

Article

A New Species of Parasitic Copepod, *Nemesis santhadevii* (Siphonostomatoida: Eudactylinidae) from the Gills of the Coral Catshark *Atelomycterus marmoratus*, from Kota Kinabalu, Malaysia [†]

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Abstract: The copepod *Nemesis santhadevii* sp. nov. (Siphonostomatoida: Eudactylinidae), which is parasitizing the gill filaments of the Coral catshark *Atelomycterus marmoratus* (Anonymous (Bennett), 1830) off Kota Kinabalu waters, Malaysia, is described and illustrated in this article. The new species *Nemesis santhadevii* prominently differs from its congeners in the following features: (1) the cephalothorax sub-circular is 1.3 times as wide as long and overlapping the second pedigerous somite; (2) the fifth somite is 0.4 times the width of the fourth; (3) the genital double somite is slightly narrower than the fifth; (4) the lowest cephalothoracic shield's body length (0.20:1) proportion; (5) the caudal rami is ovate, it has two large and three small setae; (6) and the second somite has antenna with a patch of 34–38 spinules. It is the first record of parasitic eudactylinid copepod from Sabah, East Malaysia. A checklist of global valid species of *Nemesis* Risso, 1826, is provided.

Keywords: fish parasites; crustacea; spinules; checklist; Borneo; Sabah

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1. Introduction

The copepod family Eudactylinidae Wilson C.B., 1932, includes 61 valid species in 12 genera; among them, the genus *Eudactylina* van Beneden, 1853, is the most diverse with 38 species, followed by *Nemesis* Risso, 1826, with 12 valid species. Nine genera are monotypic and the remaining genus *Eudactylinodes* Wilson C.B., 1932, includes two species [1].

Nemesis was established as a monotypic genus for the type species *N. lamna* Risso, 1826 (= *Nemesis lamna lamna* Risso, 1826) [2]. Later, Wilson [3,4] described *Nemesis versicolor* Wilson C.B., 1913, from the smooth hammerhead shark, *Sphyrna zygaena*, and *Nemesis atlantica* Wilson C.B., 1922, from the Atlantic sharpnose shark, *Rhizoprionodon* (= *Scoliodon*) *terraenovae*. Two other species, *Nemesis carchariaeaglauci* (Hesse, 1883) and *Nemesis robusta* (Beneden, 1851), were transferred to *Nemesis* [1]. The following species were, subsequently, described during the 20th century: *Nemesis pallida* Wilson C.B., 1932, *Nemesis pilosus* Pearse, 1951, *Nemesis tiburo* Pearse, 1952, *Nemesis macrocephalus* Shiino, 1957, *Nemesis aggregatus* Cressey, 1967, *Nemesis spinulosus* Cressey, 1970, and, the latest addition, *Nemesis sphyrnae* Rangnekar, 1984, from India [5–12]. The genus currently comprises 12 valid species [1].

The new species was found on the Coral catshark *Atelomycterus marmoratus*, off Kota Kinabalu waters, Malaysia. The host fish, *A. marmoratus*, is little known inshore, but is found on coral reefs, inhabiting crevices and holes on the reefs. It is caught occasionally by fisheries' vessels over coral reefs and is utilized fresh and dried, and salted for food or processed for fishmeal and oil. *Atelomycterus marmoratus* is widely distributed in the Indo-West Pacific region from Pakistan and India to Malaysia, Singapore, Indonesia, New

Guinea, Thailand, Viet Nam, the Philippines, and southern China, and north to Japan [13]. The present study describes a new species of *Nemesis* collected from *A. marmoratus* along with a checklist of global valid species of *Nemesis*.

2. Materials and Methods

Parasitic copepods were collected from the gill filaments of the host fish *Atelomycterus marmoratus* from Kota Kinabalu Fish Market (5.9825° N, 116.0717° E), Sabah, Malaysia, during a parasite survey of wild fish. The collected copepods were preserved in 70% ethanol and, subsequently, soaked in a drop of 80% lactic acid prior to examination using an Olympus BX51, Olympus, Tokyo, Japan differential phase contrast microscope. The copepods were examined by using the wooden slide method [14]. Drawings were prepared with the aid of a drawing tube mounted on a Nikon Eclipse 80i microscope, Tokyo, Japan. In the descriptions, body lengths were measured using a micrometer from the anterior margins of the cephalothorax to the posterior margins of the caudal rami, excluding the setae. All measurements are in micrometers, unless otherwise indicated. In the formula for the armature of legs 1–4 in the descriptions, Roman and Arabic numerals indicate spinules and setae of legs, respectively. Morphological terminology follows that used by Huys and Boxshall [15] and sources for the fish taxonomy and host nomenclature were confirmed using Fish Base [13] and Catalogue of Fishes [16]. The types were deposited in the Museum Collection Repository, Borneo Marine Research Institute, Universiti Malaysia Sabah, Kota Kinabalu.

3. Results

3.1. Taxonomy

Order Siphonostomatoida Burmeister, 1835.

Family Eudactylinidae Wilson C.B., 1932.

Genus *Nemesis* Risso, 1826.

Nemesis Risso, 1826: Wilson, 1922, p. 32; Yamaguti, 1963, p. 166; and Pillai 1985, p. 657.

Type species: *Nemesis lamna* Risso, 1826.

Nemesis santhadevii sp. nov. (Figures 1–6).

<https://zoobank.org/NomenclaturalActs/3b464950-ce0b-4bc6-84d6-82a538b9ce68> (accessed on 2 September 2022).

3.1.1. Type—Host

Coral catshark *Atelomycterus marmoratus* (Anonymous (Bennett), 1830) (Carcharhini-formes: Scyliorhinidae).

3.1.2. Type—Locality

Kota Kinabalu, East Malaysia (approximately 5.9825° N, 116.0717° E).

