

Redescription of *Dinemoura discrepans* Cressey, 1967 (Copepoda: Pandaridae) parasitic on four species of sharks off southeast coast of Taiwan

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Abstract: *Dinemoura discrepans* Cressey, 1967 (Copepoda, Siphonostomatoidea, Pandaridae) is redescribed based on the specimens taken from four species of sharks caught off the southeast coast of Taiwan. The four species of sharks are: pelagic thresher, *Alopias pelagicus* Nakamura; bigeye thresher, *A. superciliosus* Lowe; blacktip shark, *Carcharhinus limbatus* (Müller et Henle); and oceanic whitetip shark, *C. longimanus* (Poey). Although our redescription shows certain differences from the original description, after re-examination of the museum specimens studied by R. F. Cressey in making the original description, it was confirmed that the specimens from off Taiwan are identifiable with *D. discrepans*. *Carcharhinus limbatus* is currently known to host 19 species of parasitic copepods, of which *D. discrepans* is the first one of this copepod genus.

Keywords: Pandaridae, parasitic copepod, taxonomy, sharks, Taiwan

So far as we are aware only three species of pandarid copepods (Siphonostomatoidea) have been reported from the sharks of Taiwan (Ho 1963, Ho et al. 2003). They are: *Pandarus satyrus* Dana, 1852 from the copper shark, *Carcharhinus brachyurus* (Günther); *Pandarus carcharhini* Ho, 1963 from the blacktip shark, *Carcharhinus melanopterus* (Quoy et Gaimard); and *Dinemoura ferox* (Krøyer, 1838) from the Pacific sleeper shark, *Somniosus pacificus* Bigelow et Schroeder. In this paper we shall add one more species of pandarid, *Dinemoura discrepans* Cressey, 1967, which was found parasitic on four species of sharks captured off the southeast coast of Taiwan. The four species of sharks are: the pelagic thresher, *Alopias pelagicus* Nakamura; the bigeye thresher, *A. superciliosus* Lowe; the blacktip shark, *Carcharhinus limbatus* (Müller et Henle); and the oceanic whitetip shark, *C. longimanus* (Poey).

Our initial examination of newly collected specimens of pandarids showed that we had found an unrecorded species of *Dinemoura* bearing close resemblance to *D. discrepans*. Thus, a manuscript was prepared to report the new species and submitted to Folia Parasitologica. Fortunately, one of the referees, who reviewed our manuscript, was keen to catch and comment that the original description of *D. discrepans* by Cressey (1967) was improperly prepared and recommended us to check our description of the new species against the type material that Cressey (1967) had deposited in the U.S. National Mu-

seum. Our examination of the museum material proves that our specimens from four species of sharks of Taiwan are identifiable with *D. discrepans* and Cressey's (1967) original description of the species does contain several pieces of improper information. Therefore, our supposedly new species description is turned into a redescription of *D. discrepans*.

MATERIALS AND METHODS

Newly collected specimens. The sharks caught off Taichung, Taiwan by the local fishermen were examined with naked eye right after landing at Cheng-gong Fishing Port. The parasites were carefully removed from the host's body with a pair of forceps and immediately fixed in 70% ethanol. Back in the laboratory, the preserved specimens were soaked in 85% lactic acid for 2 to 3 days prior to dissection in lactic acid in a depression slide under the dissection microscope. The hanging drop method, devised by Humes and Gooding (1964), was employed in the examination of the isolated body parts and appendages. All drawings were made using a drawing tube mounted on the microscope. The measurements, given as the mean followed by the range in parentheses, are in millimetres and were taken from 10 randomly selected females and all 4 males in the collection.

Museum specimens. Cressey (1967) indicated in his original work on *D. discrepans* that the type material (USNM 113592), containing holotype female, allotype male, and 10 paratypes (5♀♀, 5♂♂), was deposited in the U.S. National Museum. However, mysteriously, Chad Walter of U.S. National

Museum informed us that the type lot “was never cataloged.” It is not in the computer database and also cannot be found in the type collection. Fortunately, Chad Walter found five lots of what Cressey (1967) called “Other specimens studied” in his original work. Followings are information on the labels of those five lots that we had loaned and studied for comparison:

