited to Florida, U.S.A.



**Figure 5.** Distribution of *Neoechinorhynchus lingulatus* based on verified specimens in the USNPC and the HWML. Inset cross marks the type locality; open squares represent collection locales of voucher specimens; open circles are collection locales of specimens deposited as a part of this study.

***Neoechinorhynchus magnapapillatus*  
Johnson, 1969**

*Definitive hosts:* Slider, *T. scripta*.

*Life cycle:* Unknown.

*Distribution:* Figure 6.

*Holotype:* USNPC 70484 (in excellent condition).

*Paratypes:* USNPC 70485 (1 female in excellent condition).

*Specimens (slides):* USNPC 83060 (0 [0]: 0, 0, 0, 0; 3: 1, 2, 0, 0); HWML 34625 (2 [2]: 1, 1, 0, 0; 0: 0, 0, 0, 0); HWML 45569 (2 [2]: 0, 0, 1, 1; 0: 0, 0, 0, 0).

*Specimens (vials):* None.

*Specimens to use in lieu of holotype:* USNPC 70485; HWML 34625.

*Remarks:* Only 7 specimens of *N. magnapapillatus* have been deposited in the USNPC and HWML. One lot containing 2 specimens (HWML 45569) from Florida, U.S.A., was deposited as a part of this study. The distribution of *N. magnapapillatus*, although not at all well known, appears to be restricted to North American coasts of the Atlantic Ocean and the Gulf of Mexico. The absence of this species in the innumerable sliders surveyed from localities further inland, however, suggests that our knowledge of the distribution of this species, although paltry, might also be correct.



**Figure 6.** Distribution of *Neoechinorhynchus magnapapillatus* based on verified specimens in the USNPC and the HWML. Inset cross marks the type locality; open squares represent collection locales of voucher specimens; open circles are collection locales of specimens deposited as a part of this study.

***Neoechinorhynchus pseudemydis*  
Cable and Hopp, 1954**

(Syn. *Neoechinorhynchus constrictus* Little and Hopkins, 1968)

*Definitive hosts:* Slider, *T. scripta*; mud turtle, probably *Kinosternon* sp.; gopher tortoise, *Gopherus polyphemus*.

*Life cycle:* Unknown.

*Distribution:* Figure 7.

*Holotype:* USNPC 49100 (in good condition; see Remarks).

*Paratypes*: USNPC 49100 (2 males in excellent condition; see Remarks)

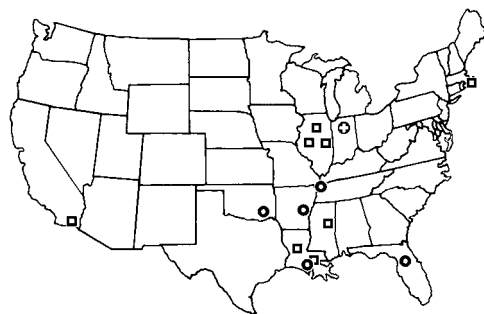
*Specimens (slides)*: USNPC 38680 (5 [2]: 0, 0, 1, 4; 1: 0, 0, 0, 1); USNPC 94794 (2 [2]: 0, 2, 0, 0; 0: 0, 0, 0, 0); USNPC 50945 (1 [1]: 0, 0, 0, 1; 0: 0, 0, 0, 0); USNPC 50947 (2 [2]: 0, 2, 0, 0; 0: 0, 0, 0, 0); USNPC 50951 (1 [1]: 0, 0, 1, 0; 0: 0, 0, 0, 0); USNPC 62974 (1 [1]: 0, 1, 0, 0; 1: 0, 0, 1, 0); USNPC 94797 (2 [2]: 1, 1, 0, 0; 0: 0, 0, 0, 0); USNPC 82347 (2 [2]: 0, 2, 0, 0; 2: 0, 1, 0, 1); USNPC 82361 (25 [23]: 6, 14, 4, 1; 65: 4, 52, 7, 2); USNPC 88660 (1 [0]: 0, 0, 0, 1; 0: 0, 0, 0); HWML 22468 (1 [0]: 0, 0, 1, 0; 0: 0, 0, 0, 0); HWML 33841 (0 [0]: 0, 0, 0, 0; 1: 0, 0, 1, 0); HWML 34123 (2 [1]: 0, 1, 0, 1; 1: 0, 0, 0, 1); HWML 45561 (3 [3]: 3, 0, 0, 0; 0: 0, 0, 0, 0); HWML 45566 (3 [3]: 1, 2, 0, 0; 0: 0, 0, 0, 0); HWML 45567 (3 [3]: 0, 3, 0, 0; 0: 0, 0, 0, 0); HWML 45568 (1 [1]: 0, 1, 0, 0; 0: 0, 0, 0, 0).

