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Morphological description of marine planktonic calanoid copepods of Family Temoridae in three bays in Mindanao, Southern Philippines

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Abstract. Three marine planktonic calanoid copepods of the *Temoridae* species, namely *Temora discaudata*, *T. stylifera* and *T. turbinata* under Family Temoridae that were commonly seen in the three bays in Mindanao (Iligan, Macajalar and Sarangani Bays) were described morphologically. The qualitative (such as the color and the shaped of the body of the organism) and the quantitative (*i.e.* body segmentation, number of segments, setae and spines on the antennule and paired legs, number of spines of the caudal ramus and the length of the appendages) attributes were used as taxonomic characters for identification of the copepod species. Further, female and male species were differentiated based on the antennules, morphology and structure of the fifth legs and the number of segments of the urosome. Female and male were described for each species and the detailed description together with the drawings and measurements are presented.
Key Words: Tropical planktonic copepods, taxonomic description, Mindanao, Southern Philippines.

Introduction. Zooplankton is critical to the functioning of ocean foodwebs because of their sheer abundance and vital ecosystem roles (Richardson 2008). Being the most prominent zooplankton, they are the most abundant multicellular animals on Earth, even outnumbering insects by possibly three orders of magnitude (Schminke 2007). Planktonic marine copepods (< 1 mm in length), from a trophic point of view, are characterize as the secondary production of the sea (Razouls et al 2005-2012, http://copepodes.obs-banyuls.fr/en) since they act as the major link between the microscopic plant and the higher trophic levels in many marine food chains. Recently, many studies had focused on the calanoid copepod species assemblage as indicators to long-term changes in plankton ecosystems in relation to hydro-climatic variability or climate change (Beaugrand et al 2002a, 2002b, 2002c; Reid & Beaugrand 2002; Beaugrand & Ibañez 2004; Lindley & Daykin 2005). Results have shown the concurrent movement of warm-water copepods polewards indicating the effect of warm ocean water to their abundance and distribution. Despite their role as probable indicators of climate change as well as their overwhelming abundance and pivotal position in marine food webs, there is still comparatively less knowledge of these pelagic copepods, specifically in the Philippine waters. Information on pelagic marine copepod species are limited to those reported by Wilson (1950) during his cruise in the Pacific Ocean on board the United States fisheries steamer “Albatross” from 1887 to 1909 and by Lacuna et al (2013) who described selected copepod species that frequently occurred in some parts in Mindanao waters. Accordingly, this paper described the morphology of some commonly encountered planktonic marine copepods in Mindanao. It is hoped that such detailed taxonomic identification may provide information that can be use for future applications to a range of policy issues such as climate change, biodiversity, pollution, eutrophication and fish stock fluctuations.

Material and Method. Copepod samples were collected from the offshore waters of the established stations in the bays of Iligan, Macajalar and Sarangani (Figure 1). Iligan Bay, which is found at the northern part of Mindanao islands, is separated in the south by Gingoog and Macajalar Bay from the coast of Northern Mindanao, and in north by the Mindanao Sea from Bohol. It is "U" shaped and is approximately 8°30'31" North Latitude, 123°43'15" East Longitude. It has a mouth of approximately 351 mi (560 km) and an area of about 2000 km^2 (Camarao 1983). The bay serves as a source of food, fish and other potential food resources such as shells and algae to the fisher folks in the nearby areas and has been identified by the Philippine Bureau of Fisheries and Aquatic Resources (BFAR) as a major fishing ground for various sea products (Lacuna et al 2013). Macajalar Bay is likewise a wide U-shaped basin with very deep water and has an estimated area of 191,400 sq m and a coastline of 25 km. It serves as a vital food producer of Misamis Oriental and as a living space for human and wildlife. It is also a source of construction materials and minerals. Sarangani Bay, located on the southern tip of Mindanao, opens up to the Mindanao and Celebes Sea on the Pacific Ocean. It is situated at 6° 07' North latitude and 125° 06' East longitude and encloses an area of 449.22 km² from Tampuan Pt. in Maasim to Sumbang Pt. in Glan.

Figure 1. Map of Mindanao Island showing the established stations in the three Bays in Mindanao. Inset is the map of the Philippines with Mindanao Island enclosed in a diamond. Legend: ● Iligan Bay; ● Macajalar Bay; ● Sarangani Bay.

The coastline length of Sarangani Bay from Glan extending to Maasim is about 79 km having an average depth of 350 m. It is recognized as the richest tuna fishing ground in the country and known for its abundant catch of tunas, scads and flying fishes including small fishes (frigate, mackerels, roundscads) and demersal fishes (snappers, breams, groupers and moonfishes) (Portugal 2000). Plankton collections were made by horizontal (towing of net for 5 minutes) and vertical (50 m depth) tows and hauls using conical plankton net (length: 1.8 m; mouth diameter: 0.45 m; mesh size opening: 300 mm). All samples collected were preserved with 5 % buffered formalin/seawater solution. Taxonomic characters for copepod identification were based on the body segmentation, number of segments, setae and spines on the antennule, maxillipeds and paired legs. For each mounted part, the number of segments and setae were counted and the details of the urosome were noted. The number of spines of the caudal ramus was also recorded. All copepod samples were identified to species by dissection and examination following the dissection procedures and techniques of Huys & Boxshall (1991). The dissected parts as well as the whole specimen were mounted on separate glass slides using Hoyer's medium as mountant and were examined and measured using a dissecting stereomicroscope. The parts projected from the microprojector were drawn in detailed. Lengths of prosome was taken dorsally starting from the anterior margin of the cephalon to the posterior tip of the last metasomal somite while urosome was made from the anterior margin of the genital somite to the posterior tip of the caudal rami not including the setae.

