Description of *Heterosentis holospinus* n. sp. (Acanthocephala: Arhythmacanthidae) from the Striped Eel Catfish, *Plotosus lineatus*, in Halong Bay, Vietnam, with a Key to Species of *Heterosentis* and Reconsideration of the Subfamilies of Arhythmacanthidae

Author(s): Omar M. Amin, Richard A. Heckmann, and Nguyen Van Ha


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Description of Heterosentis holospinus n. sp. (Acanthoecephala: Arhythmacanthidae) from the Striped Eel Catfish, Plotosus lineatus, in Halong Bay, Vietnam, with a Key to Species of Heterosentis and Reconsideration of the Subfamilies of Arhythmacanthidae

Omar M. Amin,1,4 Richard A. Heckmann,2 and Nguyen Van Ha3
1 Institute of Parasitic Diseases, 11445 E. Via Linda 2-419, Scottsdale, Arizona 85259, U.S.A., 2 Department of Biology, Brigham Young University, Provo, Utah 84602, U.S.A. (e-mail: richard.heckmann@byu.edu), and 3 Department of Parasitology, Institute of Ecology and Biological Resources, Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet, Cau Giay, Hanoi, Vietnam (e-mail: hanv_iebr@yahoo.com.vn)

ABSTRACT: Heterosentis holospinus n. sp. is 1 of 11 species of acanthocephalans collected from 13 species of marine fish in Halong Bay, Vietnam, in 2008 and 2009. The striped eel catfish, Plotosus lineatus (Thunberg, 1787), harbored a large number of individuals of the new species. Species of Heterosentis Van Cleave, 1931, are characterized by having 2 or 3 types of proboscis hooks in 10–14 rows, and trunk spines. Of the 15 known species of Heterosentis (including the new species), H. holospinus is distinguished by having a trunk entirely covered with spines and an anterior trunk cone free of spines. Only Heterosentis overstreeti Schmidt and Paperna, 1978, has a trunk that is also entirely covered with spines; it, however, differs from H. holospinus by lacking an anterior trunk cone but having 4 giant nucleated muscle cells in the anterior trunk, and 2 basal spines per proboscis hook row. Heterosentis holospinus has no such muscle cells, and the proboscis contains 3–4 spines per row. Only 2 other species of Heterosentis have anterior trunk cones: Heterosentis septacanthus (Sita, 1949) Golvan 1969, which has a cylindrical trunk and proboscis, only anterior trunk spines, and smaller proboscis hooks, and Heterosentis plotosi Yamaguti, 1935, which has 4 nucleated giant muscle cells, only anterior trunk spines, and 4–5 spines per proboscis hook row. The characteristics of H. holospinus are described and compared with those of the other 14 species of Heterosentis. A key to the 15 species of the genus is included. The justification for the retention of the 3 subfamilies of Arhythmacanthidae no longer applies, and their deletion is proposed.

KEY WORDS: Heterosentis holospinus n. sp., Acanthoecephala, entire trunk spiny, Plotosus lineatus, Halong Bay, Vietnam, 15 species comparison, key to species, deletion of subfamilies of Arhythmacanthidae.

Several species of Acanthoecephala from freshwater fish and other vertebrates have been previously described in Vietnam by Amin and Ha (2008) and Amin et al. (2000, 2004, 2008a, 2008b, 2008c). Eleven species of acanthocephalans were collected from marine fish off the eastern seaboard of Vietnam in 2008 and 2009. Of these, 6 new species belonging to Neoechinorhynchus Stiles and Hassall, 1905, were recently described (Amin et al. 2010). A seventh species of Acanthoecephala, collected from the striped eel catfish, Plotosus lineatus, referable to the genus Heterosentis, but taxonomically distinct from known species of Heterosentis, is described herein. This is the first report of a species of Heterosentis from marine fish in Vietnam.

Plotosus lineatus is the only catfish found in coral reefs. It is also found in estuaries, tide pools, and open coasts. It is widely distributed in the Indo-West Pacific from the Red Sea, Eastern Mediterranean, and East African Coasts to the western Pacific. It feeds on crustaceans, mollusks, worms, and fish (Eschmeyer, 1998; Ferraris et al., 1999; Golani, 2002).