USNM 153564 *Dinemoura discrepans* – 24 ♀♀ on *Alopias superciliosus* from Indian Ocean, Madagascar, Aug. 1961; USNM 153565 *Dinemoura discrepans* – 4 ♀♀, 2 ♂♂, 2 larvae on *Alopias superciliosus* from Pacific Ocean, west of Galapagos Islands (00°38'N, 124°23'W); USNM 153566 *Dinemoura discrepans* – 3 ♀♀, 2 ♂♂ on *Alopias superciliosus* from Indian Ocean, Madagascar, Nosy Bé, 09 Apr. 1964; USNM 153567 *Dinemoura discrepans* – 1 ♂ on *Alopias vulpinus* from Indian Ocean, Somali Basin, off Somali Republic (07°10'N, 55°05'E), 06 Feb. 1964; USNM 153568 *Dinemoura discrepans* – 17 ♀♀, 5 ♂♂ on *Alopias vulpinus* from Indian Ocean, Somali Basin, off Somali Republic (07°17'N, 55°00'E), 06 Feb. 1964.

RESULTS

Dinemoura discrepans Cressey, 1967 Figs. 1–4

Female (n = 10): Body (Fig. 1A) 18.5 (17.7–19.1) long, excluding setae on caudal ramus. Frontal plates distinctly separated. Cephalothoracic shield arch-shaped, with widely open posterior notch exposing pedigers 2 and 3, measuring 7.8 (7.4–8.2) long and 7.7 (7.6–7.8) wide (excluding lateral, hyaline membrane). Pedigerous somites 2–4 free. Posterior corners of 3rd pedigerous somite produced posterolaterally to form pair of large aliform plates, with their tips touching medial borders of cephalothoracic shield. Dorsal aliform plates on 4th pedigerous somite extending over anterior portion of genital complex, with serrated posterior borders. Genital complex arch-shaped, 7.3 (7.3–7.4) long and 4.7 (4.4–4.9) wide, with posterior corners greatly produced and bluntly tipped. Abdomen 2-segmented (Fig. 1B); proximal somite wider than long, 1.10 (1.06–1.18) × 2.07 (1.94–2.14), bearing dorsal plate with central notch on posterior border (see Fig. 1A); distal (anal) somite longer than wide, measuring 2.03 (1.94–2.20) × 1.63 (1.58–1.70), bearing subcircular plate with irregular margin (see Fig. 1A). Caudal ramus (Fig. 1B) lamelliform, 2.35 (1.85–2.75) × 1.18 (1.05–1.35), medial border fringed with row of setules, outer border armed with 1 small seta and 1 small spine, and posterior border, 1 small seta and 4 spines. Egg sac long, uniseriate (broken while soaking in lactic acid).

Antennule (Fig. 1C) 2-segmented; proximal segment with sharp, basal protrusion on anterior margin and carrying on anterodistal surface 27 short, stout, spinulose spines and 1 naked seta (on dorsal side), distal segment short, about 2.15 times as long as wide, with one subterminal seta on posterior margin and 11 setae plus 2 aesthetascs on distal margin. Antenna (Fig. 1D) 3-segmented; proximal segment (coxa) unarmed; middle segment (basis) bearing ventrodistal knob; distal segment

(endopod) long, curved claw bearing 2 setae, basal one small and middle one long. Mandible (Fig. 1F) made of 2 sections; bearing 12 teeth on medial margin of distal blade. Maxillule (Fig. 1E) comprising a globose segment bearing basal papilla with 3 small setae and distal knob tipped with broad spine. Maxilla (Fig. 1H) 2-segmented; proximal segment (lacertus) unarmed; slender distal segment (brachium) bearing distal patch of setules at base of subterminal canna, and terminal calamus subdivided into 2 segments, with small basal segments carrying patch of setules in medial-distal area and long distal segments armed with short rows of spinules throughout entire surface. Maxilliped (Fig. 1G) 3-segmented; proximal segment (corpus) armed with 2 dentiform knobs in medial-basal area and 3 similar protrusions in myxal area; middle segment (shaft) armed distally with naked seta; and distal segment sharply pointed claw.