3.1.3. Type—Material

Holotype ♀(3.2 mm) from the gill filaments of *Atelomycterus marmoratus* collected by BA Venmathi Maran 01 July 2022 (IPMB-Cr 01.00005). Paratypes: same data as holotype with the following measurements—10 ♀♀(2.8 to 3.2 mm) (IPMB-Cr 01.00006 to IPMB-Cr 01.00015).

3.1.4. Site on Host

Gill filaments.

3.1.5. Etymology

The species is named in honour of Mrs. Santhadevi Alagarrajan, the late mother of the senior author (BAVM), as a tribute and in memory of her.

3.1.6. Description

Adult Female (Figures 1–6): Cephalothorax (Figure 1A–C and Figure 2A) sub-circular, 1.3 times as wide as long, narrowing posteriorly, producing distinct neck, overlapping second pedigerous somite. Pedigerous somites two to four separated by lateral constrictions, lateral borders of segments convex, segmentation dorsally distinct, somites subequal in size. Third somite slightly wider than second, fourth slightly narrower than third. Fifth somite 0.4 times width of fourth, with small lobes carrying fifth leg. Genital double somite slightly narrower than fifth (Figure 2A,C, Figures 3A and 6G,H). Abdomen (Figure 2C) small, with three somites. Caudal rami (Figure 2C,D) ovate, with two large and three small setae.

Egg strings (Figure 1A,B) cylindrical; eggs uniseriate. Number of eggs per string ranged from 15 to 48, dependent on length of string.

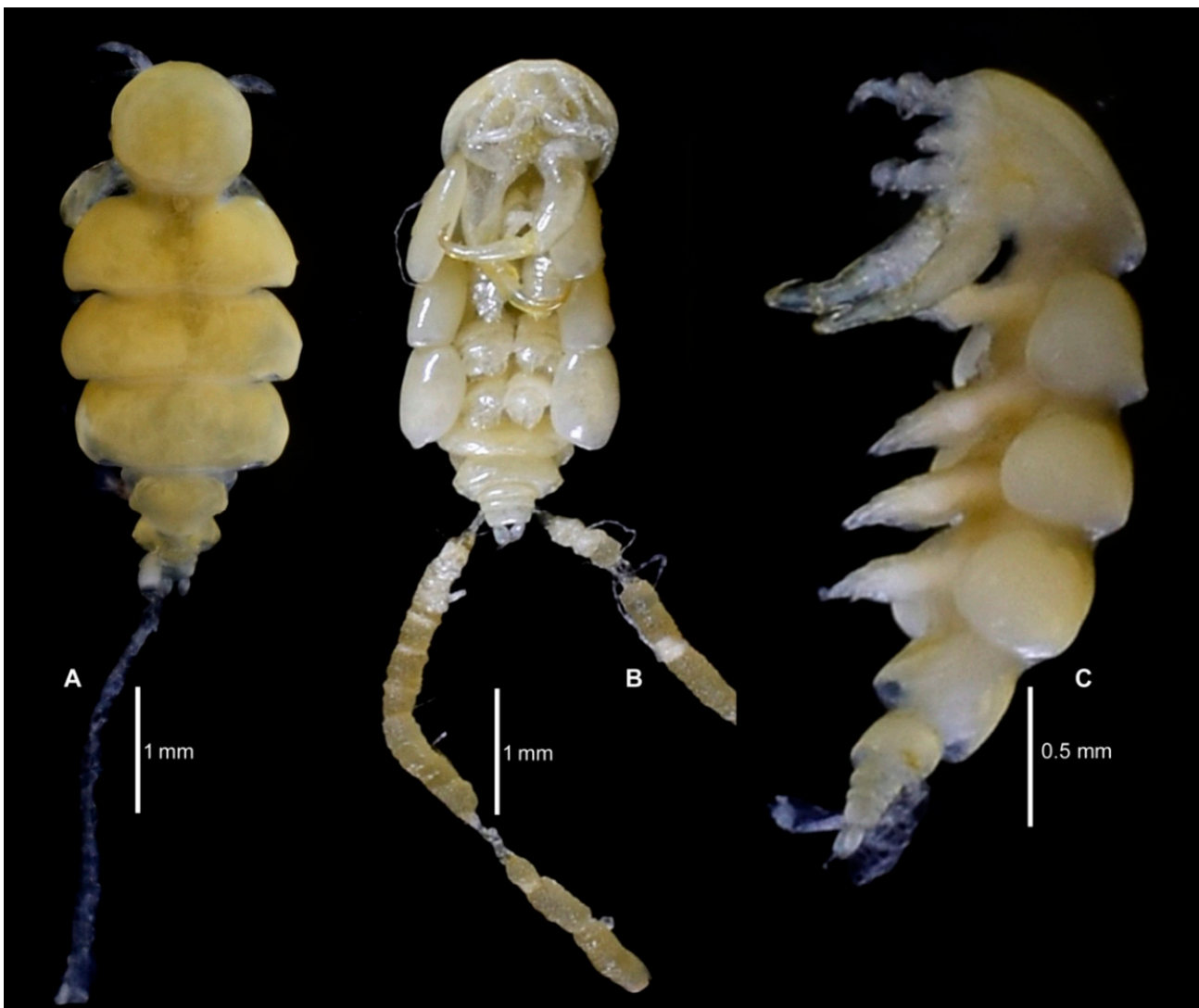


Figure 1. *Nemesis santhadevii* sp. nov. from *Atelomycterus marmoratus*, habitus. (A) dorsal with one egg string, (B) ventral showing egg strings on both sides, and (C) lateral.