MATERIALS AND METHODS

Of the 45 species of marine fish netted (Fig. 1) at Cat Ba Islands, Tonkin Gulf, Halong Bay, Vietnam (20°45’N; 107°05’E) during the spring of 2008 and 2009, 13 species were found to be infected with acanthocephalans. Of these, the striped eel catfish, Plotosus lineatus (Thunberg, 1787), collected in April 2008, harbored acanthocephalans belonging to the reported new species of Heterosentis.

Upon collection, fish were measured and photographed and then brought to the laboratory for examination. Worms were placed in water for 2–3 hr or until fully extended and then fixed in 70% ethanol. Worms were punctured with a fine needle and subsequently stained in Mayer’s acid carmine, destained in 4% hydrochloric acid in 70% ethanol, dehydrated in ascending concentrations of ethanol (24 hr each), and cleared in graduated concentrations of terpineol in 100% ethanol to 100% terpineol, then 50% terpineol in 50% Canada balsam (24 hr each). Whole worms were mounted in Canada balsam.

For scanning electron microscopy (SEM), a few specimens from P. lineatus, previously fixed in 70% ethanol, were placed in critical point drying (CPD) baskets and dehydrated in 95% ethanol followed by 3 changes of 100% ethanol for at least 10 min per soak followed by critical point drying (Lee, 2001).
1992). Samples were then mounted on SEM sample mounts, gold coated, and observed with a scanning electron microscope (FEI X L30 ESEM FEG). Digital images of the structures were obtained using digital imaging software attached to a computer.

Measurements are presented in micrometers (μm), unless otherwise stated, as range values followed by mean values in parentheses. Length measurements are given before the width; the latter refers to maximum width. Trunk length does not include the neck, proboscis, or bursa. Eggs refer only to fully developed, ripe eggs usually removed from the body cavity. Specimens were deposited in the University of Nebraska’s State Museum’s Harold W. Manter Laboratory (HWML) collection in Lincoln, Nebraska, U.S.A.

RESULTS

Fifteen specimens of striped eel catfish, P. lineatus, measuring 19.5–25.0 cm in standard length (mean 21.5 cm) were netted and examined for parasites in April 2008. Of these, 13 fish were infected with 83 specimens of the new species of Heterosentis. Thirteen male and 12 female worms were processed and whole mounted for microscopic examinations; the majority of the remaining specimens were processed for SEM examination.

**Heterosentis holospinus n. sp.** (Figs. 1–20)

**Description**

**General:** Arhythmacanthidae. With characters of the genus Heterosentis. Small fusiform worms with anterior trunk cone. Females more fusiform than males (Figs. 13, 17, 18); trunk width/length 25% (16–33%) and 22% (16–34%) in females and males, respectively. Shared structures larger in females than in males. Epidermis with many pores associated with internal crypts (Fig. 7). Body wall with many nuclear fragments (Fig. 19) and occasionally with sensory pits. Trunk entirely covered with 12–25-long, barely visible spines except on anterior cone (Fig. 2). Trunk spines randomly distributed, most dense anteriorly (Figs. 2, 4) but decrease posteriorly to the genital area. Anterior proboscis globular with small, slightly curved apical hooks in 2 usually alternating sizes with abrupt transition, and larger slightly curved subapical hooks also usually in 2 alternating sizes at 2 alternating levels (Fig. 3). All hooks with simple, posteriorly directed roots about half as long as blades (Fig. 16). Posterior proboscis cylindrical with 3 or 4 strongly curved rootless spines per row, largest anterior and gradually decreasing in size toward posterior (Figs. 3, 16). All hooks and spines in 14 longitudinal rows. Neck unremarkable. Proboscis receptacle about twice as long as proboscis, double-walled, with large lanceolate cephalic ganglion at its base, and nucleated pouch at its posterior tip (Figs. 13, 14). Lemnisci usually equal, digitiform, about twice as long as receptacle, 1 with 1 elongated giant nucleus and 1 with 2 (Figs. 13, 14). One male had 1 additional branching lemniscus. Gonopore terminal in both sexes.