Armature on rami of legs 1–4 as follows (Roman numerals indicating spines and Arabic numerals, setae):

	Exopod	Endopod
Leg 1	I-0; III,I,3	0-0; 3
Leg 2	I-1; I-1; II,I,5	0-1; 0-2; 6
Leg 3	I-1; I-1; III,5	0-0; 0-2; 1,4
Leg 4	6	4

Leg 1 (Fig. 2A) coxa small, ornamented on ventrolateral surface, with papilla bearing 2 setules and patch of spinules; basis with 1 outer and another inner plumose seta in addition to large corrugated area on ventral surface; both segments of exopod fringed with row of setules on medial margin; small proximal segment of endopod with patch of scales and its large distal segment nearly covered by corrugation on ventral surface. Leg 2 (Fig. 3A) coxa with corrugated area on ventromedial surface; basis with 1 small outer and 1 large medial plumose seta in addition to marginal papilla bearing 2 setules; exopod with large hyaline membrane on outer margin of proximal segment, that of middle and distal segment fringed with row of spinules; outer margin of endopodal segments fringed with row of setules. Leg 3 (Fig. 2B) protopod enlarged and fused to triangle-shaped intercoxal plate to form apron as in *Caligus*; outer margin of coxa bearing setules; outer plumose seta on basis (Fig. 2C) shorter than inner one (see Fig. 2B); all outer margins of exopodal segments bearing row of spinules (Fig. 2C); proximal segment of endopod greatly enlarged and fringed with row of setules (Fig. 2D). Leg 4 (Fig. 2E) lamelliform; distal corners of protopod produced into round lobe fringed with setules in distal region, outer lobe bearing on medial surface a basal papilla tipped with small plumose seta; both rami becoming broad, oval-shaped lamellae, fringed with setules on distal margin of exopod and entire outer margin plus distal margin of endopod, exopod with 6 tiny spines and endopod with 4 similar spines. Leg 5 (Fig. 1B) small knob tipped with 2 setae located near junction of abdomen and