The specimens were identified using the descriptions and taxonomic keys of Farran (1936), Dakin & Colefax (1933), Wilson (1950), Kasturirangan (1963), Owre & Foyo (1967), Bradford-Grieve (1994, 1999), Mulyadi (2004) and Al-Yamani et al (2011).

Results and Discussion. Three marine copepod species under Family Temoridae, namely *Temora discaudata*, *T. stylifera* and *T. turbinata* were identified. Female and male were described for each species and the detailed description together with the drawings and measurements are presented below.

TAXONOMIC DESCRIPTION

Family TEMORIDAE

Temora discaudata Giesbrecht, 1889

(Figures 2-7)

Occurrence. The species were commonly encountered in the horizontal and vertical waters in all stations in Iligan and Sarangani Bays. Both sexes were common in Iligan Bay, while male species are not frequent in Sarangani Bay.

Description of adult female and male. Body length: females 1.80 mm, males 1.77 mm. Both sexes have short, compact body and dark brown coloration in live specimens. The prosome of both sexes is comprised of a cephalosome and 4 metasomal segments or pedigerous somites (Figures 2a & 2b). The head-end is massive. The posterior corners of the 4th metasomal segment for the female and the male are drawn out into spines, which is symmetrical in female while asymmetrical in male. Further, the left spine in male is larger than the right (Kasturirangan 1963).

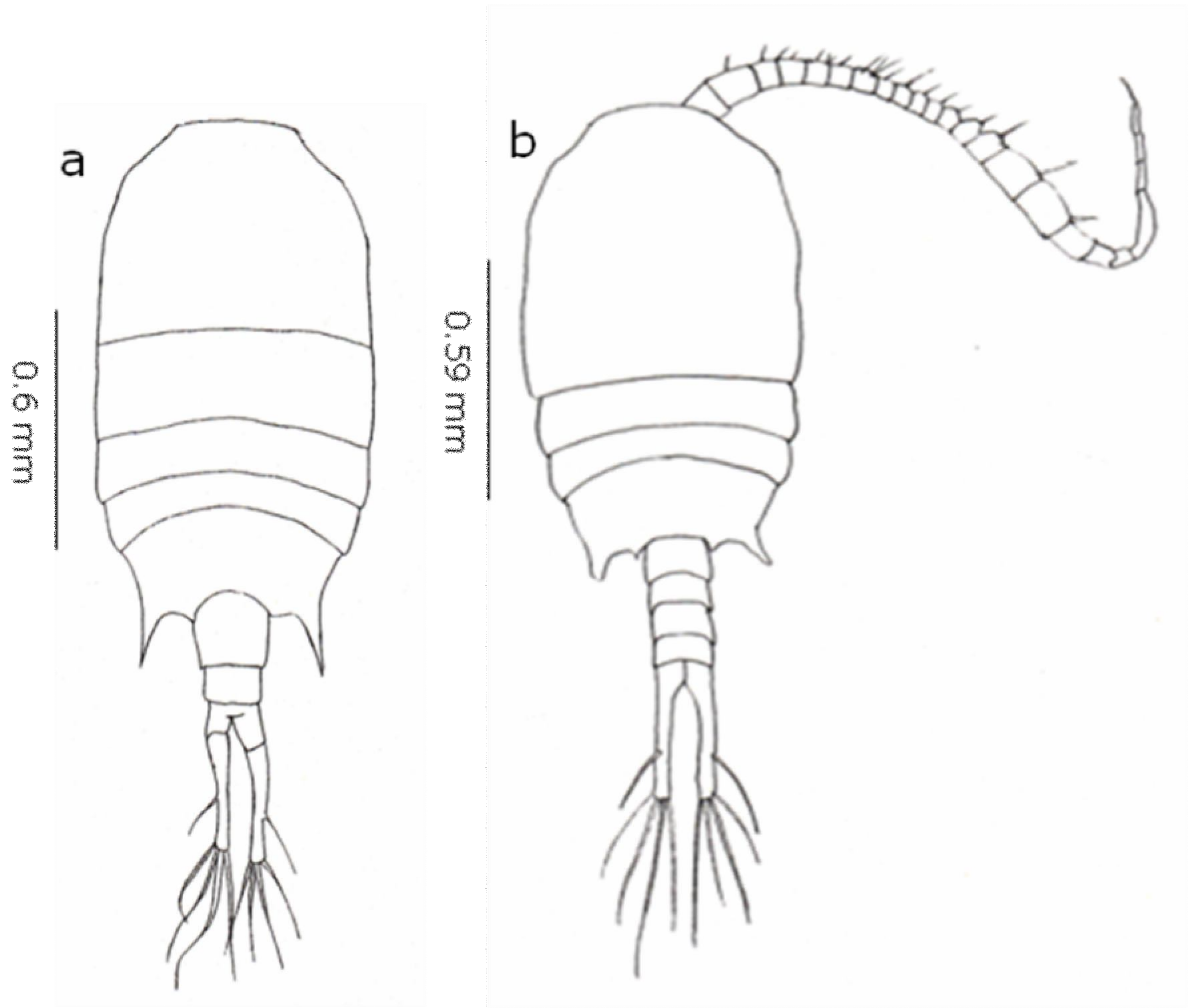

Figure 2. Dorsal view of (a) female and (b) male *Temora discaudata* Giesbrecht.