**Males (based on 13 sexually mature adults):** Anterior trunk cone 177–287 (254) long by 187–325 (254) wide; whole trunk 3.37–5.12 (4.37) mm long by 0.67–1.75 (0.97) mm wide at middle. Trunk spines 15–25 (19) long. Proboscis 187–239 (212) long by 107–156 (128) wide anteriorly. Apical hooks 35–40 (38) and 42–50 (46) long. Subapical hooks 50–70 (62) and 72–80 (75) long. Anterior basal spines 17–25 (21) long; posterior spines 10–15 (11) long. Proboscis receptacle 395–603 (491) long by 135–208 (163) wide. One lemniscus 666–1092 (923) long by 93–156 (120) wide; other lemniscus 707–1092 (896) long by 87–156 (121) wide. Reproductive system in posterior two thirds of trunk. Testes contiguous, oblong (Fig. 13). Anterior testis 603–988 (790) long by 198–541 (404) wide. Posterior testis 520–1144 (725) long by 270–520 (419) wide. Cement glands 6, in 3 tandem pairs 198–322 (235) long by 156–250 (178) wide, draining in 2 common posterior cement ducts. Sperm ducts remarkably plump joining into prominent common sperm duct 229–551 (430) long by 62–177 (121) wide at level of Saefftigen’s pouch 229–385 (289) long by 142–208 (181) wide. Common cement ducts join with common sperm duct and Saefftigen’s pouch at their posterior end, adjoined by paired glandular cellular clusters (Figs. 13, 15). Bursa occasionally constricted (Fig. 10), 260–343 (304) long by 302–332 (314) wide with prominent round sensory structures usually arranged in circular ring (Figs. 11, 12, 15).

**Females (based on 12 gravid specimens):** Anterior trunk cone 270–364 (307) long by 275–400 (338) wide; whole trunk 4.55–8.30 (6.53) mm long by 0.90–2.75 (1.61) mm wide at middle. Trunk heavier and more robust in gravid than in younger specimens (Figs. 17, 18). Trunk spines 12–27 (17) long. Proboscis 200–270 (236) long by 125–177 (147) wide anteriorly. Apical hooks 37–52 (44) long. Subapical hooks 75–90 (81) and 80–97 (88) long. Anterior basal spines 21–27 (25) long; posterior spines 12–15 (13) long. Proboscis receptacle 416–640 (547) long by 156–208 (183) wide. Lemnisci 884–1020 (938) long by 94–187 (156) wide. Reproductive system 1477–1695 (1590) long with prominent uterus, 1071–1300 (1185) long by 175–312...
(248) wide, complex vagina with plates and ligaments, and uterine bell with multiple large nucleated cells (Fig. 19). Ripe eggs oblong, occasionally with fibrillar coat (Fig. 8), 50–70 (58) long by 12–15 (14) wide, and with polar prolongation of fertilization membrane (Fig. 20). Copulating females occasionally with double cement plugs at posterior end (Fig. 9).

**Taxonomic summary**

*Type host:* Striped eel catfish, *Plotosus lineatus* (Thunberg, 1787).

*Type locality:* Halong Bay, Cat Ba Islands, Vietnam (20°45′N; 107°05′E).

*Site of infection:* Intestine.
Type specimens: HWML collection no. 49254 (holotype male and paratypes on 1 slide), and no. 49255 (allotype female and paratypes on 1 slide).

Etymology: The new species is named for the spiny trunk.

Remarks
agreed. Amin (1985) synonymized both species, recognizing that both genera have 3 types of proboscis hooks (occasionally 2 in the absence of apical hooks in some species) and trunk spines, with the inconsistent presence or absence of about 4 giant nucleated muscle cells or fragmented nuclei in the body wall (Table 1). Golvan (1994), who did not admit Amin’s (1985) synonymy, included species with apical hooks in *Heterosentis*. All authors subsequent to Amin (1985), e.g., Pichelin and Cribb (1999) and Vieira et al. (2009), agree with the synonymy. *Heterosentis magellanicus* (Szidat, 1950) (sensu Golvan, 1969) with no trunk spines is *Hypoechinorhynchus magellanicus* (Szidat, 1950).