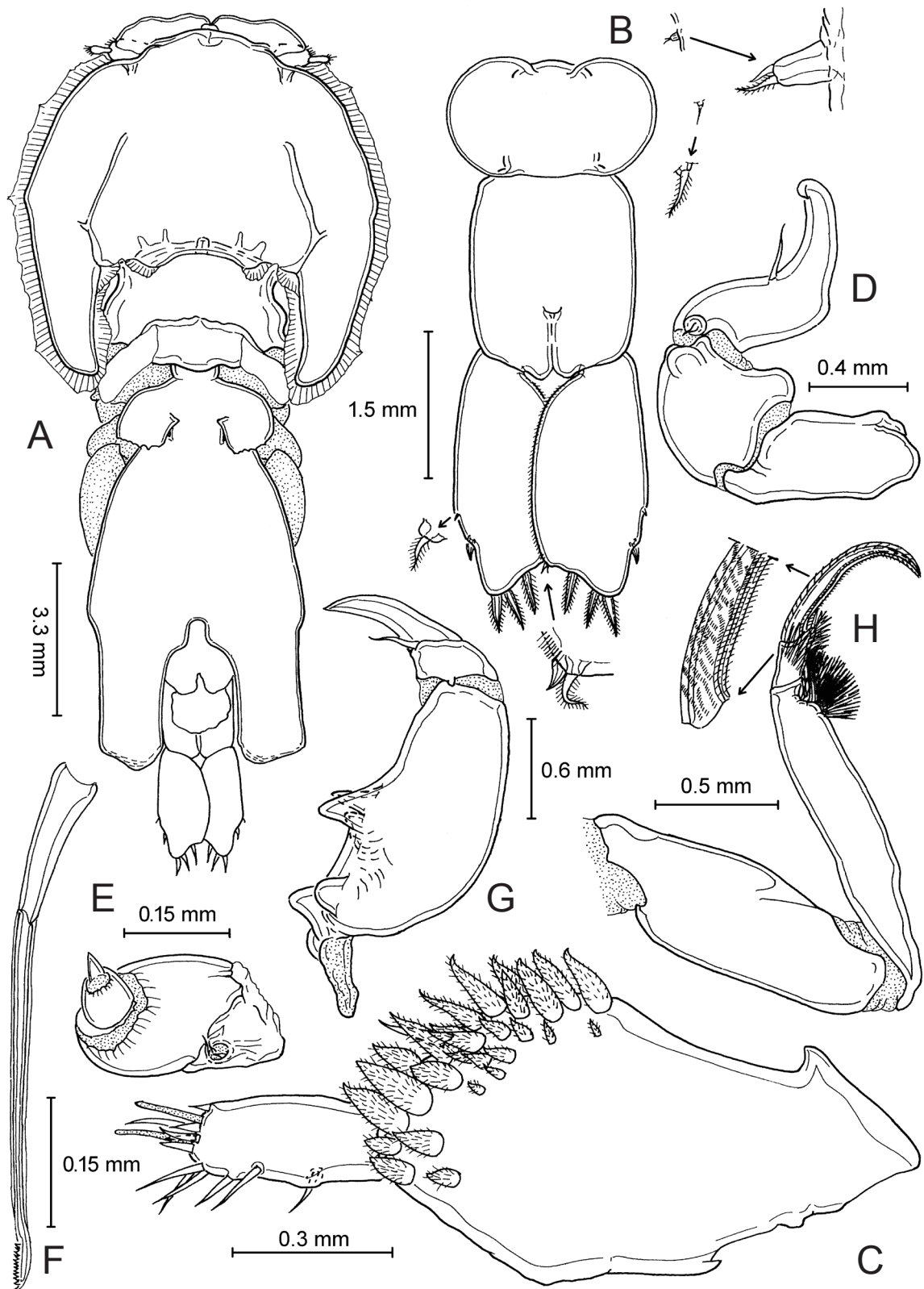


Fig. 1. *Dinemoura discrepans* Cressey, 1967; female. **A** – habitus, dorsal; **B** – abdomen and caudal rami, ventral; **C** – antennule; **D** – antenna; **E** – maxillule; **F** – mandible; **G** – maxilliped; **H** – maxilla.