The urosome in female is 3-segmented (Figure 3a), comprising of the genital segment (which has 2 fused segments) and the two urosomal segments and measures 0.59 mm. The genital aperture is located ventrally in the middle of the genital double somite/segment. The urosome of the male is 5-segmented (Figure 3b) and measures 0.56 mm. The anal segment and caudal rami are strongly asymmetrical in the female but symmetrical in male (Bradford-Grieve 1999). These characteristics differentiate them with *T. stylifera*. Both contain 5 setae on its caudal ramus. The length of the urosome including the caudal ramus is 0.59 mm for female and 0.56 mm for the male.

Both the left (Figure 4a) and right antennules (Figure 4b) of female are symmetrical, 25-segmented and measures 1.53 mm and 1.50 mm, respectively. The male antennule is 23-segmented and asymmetrical. The left male antennule (Figure 5a) resembles that of the female, while the right (Figure 5b) geniculates at segments 15 and 16 and measures 1.65 mm and 1.68 mm, respectively. The appearance of much wider segments 15 and 16 of the geniculate antennule of *T. discaudata* differentiate it with those of *T. stylifera*. Specific curved of the right antennule at segments 19-23 are also quite pronounced.

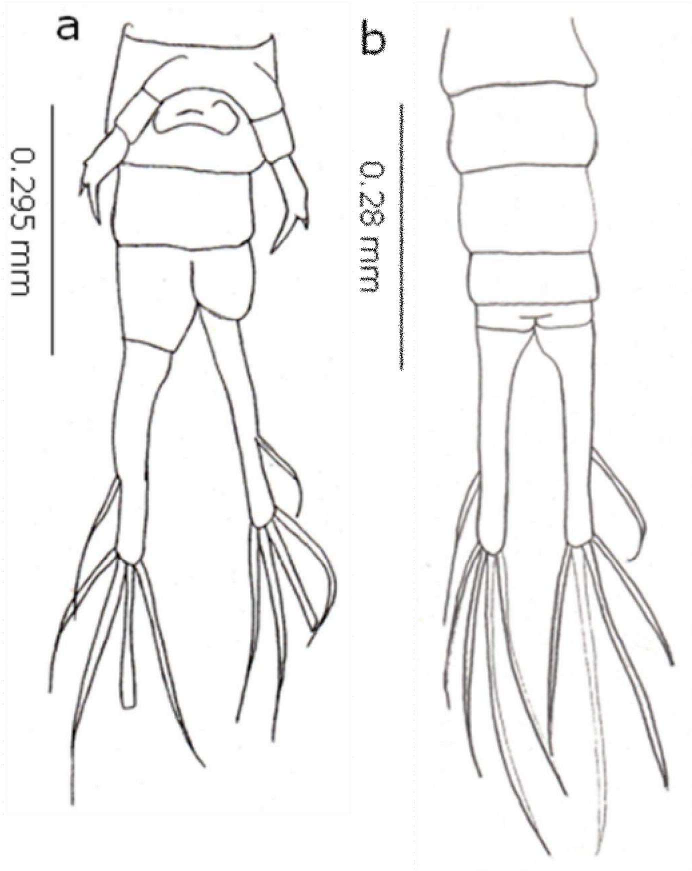

Figure 3. (a) Ventral view of female urosome and (b) dorsal view of male urosome of *Temora discaudata* Giesbrecht.

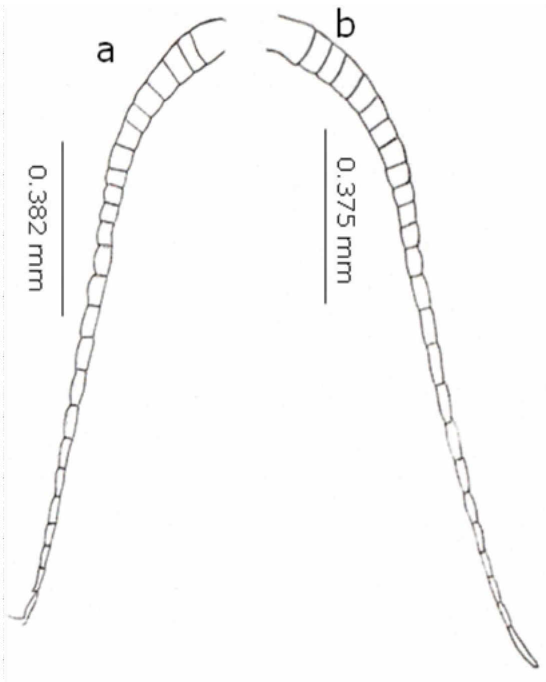

Figure 4. (a) Left and (b) right antennule of female *Temora discaudata* Giesbrecht.