Figures 13–20. *Heterosentis holospinus* n. sp. from *Plotosus lineatus*. 13. Holotype male; note the enlargement of sperm ducts. 14. Paratype male, anterior portion; note the nuclear pouch at the posterior tip of the proboscis receptacle (arrow) and the long giant lemniscal nuclei. 15. Posterior portion of male reproductive system; note the 2 enlarged common cement ducts encircling the common sperm duct and paired glandular cellular clusters (arrow) of unknown function. 16. One row of proboscis hooks and spines from a paratype female. 17. A young, somewhat slender, barely mature paratype female. 18. An older gravid and more robust female. 19. The reproductive system of a paratype female showing the complex vagina, long uterus, and multinucleated uterine bell. Note the fragmented nuclei. 20. An egg without fibrillar coat.
There are 15 species of *Heterosentis* known from marine fish currently recognized as valid. They are:

4. *Heterosentis heteracanthus* (Linstow, 1896) Van Cleave, 1931 (type species) from Australia, Antarctica, and South America (Strait of Magellan).
15. *Heterosentis zdzitowieckii* Kumar, 1992, from India.

The distribution of species of *Heterosentis* corresponds to that of their host species from the Indo-West Pacific into the Eastern Mediterranean via the Red Sea.

### Table 1. Characteristics of *Heterosentis holospinus* compared with those of other species of *Heterosentis*.

<table>
<thead>
<tr>
<th>Character</th>
<th><em>H. holospinus</em></th>
<th>Other species of <em>Heterosentis</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Apical proboscis hooks</td>
<td>Present</td>
<td>Absent in <em>H. heteracanthus</em>, <em>H. pseudobagri</em>, <em>H. cabelleroi</em>.</td>
</tr>
<tr>
<td>Subapical hooks</td>
<td>In 1 circle</td>
<td>In 2 or 3 circles in <em>H. brasiliensis</em>, <em>H. pseudobagri</em>, <em>H. cabelleroi</em>, <em>H. zdzitowieckii</em>, <em>H. mysturi</em>, <em>H. parasiluri</em>.</td>
</tr>
<tr>
<td>Basal hooks</td>
<td>Rootless</td>
<td>With roots in <em>H. mysturi</em>, <em>H. parasiluri</em>.</td>
</tr>
<tr>
<td>Anterior trunk cone</td>
<td>Present</td>
<td>Also found in <em>H. septacanthus</em>, <em>H. plotosi</em>.</td>
</tr>
<tr>
<td>Fragmented trunk nuclei</td>
<td>Present</td>
<td>Also found in <em>H. fusiformis</em>, <em>H. cabelleroi</em>, <em>H. hirsutus</em>, <em>H. zdzitowieckii</em>.</td>
</tr>
<tr>
<td>Trunk spines</td>
<td>On entire trunk</td>
<td>On entire trunk also in <em>H. overstreeti</em>.</td>
</tr>
<tr>
<td>Anterior trunk spines</td>
<td>Random</td>
<td>Only ventral in <em>H. brasiliensis</em>, only in longitudinal rows in <em>H. mysturi</em>.</td>
</tr>
<tr>
<td>Trunk muscular cells</td>
<td>Absent</td>
<td>4 nucleated muscular cells found in <em>H. fusiformis</em>, <em>H. plotosi</em>, <em>H. overstreeti</em>.</td>
</tr>
<tr>
<td>Genital trunk spines</td>
<td>Present</td>
<td>Also found in <em>H. hirsutus</em>, <em>H. parasiluri</em>, <em>H. overstreeti</em>.</td>
</tr>
<tr>
<td>Receptacle with posterior nuclear pouch</td>
<td>Present</td>
<td>Also found in <em>H. paraplagusiarum</em>, <em>H. thapari</em>.</td>
</tr>
<tr>
<td>Cephalic ganglion</td>
<td>At base of receptacle</td>
<td>More anterior in <em>H. overstreeti</em>, <em>H. mysturi</em>, <em>H. parasiluri</em>.</td>
</tr>
<tr>
<td>Lemnisci</td>
<td>Longer than receptacle</td>
<td>Much longer than receptacle in <em>H. fusiformis</em> and <em>H. brasiliensis</em>.</td>
</tr>
<tr>
<td>Testes</td>
<td>In tandem</td>
<td>Shorter than receptacle in <em>H. thapari</em> and <em>H. cabelleroi</em>.</td>
</tr>
<tr>
<td>Female gonopore</td>
<td>Terminal</td>
<td>Oblique only in <em>H. fusiformis</em>.</td>
</tr>
<tr>
<td>Eggs</td>
<td>With polar prolongation of fertilization membrane</td>
<td>Subterminal in <em>H. paraplagusiarum</em>, <em>H. brasiliensis</em>.</td>
</tr>
</tbody>
</table>