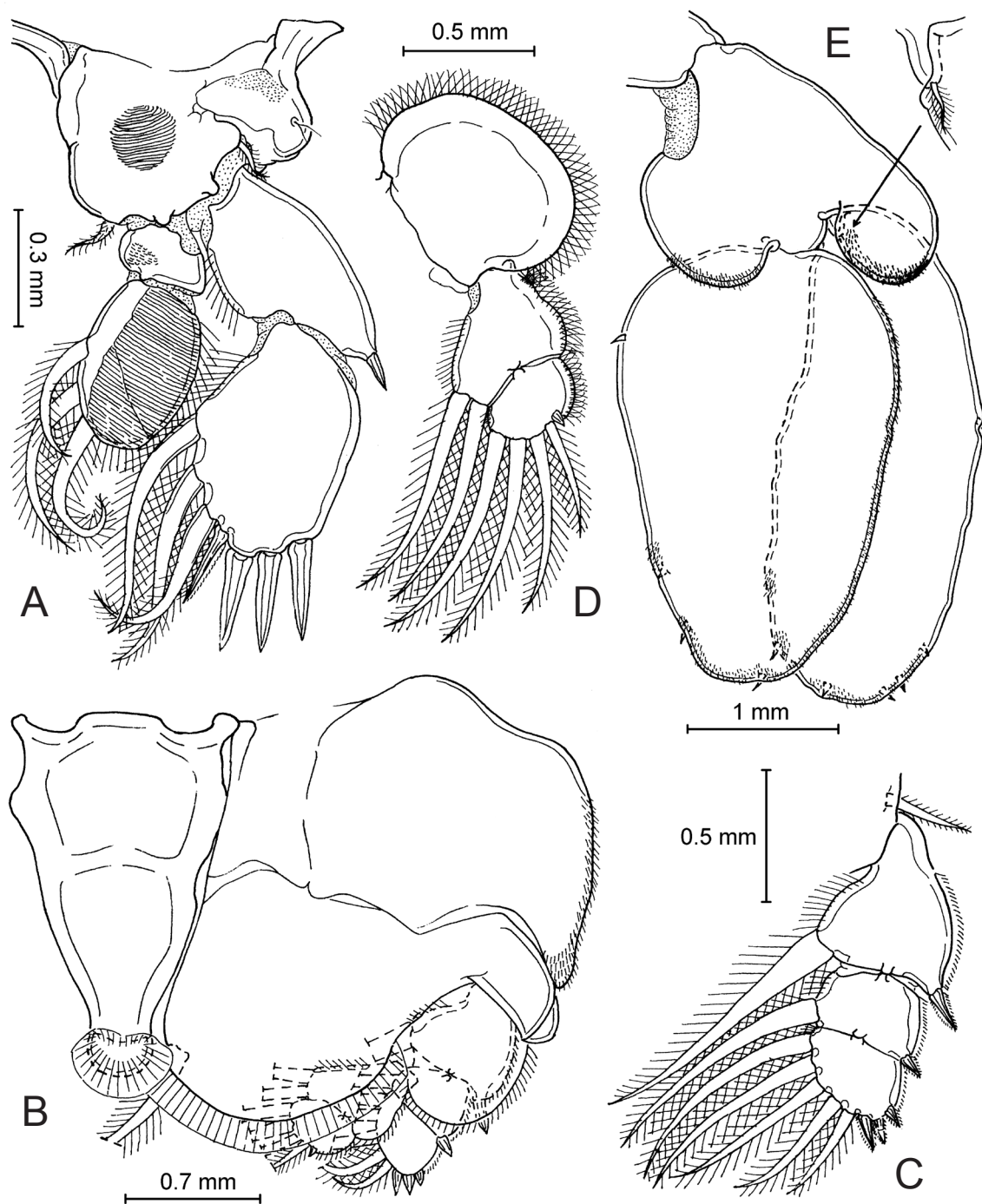


Fig. 2. *Dinemoura discrepans* Cressey, 1967; female. A – leg 1; B – leg 3 and intercoxal plate; C – leg 3 exopod; D – leg 3 endopod; E – leg 4.

genital complex. Leg 6 (Fig. 1B) seta-bearing papilla in the vicinity of leg 5.

Male (n = 4): Body form (Fig. 3B) generally as in female, measuring 11.01 (9.62–11.74) long, excluding setae on caudal ramus. Cephalothoracic shield subcircular, 5.23 (5.02–5.36) long and 5.10 (4.84–5.56) wide. Pedigers 2–4 free, with a pair of aliform plates on 3rd and 4th pedigers as in female. Genital complex 2.97 (2.58–3.52) × 2.63

(2.40–2.82), shaped more or less as in female, except for having shorter posterolateral process with serrated tip (Fig. 3B). Abdomen 2-segmented; proximal somite wider than long, 0.47 (0.42–0.50) × 0.80 (0.70–0.88); distal (anal) somite also wider than long, 0.85 (0.74–0.92) × 1.05 (0.94–1.12). Caudal ramus (Fig. 3B) constructed and armed as in female but smaller, 1.36 (1.18–1.48) × 0.53 (0.48–0.56).