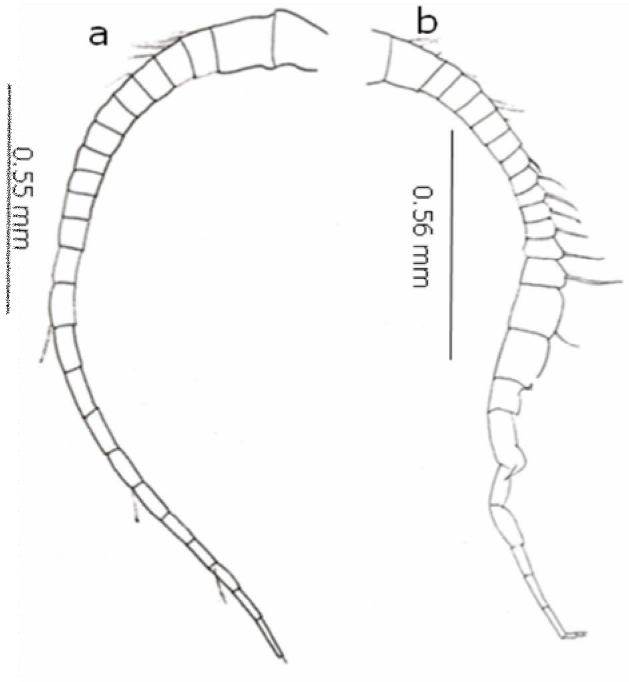

Figure 5. (a) Left and (b) right antennule of male *Temora discaudata* Giesbrecht.

Swimming legs 1 to 4 of both sexes (Figures 6 a-d and 7 a-d) are biramous. In female, legs 1 to 4 (Figures 6 a-d) have 2-segmented exopodites and 2-segmented endopodites, except for the exopodite of leg 1 (Figure 6a) which is 3-segmented (Kasturirangan 1963). In male, legs 1 to 4 (Figures 7 a-d) bears 3-segmented exopodites and 2-segmented endopodites. Giesbrecht (1892) and Bradford-Grieve (1999) observed the presence of row of spines on the outer margin of the terminal spine of the exopod segment 3 of leg 2, but were absent in our specimen. The swimming leg 5 is uniramous in both sexes and has 3-segmented exopod. The female measures 0.29 mm and male measures 0.29 mm. In female, both sides of the legs are symmetrical (Figure 6e). The first and the second exopodal segments are devoid of any spines and setae except for the third exopodal segment where the inner spine is longer than the 2 terminal spines, which are almost equal in length (Al-Yamani et al 2011). In male, both sides of the legs are asymmetrical (Figure 7e). The basis of the left of leg 5 has a wide thumb-like process with a flattened terminal segment bearing 4 marginal spines. On the right of leg 5, the terminal segment is hook-like and sharply bent backwards (Al-Yamani et al 2011).