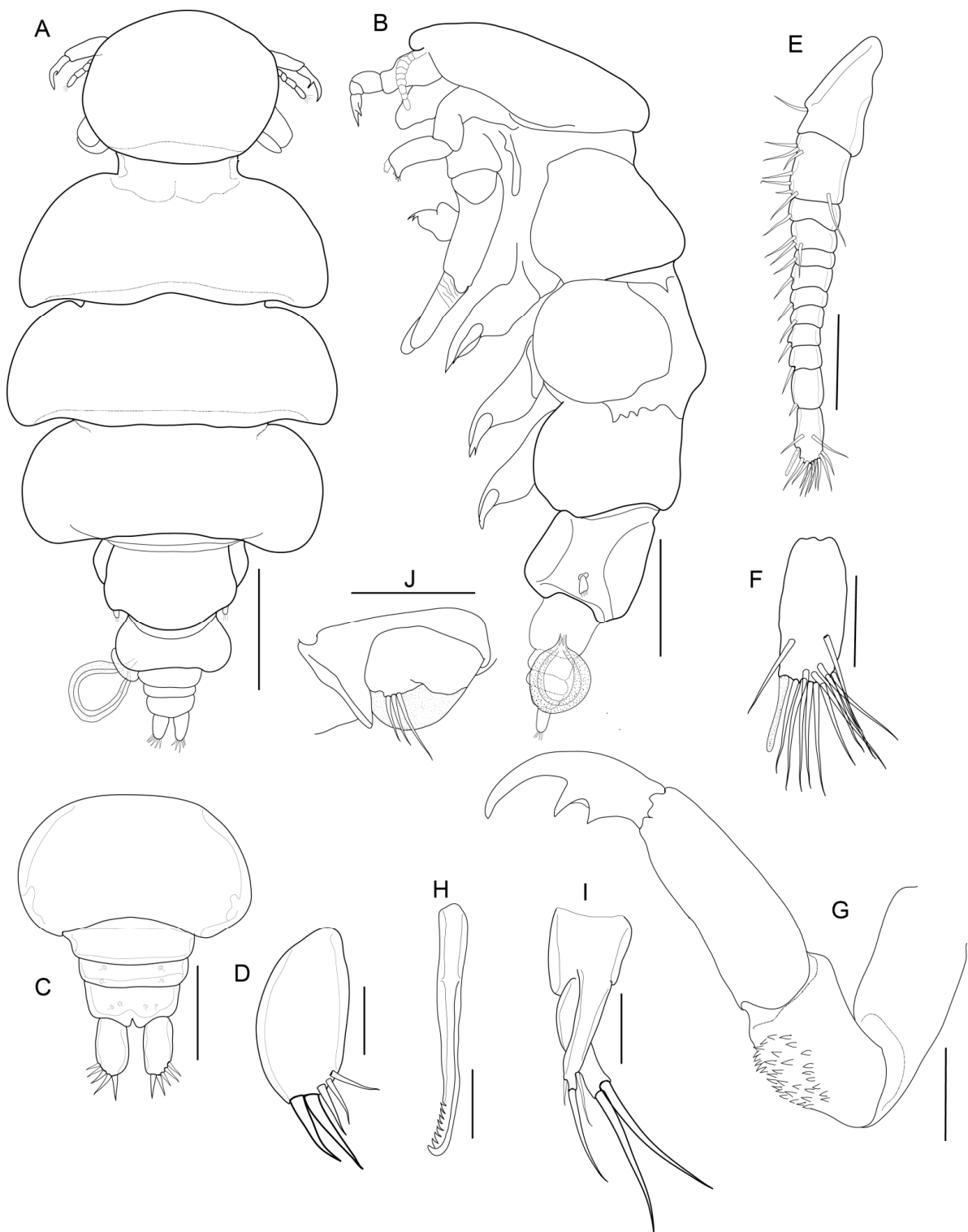


Figure 2. *Nemesis santhadevii* sp. nov. from *Atelomycterus marmoratus*, paratype female. (A) habitus, dorsal view; (B) habitus, ventral view; (C) genito-abdomen; (D) caudal ramus; (E) antennule; (F) antennule apex; (G) antenna; (H) mandible; (I) maxillule; and (J) leg 5. Scale bar: (A,B) = 1 mm; (C) = 0.5 mm; and (D–J) = 0.01 mm.