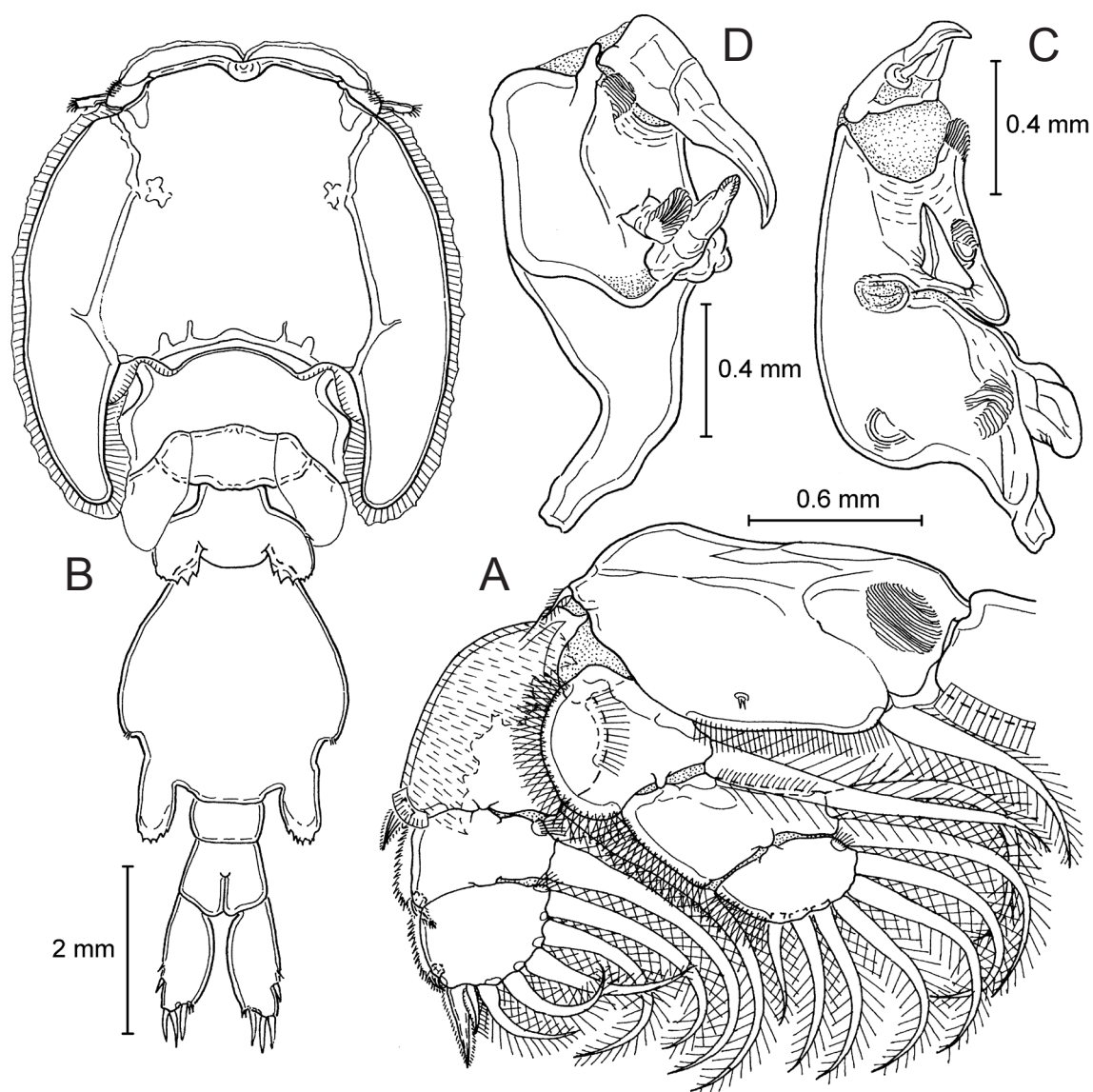


Fig. 3. *Dinemoura discrepans* Cressey, 1967; female (A) and male (B–D). A – leg 2; B – habitus, dorsal; C – maxilliped, anterior; D – maxilliped, posterior.

Antenna (Fig. 4A) 3-segmented; proximal segment (coxa) with adhesion pad on distal margin; middle segment (basis) largest, with large V-shaped adhesion pad close to lateral margin, similar but smaller pad located close to medial margin, and another small pad on medio-distal corner; distal segment (endopod) robust claw bearing 2 basal setae and large, subterminal tooth. Maxilliped (Fig. 3C, D) 3-segmented; proximal segment (corpus) largest, armed with 5 adhesion pads in addition to large conical process in myxal area; middle segment (shaft) smallest and armed with seta; distal segment long, sharply pointed claw. Protopod of leg 1 (Fig. 4B) armed, in addition to outer and inner seta, with bisetule-bearing papilla on lateral margin, 2 adhesion pads on ventral surface, and patch of scales close to posteromedial margin. Proximal segment of endopod also bearing adhesion pad on

ventral surface. Distal endopodal segment of leg 3 small (Fig. 4C), armed with stout, outwardly protruded spine on lateral margin and another spine plus 4 plumose setae on medial margin. Leg 4 (Fig. 4D) with lamelliform rami and fringed with setules on lateral margin; exopod armed with 7 spines and endopod, 5 spines. Leg 5 (Fig. 4E) represented by 2 pinnate setae plus 1 setule located on posterolateral margin of genital complex at base of posterior process. Leg 6 (Fig. 4E) represented by small papilla tipped with 2 setules located at distal-outer rim of ventral ridge on genital complex.