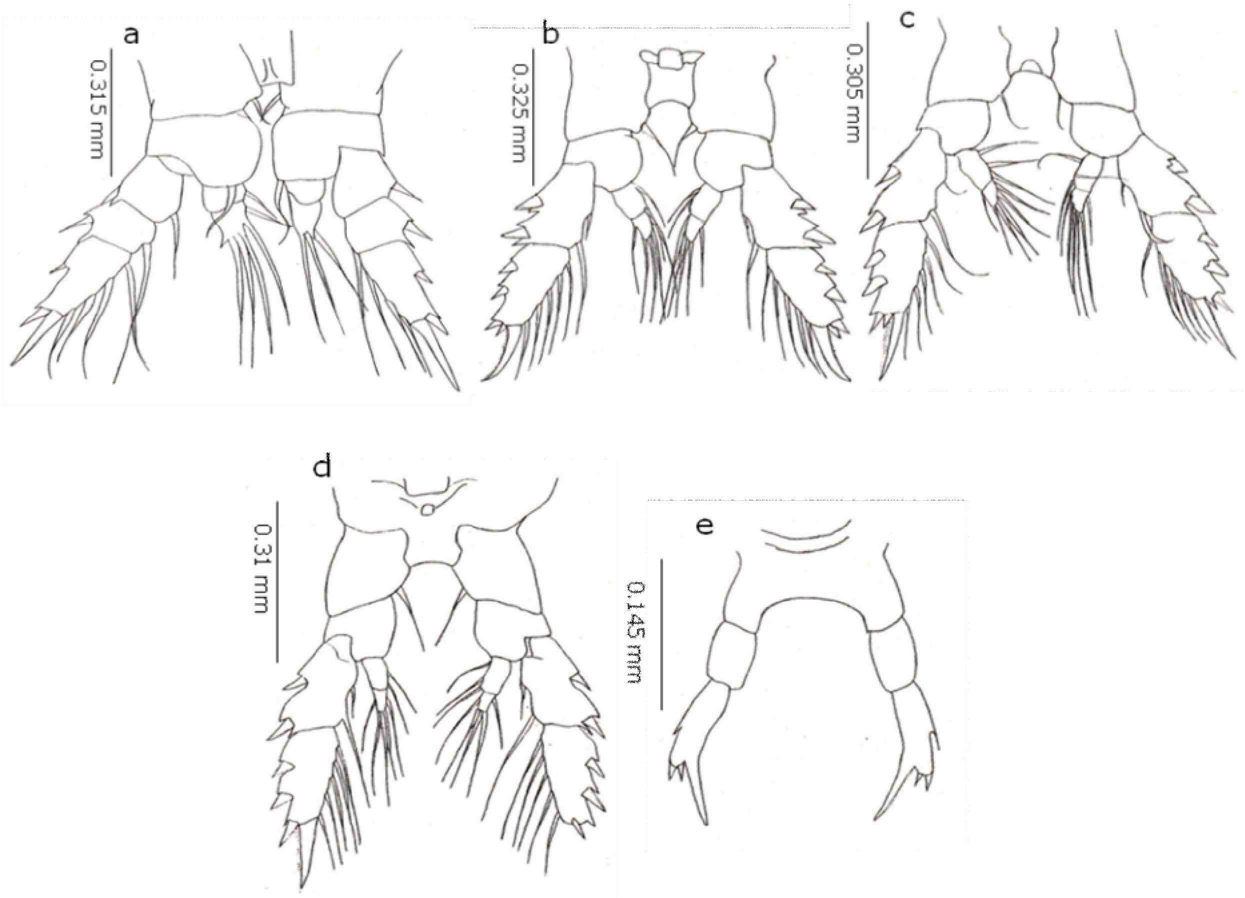

Figure 6. Female swimming (a) leg 1, (b) leg 2, (c) leg 3, (d) leg 4, and (e) leg 5 of *Temora discaudata* Giesbrecht.

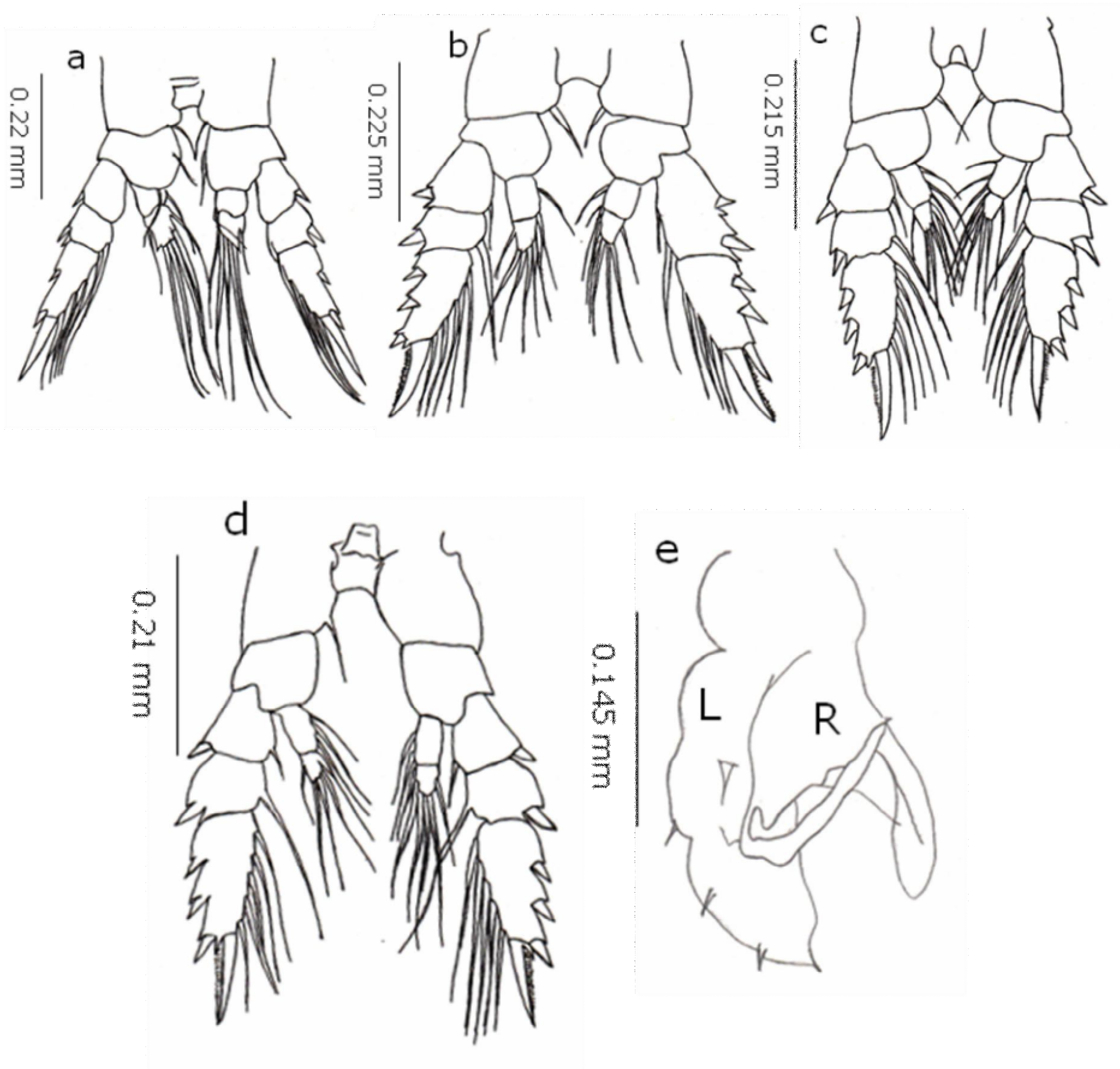

Figure 7. Male swimming (a) leg 1, (b) leg 2, (c) leg 3, (d) leg 4, and (e) leg 5 of *Temora discaudata* Giesbrecht. Legend: L – left, R - right.