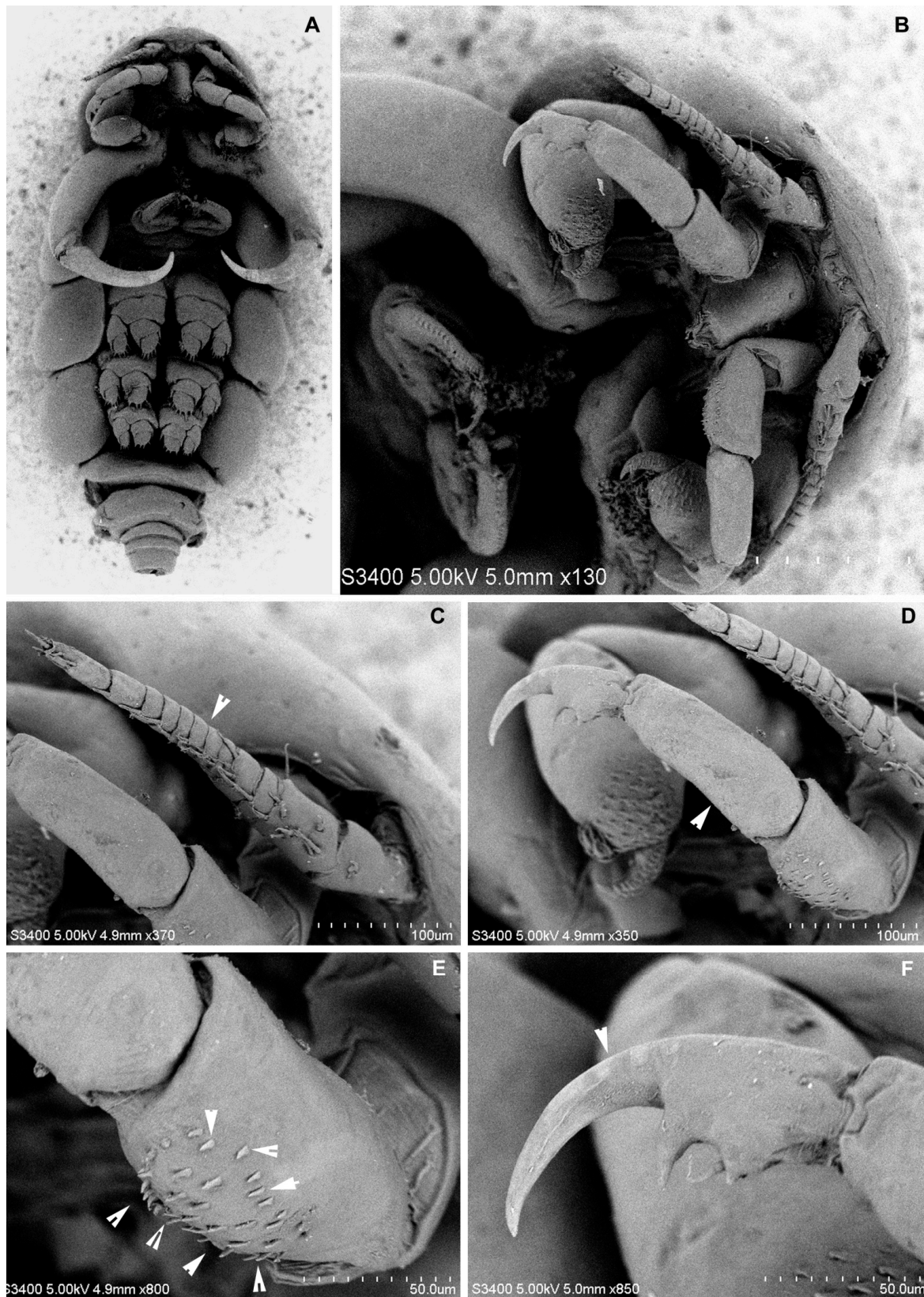


Figure 3. *Nemesis santhadevii* sp. nov. from *Atelomycterus marmoratus*, paratype female. (A) habitus, ventral view; (B) ventral view showing cephalic appendages; (C) antennule, arrow showing segments; (D–F) antenna; (E) arrow showing spinules; and (F) arrow showing the bent claw of the distal segment.