Key to species of *Heterosentis*

A new key to the 15 valid species of *Heterosentis* is given next. Pichelin and Cribb (1999) provided an abbreviated key to 12 species with uncertain reference to the apical hooks that emphasized proboscis hook measurements and trunk spine distribution. We agree with Zdzitowiecki (1991), who resolved this issue in his diagnosis of *Heterosentis* by indicating that the
proboscis has “two or three types of hooks,” recognizing that the apical hooks are not present in a few species (Table 1). The statement by Petrochenko (1956) that *H. plotosi* has “more than two large hooks in each row” in the “anterior part of the proboscis” is an incorrect interpretation of Yamaguti’s (1935) description of the proboscis hooks of that species as of “two kinds of hooks,” which is in obvious contrast to his fig. 28 (p. 274) that clearly shows smaller apical hooks. In his diagnosis of *Arhythmacanthus* based on the recognition of only 1 species, *H. fusiformis*, Yamaguti (1963) incorrectly indicated that apical hooks and basal spines are rootless. The descriptive literature indicated that the apical hooks do have roots, and basal spines in 2 species, *H. mysturi* and *H. parasiluri*, are also rooted. Yamaguti’s diagnosis should be qualified to indicate that the giant nucleated muscle cells in the anterior trunk of *H. fusiformis* are only “occasionally” present, since they are found in only 2 other species, *H. overstreeti* and *H. plotosi*.

The following key is to species found in marine fish usually in coastal or associated waters of the countries noted.

1. Trunk with anterior well-defined cone. Proboscis with 1, 1, and 3–5 circles of apical, subapical, and basal hooks/spines, respectively, in 14 longitudinal rows ............................ 2
   Trunk without anterior cone. Proboscis with 0–1, 1–3, 2–5 circles of apical, subapical, and basal hooks/spines, respectively, in 10 longitudinal rows ............................ 4

2. Trunk fusiform entirely covered with spines except on anterior cone. Posterior receptacle wall with nucleated pouches. In Vietnam .............................. *Heterosentis holospinus*. Trunk fusiform or cylindrical, without fragmented nuclei, with only anterior trunk spines also on anterior cone. Posterior receptacle wall without nuclear pouches ............................ 3


4. Proboscis with 1, 1, and 2 apical, subapical, and basal hooks/spines, respectively, per row. Trunk cylindrical with 4 giant nucleated muscle cells and entirely covered with spines. Cephalic ganglion anterior to base of receptacle. In Israel .......................... *Heterosentis overstreeti*. Proboscis with no apical hooks or with apical hooks and more subapical hooks or basal spines per row. Trunk cylindrical or fusiform with or without giant muscle cells but covered only anteriorly and occasionally posteriorly with spines. Cephalic ganglion at or near base of receptacle ............................ 5

5. Trunk fusiform with 4 giant muscle cells, scattered fragmented nuclei, and anterior spines only. Subapical proboscis hooks 188–210 long. Testes postequatorial, oblique. Two or 4 very long lemnisci. In Japan .............................. *Heterosentis fusiformis*. Trunk fusiform or cylindrical without giant muscle cells, with or without fragmented nuclei, and with anterior or anterior and posterior spines. Subapical hooks shorter than 133 long. Testes tandem in variable locations. Lemnisci 2, variable in length ............................ 6

6. Proboscis with 10 longitudinal rows of hooks. Trunk fusiform with anterior spines positioned only ventrally. With 2 very long lemnisci. Testes postequatorial. Female gonopore subterminal. In Brazil .......................... *Heterosentis brasiliensis*. Proboscis with 10–14 longitudinal rows of hooks. Trunk fusiform or cylindrical with anterior spines encircling entire trunk. Lemnisci somewhat longer or decidedly shorter than receptacle. Testes in variable locations. Female gonopore terminal or subterminal ............................ 7