Present descriptions are similar with those described and figured by Giesbrecht (1892), Mori (1937), Kasturirangan (1963), Chen & Zhang (1965), Greenwood (1978), Bradford-Grieve (1999), Phukham (2008), and Al-Yamani et al (2011).

Pacific Ocean Records: Farran (1936), Mori (1937), Dakin & Colefax (1933), Kasturirangan (1963), Chen & Zhang (1965), Greenwood (1978), Bradford-Grieve (1999), Mulyadi (2002), Othman & Toda (2006), and Phukham (2008).

Temora stylifera Dana, 1849
(Figures 8-13)

Synonym: *Calanus stylifer* Dana, 1849.

Occurrence. Both sexes were commonly encountered in the horizontal and vertical waters in all stations in Macajalar Bay only.

Description of adult female and male. Body length: females 2.70 mm, males 3.51 mm. Head end is massive for both sexes with compact and short body. When the specimen is alive, it is brown in coloration. The prosome comprises of a cephalosome and a 4 free pedigerous somites or metasomal segments for both female (Figure 8a) and male (Figure 8b). The posterior corners of the last metasomal segment for both sexes are drawn out into spines. These spines are symmetrical for female and slightly asymmetrical in male with the left spine slightly larger than the right.

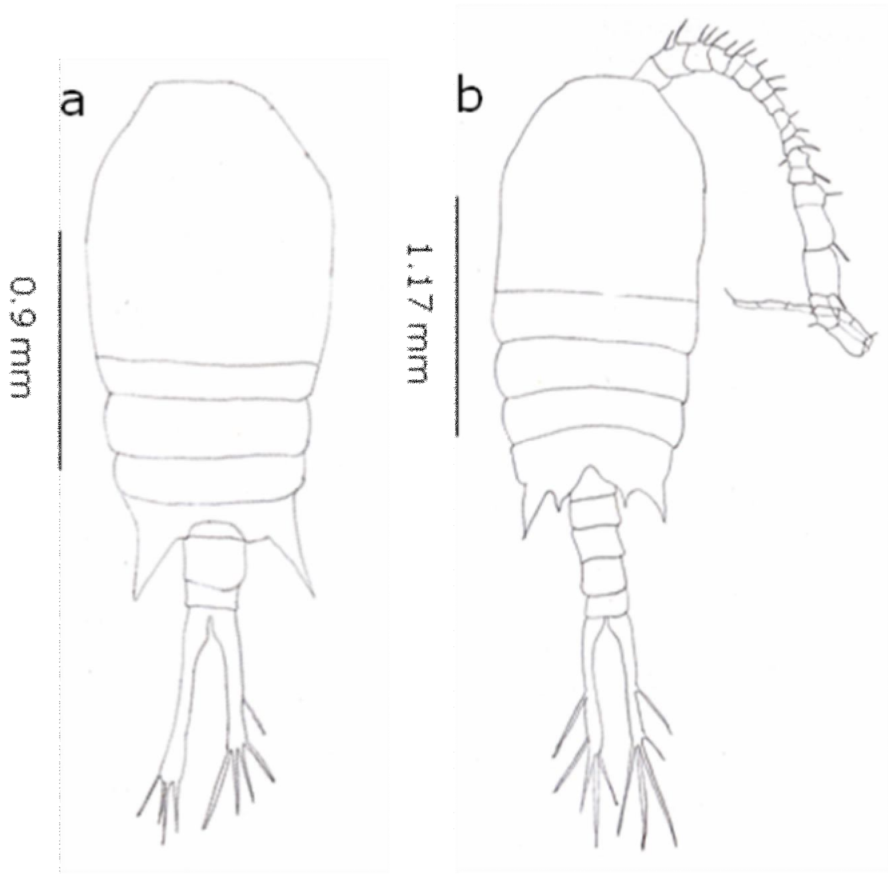

Figure 8. Dorsal view of (a) female and (b) male *Temora stylifera* Dana.

The female urosome is 3-segmented (Figure 9a), while that of the male is 5-segmented (Figure 9b). It measures of 0.51 mm and 0.78 mm for female and male, respectively. The caudal rami of both sexes are symmetrical unlike that in *T. discaudata* where it is asymmetrical. For both sexes, it bears 5 setae, 4 of which are located at the terminal end while the other one is positioned on the outer margin of the middle portion of the caudal ramus.

The left and right antennules of the female are 24-segmented and 25-segmented, respectively (Figures 10 a,b) and measures 2.25 mm for the left and 2.46 mm for the right antennule. In male, both antennules are 25-segmented (Figure 10 c,d). The left antennules (Figure 10c) measures 2.85 mm and resembles with the female, while the right (Figure 10d) which measures 2.91 mm geniculates at segments 16 and 17 and are slightly narrow in width when compared to those of *T. discaudata*. The right antennule strongly curved at segments 20-25.