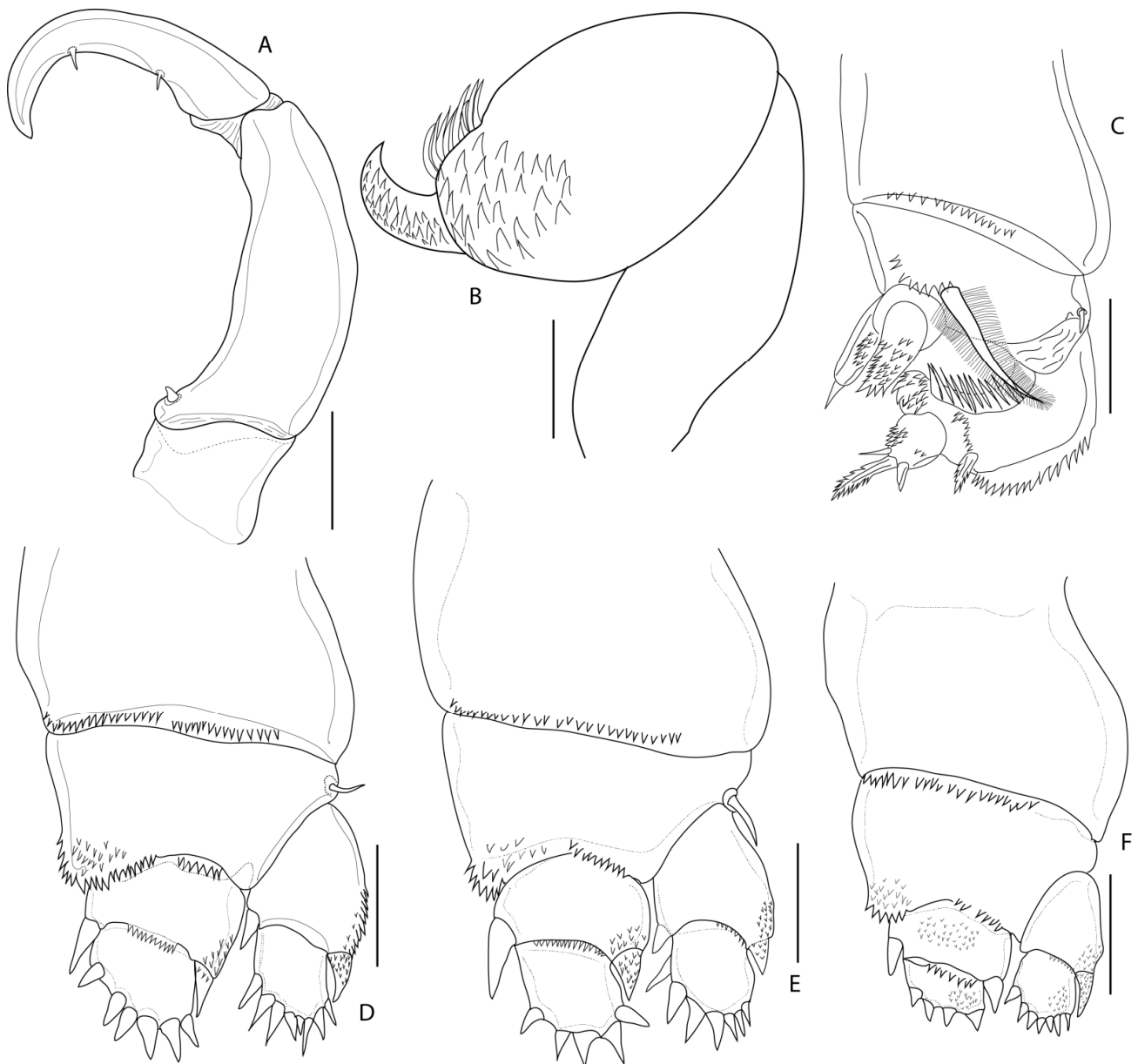


Figure 4. *Nemesis santhadevii* sp. nov. from *Atelomycterus marmoratus*, paratype female. (A) maxilliped; (B) maxilla; (C) leg 1; (D) leg 2; (E) leg 3; and (F) leg 4. Scale bar: (A,B) = 0.02 mm; and (C–F) = 0.5 mm.

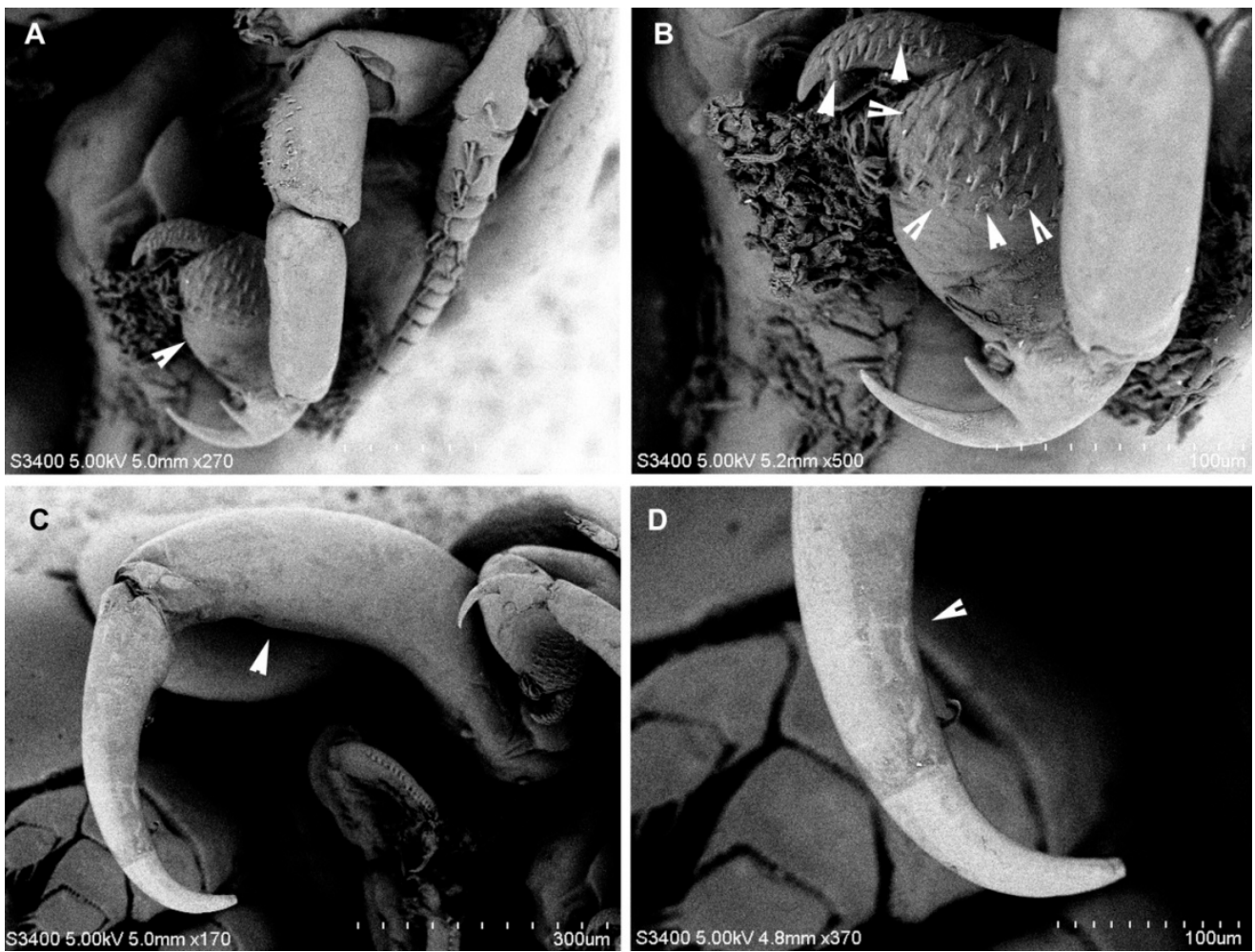


Figure 5. *Nemesis santhadevii* sp. nov. from *Atelomycterus marmoratus*, female. (A) maxilla (arrow); (B) maxilla (arrow showing spinules); (C) maxilliped (arrow); and (D) maxilliped terminal segment (arrow).