*Specimens (vials)*: USNPC 18866 (4 females, 1 male; cannot be verified); USNPC 27254 (12 fragments of female worms, 1 whole female; cannot be verified, see also *N. emydis* and *N. emyditoides*); USNPC 34570 (see *N. emyditoides*); USNPC 42739 (2 females, 3 males; verified as *N. pseudemydis*, 2 slides made); USNPC 44210 (see *N. emyditoides*); USNPC 50945 (38 females, 35 males; verified as *N. pseudemydis*, 1 slide made, see also *N. emyditoides*); USNPC 50947 (138 juveniles, 19 males; verified as *N. pseudemydis*, 2 slides made, see also *N. emyditoides*); USNPC 50951 (12 females, 25 males; verified as *N. pseudemydis*, 1 slide made); USNPC 66144 (13 females, 11 males; verified as *N. pseudemydis*, 2 slides made, see also *N. emyditoides*).

*Specimens to use in lieu of holotype*: HWML 45561; USNPC 82361.

*Remarks*: Cable and Hopp (1954) reported that they deposited 1 female holotype and 3 paratypes (1 female and 2 males), all in the same lot. On examination, all 4 slides bear the word “Co-type.” Among the 2 slides of female worms, 1 has written on the coverslip “Poss Holotype,” apparently added after deposition. One of the slides of females has a large “2” scratched on the slide; this specimen is not *N. pseudemydis* but rather *N. emyditoides*. The female worm on the slide not bearing the 2, but bearing the Poss Holotype, is therefore the type by indication. The specimen base of *N. pseudemydis* is in comparatively good condition. Only 3 lots of slides of 13 contain no identifiable specimen (USNPC 88660; HWML 22468, 33841), including specimens from 5 lots of unmounted

specimens mounted herein for the first time. Overall, of 45 females, 37 were identifiable, and 9.5% of all specimens (116) were excellent, 65.5% were good, 13.8% were fair, and 11.2% were poor. Ten specimens in 4 lots were deposited as a part of this study: HWML 45561 (from Reelfoot Lake, Lake and Obion counties, Tennessee, U.S.A.), HWML 45566 (from Monroe County, Arkansas, U.S.A.), HWML 45567 (from near Alachua County, Florida, U.S.A.), and HWML 45568 (from Atchafalaya NWR, Pointe Coupee Parish, Louisiana, U.S.A.). The known distribution of *N. pseudemydis* is similar to that of *N. emyditoides*, mainly along the Mississippi river, with a couple of outliers. Specimens were deposited from Wood’s Hole, Massachusetts, U.S.A. (USNPC 38680), which is outside the native range of the host from which it was recovered (*T. scripta*) and from the San Diego Zoo, San Diego, California, U.S.A. (USNPC 42739).



**Figure 7.** Distribution of *Neoechinorhynchus pseudemydis* based on verified specimens in the USNPC and the HWML. Northernmost locale in Louisiana lacks specific locality information; records from Massachusetts and California might be from introduced turtles. Inset cross marks the type locality; open squares represent collection locales of voucher specimens; open circles are collection locales of specimens deposited as a part of this study.

### ***Neoechinorhynchus schmidtii* Barger, Thatcher and Nickol, 2004**

*Definitive hosts*: Slider, *Trachemys venusta* (= *Trachemys scripta venusta*) see remarks.

*Life cycle*: Unknown.

*Distribution*: Figure 8.

*Holotype*: USNPC 92883 (in excellent condition).

*Paratypes*: HWML 17667 (9 females in good to excellent condition).

*Specimens (slides)*: None other than paratypes.

*Specimens (vials)*: None

*Specimens to use in lieu of holotype:* HWML 17667.

*Remarks:* *Neoechinorhynchus schmidti* was the first species of acanthocephalan from turtles described from material collected outside the continental United States, from a slider collected near Villahermosa, Tabasco, Mexico. No other specimen has been deposited. Carl Ernst (pers. comm.) has examined the type hosts of *N. schmidti* and concluded that they are *T. venusta*, not *T. scripta* as reported by Barger et al. (2004).



**Figure 8.** Distribution of *Neoechinorhynchus schmidti* based on verified specimens in the USNPC and the HWML. Inset cross marks the type locality; open squares represent collection locales of voucher specimens; open circles are collection locales of specimens deposited as a part of this study.

***Neoechinorhynchus stunkardi*  
Cable and Fisher, 1961**

*Definitive hosts:* False map turtle, *G. pseudogeographica*; Pascagoula map turtle, *Graptemys flavimaculata*.

*Life cycle:* Unknown.

*Distribution:* Figure 9.

*Holotype:* USNPC 39071 (in excellent condition).