Newly collected specimens

Hosts: *Alopias pelagicus* Nakamura and *A. superciliosus* Lowe (Elasmobranchii, Alopiidae); *Carcharhinus limbatus*

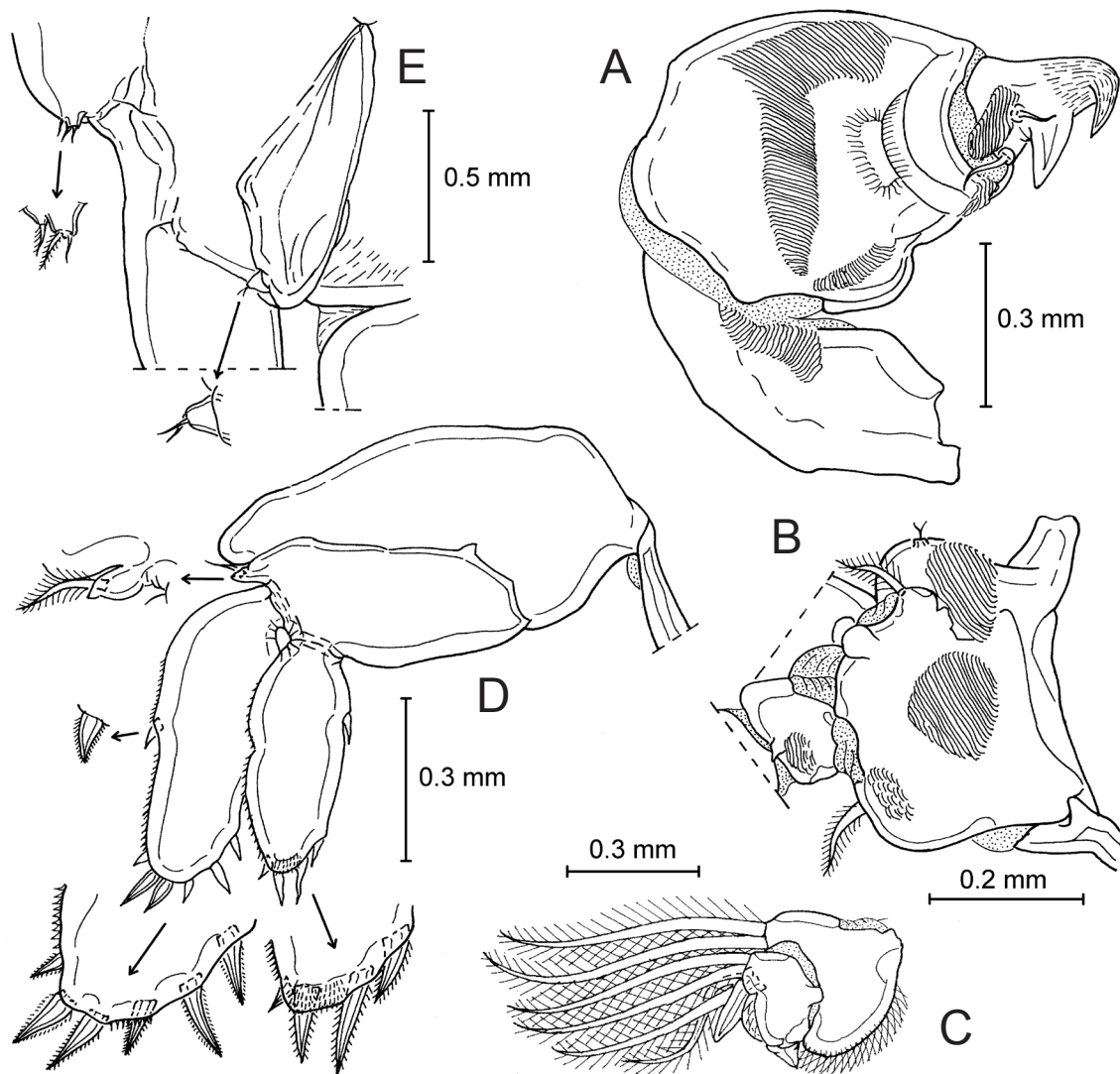


Fig. 4. *Dinemoura discrepans* Cressey, 1967; male. **A** – antenna; **B** – leg 1, showing protopod and proximal segment of endopod; **C** – leg 3 endopod; **D** – leg 4; **E** – posterolateral corner of genital complex, showing leg 5 and leg 6.

Müller et Henle and *C. longimanus* (Poey) (Elasmobranchii, Carcharhinidae).

Locality: Off Tai-dong, Taiwan.

Date of collection: 2 May, 2009; 4 May, 2009; 29 January, 2010; 12 April, 2010; and 20–21 April, 2010.

Site of infection: Base of anal fin, lateral surface of head, and ventral surface in vicinity of anus.

Prevalence: 100% (6 hosts infected of 6 examined).

Mean intensity: 10.3 (62 parasites found on 6 hosts examined).