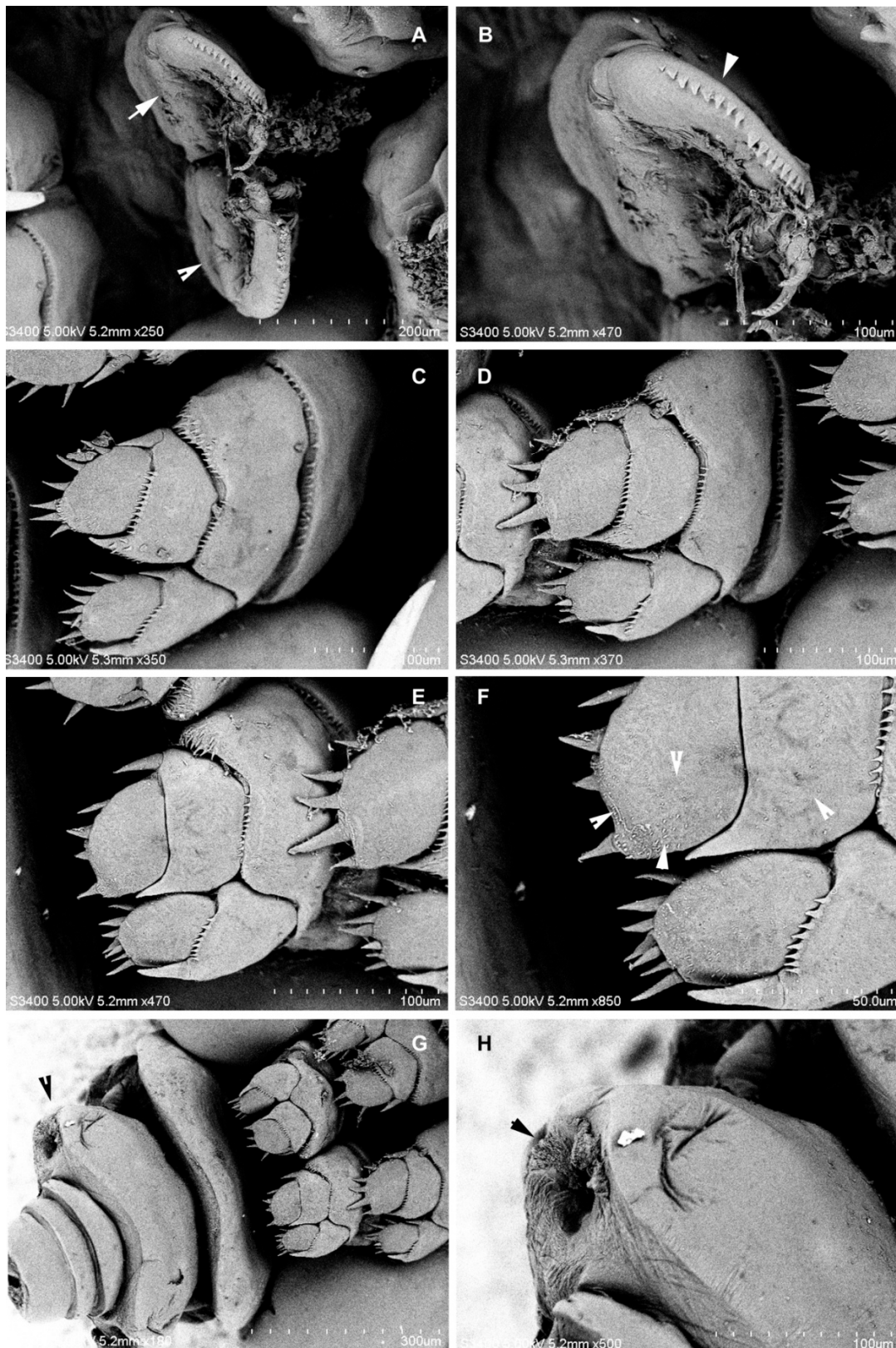


Figure 6. *Nemesis santhadevii* sp. nov. from *Atelomycterus marmoratus*, ovigerous female. (A) leg 1, right and left (arrows); (B) leg 1, high magnification (arrow showing denticles); (C) leg 2; (D) leg 3; (E) leg 4; (F) leg 4, high magnification (arrow showing spinules); and (G,H) genital double somite (arrow).

Antennule (Figures 2E and 3B–D) 12-segmented, elongated; segments 1 and 2 longer than others, segments 4–10 subequal in length, segments 12 longer than 11. All segments with setae, segments 3, 5–11 each with one seta on disto-lateral margin; segment 2 with eight setae, segment 4 with three setae, terminal segments with cluster of 12 setae and 1 aesthetasc. Antenna (Figures 2G and 3D–F) 4-segmented, segment 1 unarmed, 2 stouter than third, with patches of 34–38 denticles, segment 3 unarmed, 1.5 times longer than 2, distal segment claw like, with two strong spinules (Figure 3F). Mandible (Figure 2H) unsegmented, elongated; inner distal margin with eight short denticles. Maxillule (Figure 2I), inner lobe (endite) with two long spinules, outer lobe (palp) with two short and one long spinules. Maxilla (Figure 4B and Figure 5A,B) 3-segmented, basal segment elongated unarmed, segment 2, 1.6 times as long as wide, 1.4 times as wide as segment 1, distally with patch of 25–29 denticles; distal segment claw like, armed with patches of 32–38 denticles. Maxilliped (Figures 4A and 5C,D) 3-segmented, basal segment unarmed, shorter than others, segment 2 longest, 3 times as long as basal segment, inner proximal margin with one short spine, distal segment, claw like, with short spine on inner proximal and distal margins.