*Paratypes:* USNPC 50946 (1 slide with fragments [made herein] and 1 vial with 256 worms and fragments of worms; see Remarks).

*Specimens (slides):* USNPC 50946 (1 [1]: 0, 0, 0, 1; 0: 0, 0, 0, 0); USNPC 71292 (6 [6]: 2, 1, 2, 1; 3: 0, 1, 2, 0); USNPC 94798 (3 [3]: 0, 0, 3, 0; 0: 0, 0, 0, 0); HWML 15800 (1 [1]: 0, 0, 1, 0; 0: 0, 0, 0, 0).

*Specimens (vials):* None.

*Specimens to use in lieu of holotype:* USNPC 71292.

*Remarks:* *Neoechinorhynchus stunkardi* has been reported only sporadically. The largest collection of the species (34 specimens from 1 *G. pseudogeog-*

*raphica*) was made by Acholonu (1969) when redescribing the species. Unfortunately, only 9 of those specimens were deposited (USNPC 71292). In their description, Cable and Fisher (1961) listed USNPC 50946 as “deposited material.” This lot contains many small worms that are in very poor condition. Female worms lack the distinctive posterior swelling and the conical papilla. However, the worms were obviously treated poorly before preservation; they are contorted, fragile, and contracted. Examination of eggs confirms they are *N. stunkardi*, but the specimens are poor representatives of the species. One slide was made from this material and deposited. The distribution of *N. stunkardi* is poorly known, with only 3 confirmed reports. The type locality was given only as the upper Mississippi river watershed in Illinois, U.S.A., so the locale shown in Figure 9 is approximate. Since then, specimens from only 2 locales have been deposited, from map turtles in Louisiana and Mississippi, U.S.A.

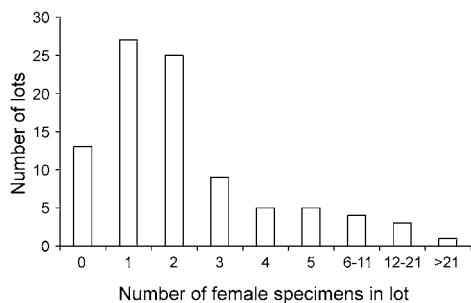


**Figure 9.** Distribution of *Neoechinorhynchus stunkardi* based on verified specimens in the USNPC and the HWML. Details of type locality not specific. Inset cross marks the type locality; open squares represent collection locales of voucher specimens; open circles are collection locales of specimens deposited as a part of this study.

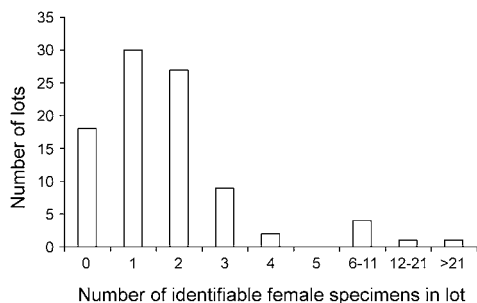
## DISCUSSION

Deposited specimens are the only verifiable records of host use and geographical distribution of species of parasites. As the biological community becomes more interested and active in the pursuit of comprehensive documentation of biotic diversity, the public specimen base is likely to grow substantially in size and become more rapidly accessible. Issues related to conservation, public health, economics, and myriad disciplines within the biological sciences depend on an accurate and information-rich public specimen base (Hoberg, 2002, and references therein).

It is difficult, if not impossible, to plan future research endeavors in the area of biodiversity if what is known is difficult to access. However, “the reality is



**Figure 10.** Number of permanently mounted female specimens per lot in the USNPC and HWML of the 9 species of *Neoechinorhynchus* from turtles.



**Figure 11.** Number of permanently mounted verified female specimens per lot in the USNPC and HWML of the 9 species of *Neoechinorhynchus* from turtles.

that for all but a few taxa, much data is outdated or unreliable . . . rapid access to bad data is unacceptable” (Wheeler et al., 2004). The information that the specimen base holds for taxonomic groups needs to be verified and corrected, where necessary, as much as it needs to be made rapidly accessible, if more informative efforts at documenting and understanding the causes and consequences of biodiversity are to be successful.

The *Neoechinorhynchus* species of turtles are an interesting group of parasites from an evolutionary perspective. The similarity among species in character states that are frequently used to distinguish species in other groups of acanthocephalans suggests a monophyletic origin of the group. However, by grouping species of *Neoechinorhynchus* into 2 subgenera based on egg anatomy, Amin (2002) implicitly hypothesized that turtles have been colonized by acanthocephalans at least 2 times. In addition, to date no acanthocephalan has been reported from a turtle outside of North America, suggesting that colonization of turtles might have occurred relatively recently. However, most of the turtle species of the world have not been surveyed for parasites (Platt, 1992). All 9 species of *Neoechinorhynchus* in turtles have been reported most frequently from emydid turtles, particularly *T. scripta* and various species of *Graptemys*. Because of their close evolutionary relationship and ecological similarity to emydids, the batagurid turtles of Mexico, Central America, and South America are prime candidates for the discovery of new species of *Neoechinorhynchus*, and survey of these turtles ultimately is necessary to resolve the origins and diversification of this group.