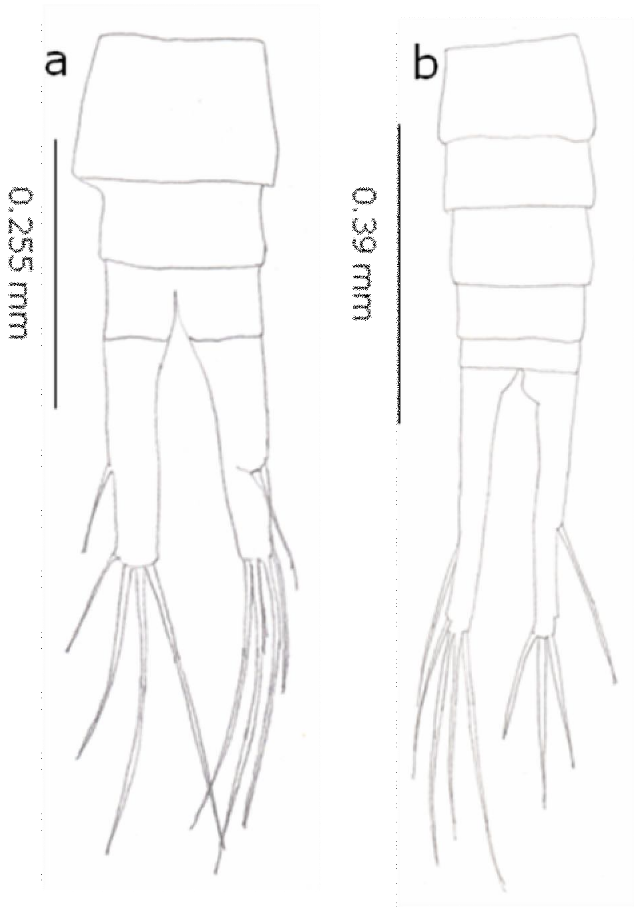

Figure 9. Ventral view of (a) female urosome and dorsal view of (b) male urosome.

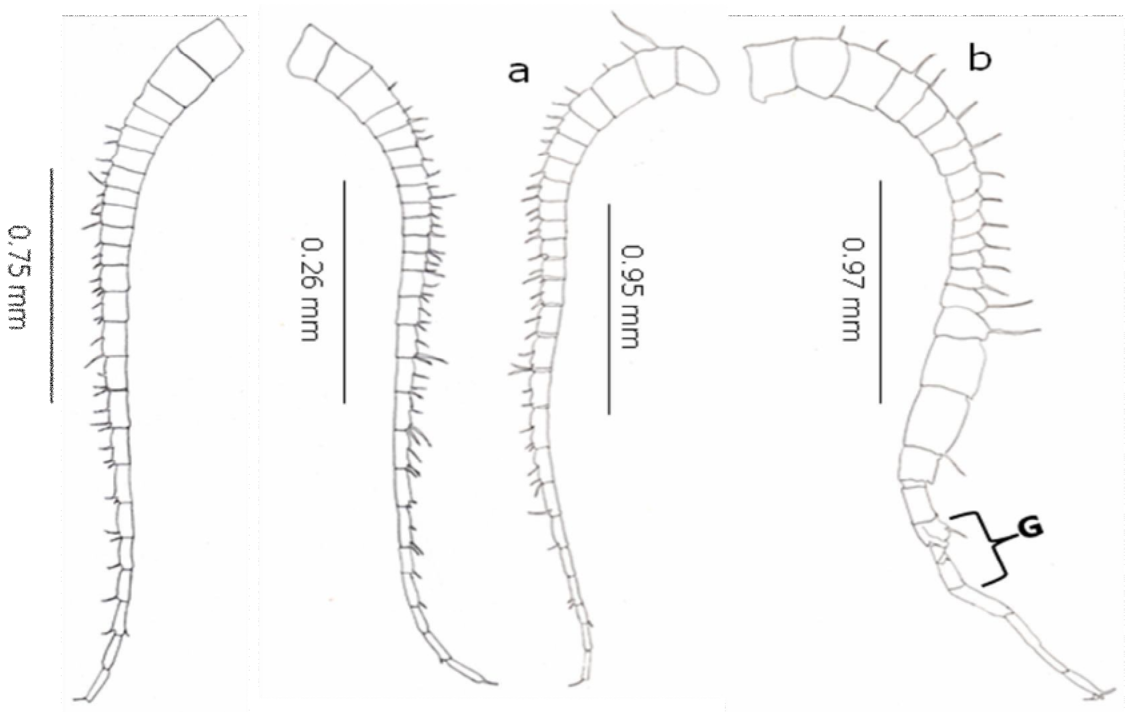

Figure 10. Female (a) right and (b) left antennules; male (c) left and (d) right antennules of *Temora stylifera* Dana. G: geniculation

Swimming legs 1 to 4 of both sexes (Figures 11 a-d and 12 a-d) are biramous. In female, legs 1 to 4 (Figures 11 a-d) have 2-segmented exopodites and 2-segmented endopodites, except for the exopodite of leg 1 (Figure 11a) which is 3-segmented (Kasturirangan 1963). In male, legs 1 to 4 (Figures 12 a-d) bears 3-segmented exopodites and 2-segmented endopodites. Giesbrecht (1892) and Bradford-Grieve (1999) observed the presence of row of spines on the outer margin of the terminal spine of the exopod segment 3 of leg 2, but were absent in our specimen. The swimming leg 5 is uniramous in both sexes and has 3-segmented exopod (Figure 11e and 12e). The female measures 0.36 mm, while the male measures 0.81 mm. In female, both sides of the legs are symmetrical (Figure 11e). The first and second exopodal segments do not contain any spines or setae but the third segment has 2 terminal spines of almost equal in length and a longer inner spine. In male, both sides of the legs are asymmetrical (Figure 7e), with the middle and last segments of the right leg very short that ends into a claw (Kasturirangan 1963). The basis of the left of leg 5 has a wide thumb-like process with a flattened terminal segment bearing 3 or 4 marginal spines. On the right of leg 5, the terminal segment is hook-like and sharply bent backwards.