Legs 1–4 (Figure 4C–F) biramous, covered by spinules; rami 2-segmented. Leg 1 (Figures 4C and 6A,B), coxae 1.2 times as wide as long, distal margin with 14–15 short spinules; basis with one short seta at outer margin, one long plumose seta on median margin; exopod with prominent incision on outer border, row of denticles followed by pectinate scales, distal lower lobe with three spinules, apical protrusion covered with denticles; endopod somites spinulose, distal segment with 1 apical spine. Leg 2 (Figures 4D and 6C), coxae 1.9 times as wide as long, distal margin with 33–35 short spinules; basis with one short seta at outer margin, inner endopod basis with 30–35 marginal spinules and patches of 14–16 spinules; exopod distal segment with 8 spinules, unequal; proximal segment with 2 spinules; endopod with 6 and 2 spinules on distally and proximally, respectively. Leg 3 (Figures 4E and 5D), coxae 1.6 times as wide as long, distal margin with 27–30 short spinules; basis with one seta at outer margin, inner endopod basis with 18–22 marginal spinules and patches of 7–10 spinules; exopod distal segment with 7 spinules, 3 smaller; 2 spinules proximally; endopod with 5 robust spinules and 2 spinules proximally; Leg 4 (Figures 4F and 5E,F), coxae distal margin with 22–25 short spinules; basis inner margin with 11–14 marginal spinules and patches of 8–11 spinules; exopod and endopod with 7 and 4 spinules, respectively on distal segment (Table 1). Fifth leg, small lobe bearing 3 setae (Figure 2J).

Table 1. The setal formula of rami of legs of the female *Nemesis santhadevii* sp. nov. (Roman numerals indicate the spine and the Arabic numerals indicate the setae).

	Coxa	Basis	Exopod		Endopod	
			Proximal	Distal	Proximal	Distal
Leg 2	0-0	1-0	0-II	0-VIII	0-II	0-VI
Leg 3	0-0	1-0	0-II	0-VII	0-II	0-V
Leg 4	0-0	0-0	0-I	0-VII	0-II	0-IV

3.1.7. Distribution

It is known only from the type locality, North Borneo of the South China Sea, Malaysia.

4. Discussion

The genus *Nemesis* is distinguished from other eudactylinids by the following combinations of characteristics: (1) the rounded cephalothorax is narrower than the second pedigerous somite; (2) the pedigerous somites from two to four are free, and laterally folded downwards, and dorsal projections are absent; (3) the tergites of the free pedigerous somites are well defined and ornamented; (4) the fifth somite is generally much narrower than the fourth, having postero-lateral lobes carrying the vestigial legs; (5) antennule 13–14 are

segmented; and (6) the first leg is highly modified, and coxal setae are absent in legs 2–4 [4,17,18].

The species of *Nemesis* can be determined based on: the proportion of the dorsal cephalothoracic shield compared to body length; the comparative sizes of the second to the fifth pedigerous somites; the size of the fifth somite; and variation in the appendages [3,6,8,9,11,18].

The most combinations of diagnostic characteristics of *Nemesis santhadevii* sp. nov. include: (1) the sub-circular cephalothorax is 1.3 times as wide as it is long, and it overlaps the second pedigerous somite; (2) the fifth somite is 0.4 times the width of fourth; (3) the genital double somite is slightly narrower than the fifth somite; (4) the caudal rami has two large and three small spinules; (5) segment 2 of the antenna has a patch of 34 to 38 short spinules; and (6) the structure and the number of setae or spines on legs 1–4 (Table 1). *N. santhadevii* sp. nov. appears to be the 13th species of the genus *Nemesis* and the first from Malaysia and the South China Sea. Species of *Nemesis* are distinguished from each other mainly by one or two minor differences [18].

By observing the following characteristics, *N. santhadevii* sp. nov. can be distinguished from most of its congeners (see Table 2) in: the lowest cephalothoracic shield's proportion to body length (0.20:1) in the female of *N. santhadevii* sp. nov. (compared with more than 0.25:1 in all other species); the size of the fifth somite is 0.4 times the width of the fourth (compared with being slightly narrower than the fourth in most congeners and equal to the fourth in *N. lamna*); the comparative sizes of the second to the fifth pedigerous somites—in *N. santhadevii* sp. nov., somites two and three are equal, and somite four is slightly narrower than three (compared with somites two to five being equal or subequal or decreasing in size from somites two to five in other species). In the structure of antennae, *N. tiburo* and *N. santhadevii* sp. nov. have only one patch of spinules on the second somite, but both species can be distinguished from each other by the third somite of the antenna—without spinules in *N. santhadevii* sp. nov. and with spinules in *N. tiburo*.

Table 2. Inter-specific characteristics between the species of *Nemesis* Risso, 1826.

	Species	Morphological Characteristics			References	
		Cephalothoracic Shield: Body Length	Comparative Size of second to fifth Pedigerous Somites	Fifth Pedigerous Somite		Nature of Spinules of Segments in Antenna
1	<i>N. aggregatus</i> Cressey, 1967	0.33:1	Somites 2–4 equal in size, somite 5 is slightly narrower than the others	Slightly narrower than the fourth somite	A patch of 10–12 spinules on segment 2	[10,18]
2	<i>N. atlantica</i> Wilson C.B., 1922	0.28:1	Subequal in size	Abruptly narrower than the fourth somite	Patches of 25–40 spinules on segment 2	[3,10]
3	<i>N. carchariaeaglauci</i> (Hesse, 1883)	-	-	-	-	[19]
4	<i>N. lamna</i> Risso, 1826	0.25:1	Equal in size	Equal to the fourth somite	Patches of 25–40 spinules on segment 2	[2,5,6,10,11,18,20–23]
5	<i>N. macrocephalus</i> Shiino, 1957	0.39:1	Decreasing in size posteriorly	Slightly narrower than the fourth somite	Patches of 25–40 spinules on segment 2	[9]
6	<i>N. pallida</i> Wilson C.B., 1932	0.29:1	Subequal in size	Slightly narrower than the fourth somite	Patches of 25–40 spinules on segment 2	[6]
7	<i>N. pilosus</i> Pearse, 1951	0.33:1	Decreasing in size posteriorly	Slightly narrower than the fourth somite	Patches of 25–40 spinules on segment 2	[7,11]
8	<i>N. robusta</i> (Beneden, 1851)	0.29:1	Subequal in size	Abruptly narrower than the fourth somite	Patches of 25–40 spinules on segment 2	[10,18,21–24]

Table 2. Cont.