Although turtles in North America have been the subject of numerous parasitological studies, including several focused surveys, the species of *Neoechinorhynchus* from turtles are poorly represented in the

major parasitology museums. The most ambitious survey was that of Martin (1973), who surveyed the parasites of 287 turtles belonging to 7 species; however, no specimen was deposited. The majority of specimens in the USNPC and the HWML were deposited before the diversity of the *Neoechinorhynchus* of turtles was recognized; most deposited material since Cable and Hopp (1954) is the product of species descriptions.

Overall, the USNPC and HWML hold 253 female and 176 male *Neoechinorhynchus* of turtles on slides, including those made and deposited as a part of this study. Over 1,200 specimens remain stored in vials. Eighty of the 103 species–lot combinations contain at least 1 identifiable specimen. Of the females on slides, 186 (73.5%) could be identified; no male worm could be identified. However, only 129 (50.9%) of the females on slides are in excellent (40) or good (89) condition; 124 (49.1%) are in fair (53) or poor (71) condition. Only 3 species are represented by more than 50 permanently mounted, identifiable specimens in the museums, *N. emydis*, *N. emyditoides*, and *N. pseudemydis*. With the exception of USNPC 34536 and 90151 and HWML 10356, 10433, and 40174, specimens remaining in vials are mostly juveniles, males, and unsuitable for the preparation of permanent mounts.

The above conditions make the existing collections unsuitable for most taxonomic or systematic purposes. Many lots contain only a few specimens, and most contain fewer than 2 female specimens (Fig. 10). Only a few lots in the USNPC or HWML contain more than 5 identifiable females (Fig. 11). Many specimens were deposited as vouchers as part of investigations with goals not related to taxonomy or systematics. Thus, the specimen base of *Neoechinorhynchus* from turtles contains only 3 large series of specimens from a single population (*N. pseudemydis*, USNPC 82361 on slides; *N. emydis*, HWML 10356

and HWML 10433 in vials). This situation precludes search for taxonomic characters beyond those used currently for species identification.

Host use of *Neoechinorhynchus* spp. from turtles is confined almost entirely to emydid turtles. Chief among these are *T. scripta* and several species of *Graptemys*. Reports of *Neoechinorhynchus* from chelydrids, kinosternids, trionychids, and testudinids are scattered, and these turtles might constitute ecological sinks. The status of *C. picta* as host for *Neoechinorhynchus* species remains unresolved. Although reported as a host relatively frequently, *C. picta* is rarely heavily infected, and it is a confirmed host only for *N. chrysemydis* and *N. emyditoides*. Most of the narrowly endemic species of *Graptemys* have yet to be surveyed for acanthocephalans; the exceptions being *G. flavimaculata*, from which *N. stunkardi* was reported (Steinauer and Horne, 2002), and *G. versa*, from which *N. emydis* was reported (this study). There is a possibility that undiscovered species of *Neoechinorhynchus* are present in endemic *Graptemys*; however, all species of *Graptemys* have distributions overlapped by that of *T. scripta*, which is a confirmed host for 6 of the 9 species of *Neoechinorhynchus*. Thus, endemic *Graptemys* spp. might harbor only *Neoechinorhynchus* already described. Other turtle species deserving more scrutiny are the chicken turtle (*Deirochelys reticularia*), the spotted turtle (*C. guttata*), the bog turtle (*Clemmys muhlenbergii*), the wood turtle (*C. insculpta*), various cooters (*Pseudemys* spp.), and Blanding's turtle (*E. blandingii*).

The confirmed distributions of *Neoechinorhynchus* from turtles fall into 2 general categories. *Neoechinorhynchus chrysemydis*, *N. emydis*, *N. emyditoides*, *N. pseudemydis*, and *N. stunkardi* are all confirmed throughout the Mississippi river valley and a potpourri of other locales, whereas *N. chelonos*, *N. lingulatus*, and *N. magnapapillatus* are confirmed only from states on the eastern Atlantic seaboard and coast of the Gulf of Mexico. Although the species in the former group are almost certainly more widely distributed than can be confirmed presently, the absence of the species of the latter group in the numerous surveys west of the Appalachian Mountains suggests that they might be restricted to the east coast. *Neoechinorhynchus schmidtii* is confirmed only from its type locality in Mexico, and it is joined by *N. emyditoides* as the only species confirmed from Mexico.

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