Deposition of voucher material: 21 vouchers (1 male in USNM 1150346, 20 females in USNM 1150347) deposited in the National Museum of Natural History, Smithsonian Institution, Washington DC, USA; dissected individuals and remaining intact specimens are kept in the collection of the second author.

DISCUSSION

The redescription given above was made from the specimens collected from off Taiwan. Comparison of these specimens with the original description by Cressey (1967) shows that the specimens from off Taiwan differ from Cressey's (1967) original description in having in the female: (1) five (instead of three) conical processes on medial surface of the corpus of the maxilliped; (2) eight (instead of nine) elements on the distal, exopodal segment of leg 3; and (3) bearing a formula of I,4 (instead of 4) on the distal, endopodal segment of leg 3; and in the male: (4) a huge subterminal tooth on the antennal claw; and (5) both rami of leg 4 becoming lamelliform. Nevertheless, by examining Cressey's (1967) "Other specimens studied," we are convinced that the specimens from off Taiwan are conspecific with Cressey's (1967) specimens from the Indian Ocean and eastern Pacific Ocean. There-

Table 1. Copepod parasites reported from the blacktip shark (*Carcharhinus limbatus*).

Parasite	Locality	Authority
<i>Alebion carchariae</i> Krøyer, 1863	western North Atlantic	Cressey 1970
<i>Alebion maculatus</i> Wilson, 1932	Indian Ocean	Cressey 1972
<i>Dinemoura discrepans</i> Cressey, 1967	western North Pacific	This study
<i>Dysgamus limbatus</i> Pearse, 1952	Gulf of Mexico	Pearse 1952
<i>Eudactylina aspera</i> Heller, 1865	Gulf of Mexico	Cressey 1970
<i>Eudactylina breviabdomina</i> Pearse, 1952	Gulf of Mexico	Pearse 1952
<i>Kroyeria gracilis</i> Wilson, 1932	India	Pillai 1985
<i>Kroyeria lineata</i> van Beneden, 1853	Gulf of Mexico	Wilson 1935
<i>Kroyeria longicauda</i> Cressey, 1972	Gulf of Mexico	Cressey 1970
<i>Kroyeria spatulata</i> Pearse, 1948	Gulf of Mexico	Pearse 1947
<i>Lepeophtheirus eurus</i> Bere, 1936	Gulf of Mexico	Cressey 1970
<i>Nemesis atlantica</i> Wilson, 1922	Gulf of Mexico	Cressey 1970
<i>Nemesis pilosus</i> Pearse, 1951	Gulf of Mexico	Cressey 1970
<i>Nemesis robusta</i> (van Beneden, 1851)	western North Atlantic	Pearse 1947*
<i>Nesippus orientalis</i> Heller, 1868	Gulf of Mexico	Cressey 1970
<i>Nesippus crypturus</i> Heller, 1868	Gulf of Mexico	Cressey 1970
<i>Pandarus sinuatus</i> Say, 1818	Gulf of Mexico	Pearse 1952
<i>Perissopus dentatus</i> Steenstrup et Lütken, 1861	Gulf of Mexico	Cressey 1970
<i>Pseudopandarus bombayensis</i> Rangnekar et Rangnekar, 1972	India	Rangnekar and Rangnekar 1972

*The parasite was called "*Nemesis pallida* Wilson, 1932" in this report.

fore, the five discrepancies enumerated above are considered merely improper observation and/or interpretation made by Cressey (1967).

According to Cressey (1967), *D. discrepans* is a parasite on the body surface of *Alopias vulpinus* (Bonnaterre) from the Indian Ocean and *Alopias superciliosus* Lowe from the Pacific Ocean. However, in Taiwan this species of parasite is not only found on *Alopias* sharks, but also on *Carcharhinus* sharks.

The blacktip shark (*Carcharhinus limbatus*) is a cosmopolitan species (Froese and Pauly 2011). Among the four species of sharks from off Taiwan carrying *D. discrepans*, the blacktip shark is the most frequently reported shark around the world for hosting copepod parasites. Up to the present, it has been known to carry 18 species of parasitic copepods (Table 1). Nevertheless, this is the

first time a species of *Dinemoura* has been recorded from this rich parasite-carrying host. This is also the first time to record infection of parasitic copepod on the blacktip shark from the entire Pacific Ocean (Table 1).

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