	Species	Morphological Characteristics			References	
		Cephalothoracic Shield: Body Length	Comparative Size of second to fifth Pedigerous Somites	Fifth Pedigerous Somite		Nature of Spinules of Segments in Antenna
9	<i>N. santhadevii</i> sp. nov.	0.20:1	Somites 2 and 3 are equal in size, somite 4 is slightly narrower than somite 3	0.4 times the width of the fourth somite	Patches of 34–38 short spinules on segment 2. It is stouter than segment 3. Segment 3 is unarmed.	Present study
10	<i>N. sphyrynae</i> Rangnekar, 1984	0.33:1	Decreasing in size posteriorly	Abruptly narrower than the fourth somite	Two rows of 12–14 spinules on segment 2	[12]
11	<i>N. spinulosus</i> Cressey, 1970	0.28:1	Decreasing in size posteriorly	Slightly narrower than the fourth somite	Segment 2 with two patches of spinules, the inner patch composed of heavier spinules than the outer patch; segment 3 has a patch of spinules along the inner border	[11]
12	<i>N. tiburo</i> Pearse, 1952	-	-	-	A row of spinules on segments 2 and 3	[8]
13	<i>N. versicolor</i> Wilson C.B., 1913	0.29:1	Subequal in size	Abruptly narrower than the fourth somite	A row of spinules on segments 2 and 3	[3,10,17,18]

Most species of *Nemesis* have been reported from more than one host (see Table 3). The type species *N. lamna* has been reported from seven species of elasmobranch fishes. Both *N. atlantica*, and *N. pallida*, have been reported from six different host fishes. Four species, such as *N. santhadevii* sp. nov., *N. tiburo*, and *N. sphyrynae*, have so far been reported only from their respective type hosts [3,6,8,9,11,12,18].

Table 3. List of valid species of *Nemesis* Risso, 1826, with their fish hosts and distribution record.

List of Species	Host	Distribution	References
<i>N. aggregatus</i> Cressey, 1967	<i>Alopias vulpinus</i> (Bonnaterre, 1788) <i>Alopias pelagicus</i> (Nakamura, 1935)	Indian Ocean	[10,18]
<i>N. atlantica</i> Wilson C.B., 1922	<i>Rhizoprionodon terraenovae</i> (Richardson, 1836), <i>Carcharhinus brevipinna</i> (Müller and Henle, 1839), <i>Carcharhinus leucas</i> (Müller and Henle, 1839), <i>Carcharhinus limbatus</i> (Müller and Henle, 1839), <i>Carcharhinus acronotus</i> (Poey, 1860), <i>Sphyrna mokarran</i> (Rüppell, 1837)	Beaufort, Florida	[3,10]
<i>N. carchariae</i> Hesse, 1883	<i>Prionace glauca</i> (Linnaeus, 1758) <i>Triakis semifasciata</i> (Girard, 1855)		By generic transfer [19]
<i>N. lamna</i> Risso, 1826	<i>Cetorhinus maximus</i> (Gunnerus, 1765), <i>Isurus oxyrinchus</i> (Rafinesque, 1810), <i>Carcharodon carcharias</i> (Linnaeus, 1758), <i>Lamna nasus</i> (Bonnaterre, 1788), <i>Alopias vulpinus</i> , <i>Odontaspis ferox</i> (Risso, 1810), <i>Lichia amia</i> (Linnaeus, 1758)	Mediterranean, European Sea, California coast, Kerala Coast, India	[2,5,6,10,11,18,20–23]
<i>N. macrocephalus</i> Shiino, 1957	<i>Carcharhinus melanopterus</i> (Quoy and Gaimard, 1824)	Hamazima, Mie Prefecture	[9]

Table 3. Cont.

List of Species	Host	Distribution	References
<i>N. pallida</i> Wilson C.B., 1932	<i>Alopias vulpinus</i> , <i>Carcharhinus plumbeus</i> (Nardo, 1827), <i>Carcharias taurus</i> (Rafinesque, 1810), <i>Galeocerdo cuvier</i> (Péron and Lesueur, 1822), <i>Carcharodon carcharias</i> , <i>Carcharhinus obscurus</i> (Lesueur, 1818)	Martha's Vineyard (Atlantic)	[6]
<i>N. pilosus</i> Pearse, 1951	<i>Carcharias taurus</i> (= <i>Carcharias littoralis</i>) (Type host) <i>Negaprion brevirostris</i> (Poey, 1868), <i>Carcharhinus brevipinna</i> , <i>Carcharhinus limbatus</i>	Bahamas (type locality)	[7,11]
<i>N. robusta</i> Beneden, 1851	<i>Carcharodon carcharias</i> <i>Lamna nasus</i>	-	By generic transfer [10,18,21–24]
<i>N. santhadevii</i> sp. nov.	<i>Atelomycterus marmoratus</i> (Anonymous (Bennett), 1830)	Kota Kinabalu, Malaysia (Type locality)	Present study
<i>N. sphyrynae</i> Rangnekar, 1984	<i>Sphyrna zygaena</i> (Linnaeus, 1758)	Bombay, India	[12]
<i>N. spinulosus</i> Cressey, 1970	<i>Carcharhinus milberti</i> (Müller and Henle, 1839) (= <i>Carcharhinus plumbeus</i>) (Type host), <i>Carcharhinus obscurus</i>	Sarasota, Florida	[11]
<i>N. tiburo</i> Pearse, 1952	<i>Sphyrna tiburo</i> (Linnaeus, 1758)	Bahamas	[8]
<i>N. versicolor</i> Wilson C.B., 1913	<i>Sphyrna zygaena</i> , <i>Carcharhinus brevipinna</i>	West Indies, Madagascar	[3,10,17,18]

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