7. Apical proboscis hooks absent ............................ 8
   Apical proboscis hooks present ............................ 10

8. Trunk cylindrical with many fragmented nuclei. Proboscis globular with 2 and 4 subapical hooks and basal spines, respectively, per row. Lemnisci markedly shorter than receptacle. In Tamil Nadu .......................... *Heterosentis cabelleroi*. Trunk cylindrical or fusiform with no fragmented nuclei. Proboscis claviform with 1–3 and 2–4 subapical hooks and basal spines, respectively, in a row. Lemnisci longer than receptacle ............................ 9

9. Trunk fusiform with anterior spines extending to level of posterior end of receptacle or lemnisci. Proboscis with 3 subapical and 2 basal hooks in 12 rows. Hooks not dorsoventrally differentiated. Testes postequatorial. In China ............................ *Heterosentis pseudobagri*. Trunk cylindrical with anterior trunk spines extending to midbody. Proboscis with 1 (rarely
DISCUSSION

Perspectives on *Heterosentis* and the subfamilies of *Arhythmacanthidae*

Aside from the description of *H. holospinus*, this work provides a fresh review of the genus *Heterosentis*, which belongs in the subfamily Arhythmacanthinae Yamaguti, 1935, of Arhythmacanthidae Yamaguti, 1935 (see Amin, 1985). The presence of 3 subfamilies in Arhythmacanthidae was primarily based on the presence, distribution, or absence of trunk spines (Golvan, 1969): (1) Arhythmacanthinae with anterior trunk spines and globular proboscis, (2) Neoacanthocephaloidinae Golvan, 1960, with anterior and genital spines and short cylindrical proboscis with 2 types of hooks, and (3) Paracanthocephaloidinae Golvan, 1969, with no trunk spines but with short cylindrical proboscis having 2 types of hooks. However, *Paracanthocephaloides chabanaudi* (Dollfus, 1951) Golvan, 1969 (type) clearly shows 3 types of proboscis hooks (Fig. 129C in Golvan, 1969) and *Paracanthocephaloides soleae* (Porta, 1905) Paggi and Orecchia, 1983, has 1 type of proboscis hook and no trunk spines, and it was later transferred to genus *Solearhynchus* De Buron and Millard, 1985. Similarly, *Paracanthocephaloides kостьлеви* (Meyer, 1932) Pichelin and Cribb, 1999, has been transferred to *Solearhynchus* (see Kvach and Oguz, 2010). The presence of globular, cylindrical, or claviform proboscis, 2 or 3 types of proboscis hooks, and genital spines in various species of *Heterosentis* (Table 1) eliminates the distinction at least between the first 2 subfamilies. The synonymy of *Arhythmacanthus* with *Heterosentis* (see Amin, 1985) and the demonstration that species of *Heterosentis* may have 2 or 3 different types of hooks/spines on the proboscis (this paper; Zdzitowiecki, 1991; Pichelin and Cribb, 1999) add an additional dimension to the argument for the synonymy of Paracanthocephaloidinae with Arhythmacanthidae. In addition, the
finding of trunk spines in Acanthocephaloidea propinquus (Dujardin, 1845) Meyer, 1932 (type) (Neoacanthocephaloidinae), which was previously thought to have none, the synonymization of Yamagutiensis Golvan, 1969, with Acanthocephaloidea Meyer, 1932, by Araki and Machida (1987), and our findings (Table 1) and those of Pichelin and Cribb (1999) point to the irrelevance of trunk spines in the distinction of the Golvan (1969) subfamily system, which we here proposed to delete altogether. Pichelin and Cribb (1999) offered a key to the genera of the Arhythmacanthidae that, however, did include Hypoechinorhynchus Yamaguti, 1939, and seemed to synonymize Neoacanthocephaloides Cable and Quick, 1954, with Acanthocephaloidea.

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Pichelin, S. and T. H. Cribb. 1999. A review of the Arhythmacanthidae (Acanthocephala) with a description of Heterosentis hirsutus n. sp. from Cnidoglanis...