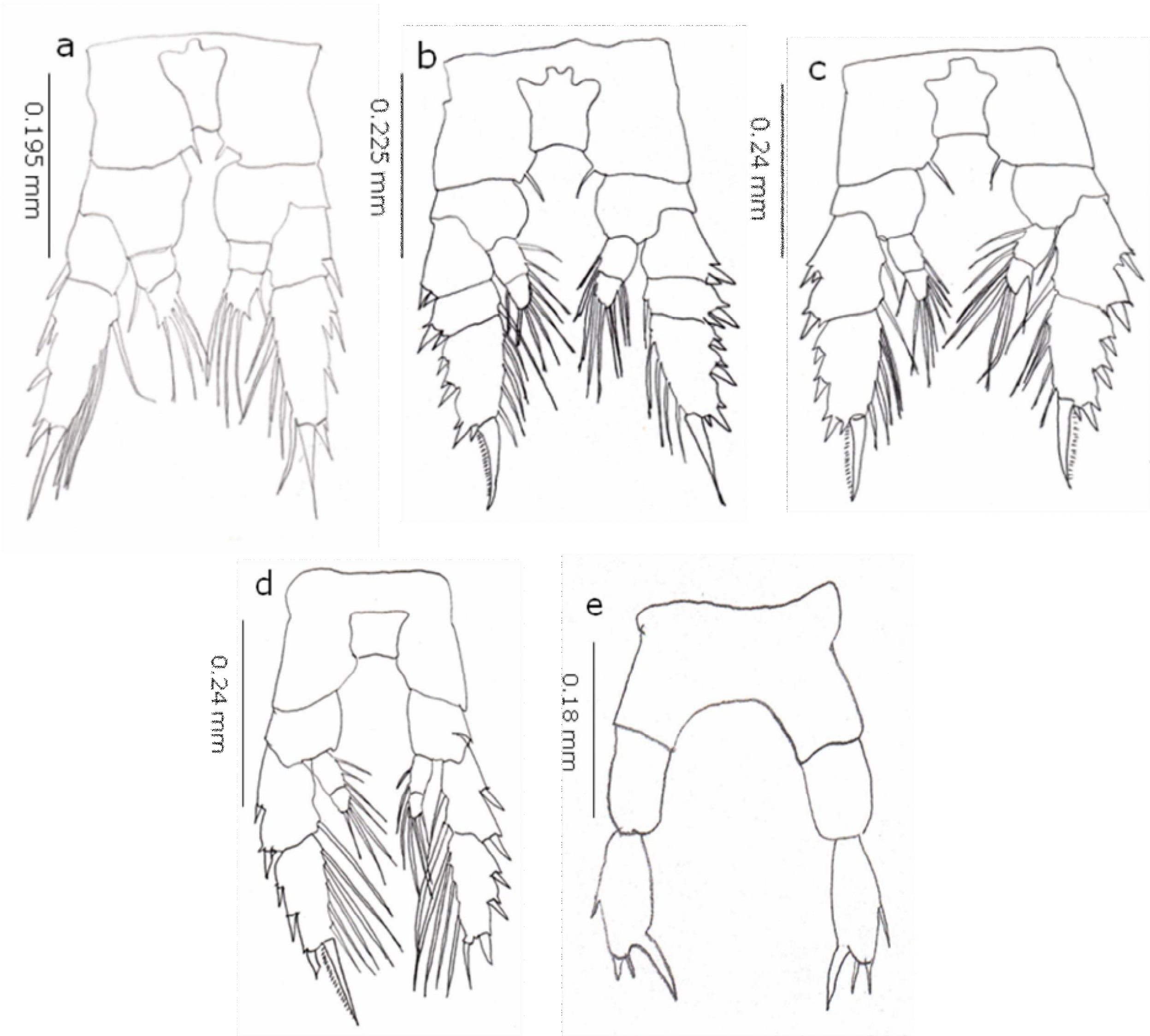

Figure 11. Female swimming (a) leg 1, (b) leg 2, (c) leg 3, (d) leg 4, and (e) leg 5 of *Temora stylifera* Dana.

The morphology of *T. stylifera* is similar with *T. discaudata* except in the anal segment and caudal rami where the former species exhibited symmetry in structures for both sexes but the latter species showed strong asymmetry in female only.

The present descritpions are similar with those described and figured by Giesbrecht (1892), Kasturirangan (1963), Ramirez (1966), and Owre & Foyo (1967).

Remarks. Wilson (1950) also reported this species in Iloilo Straits, Philippine Island.

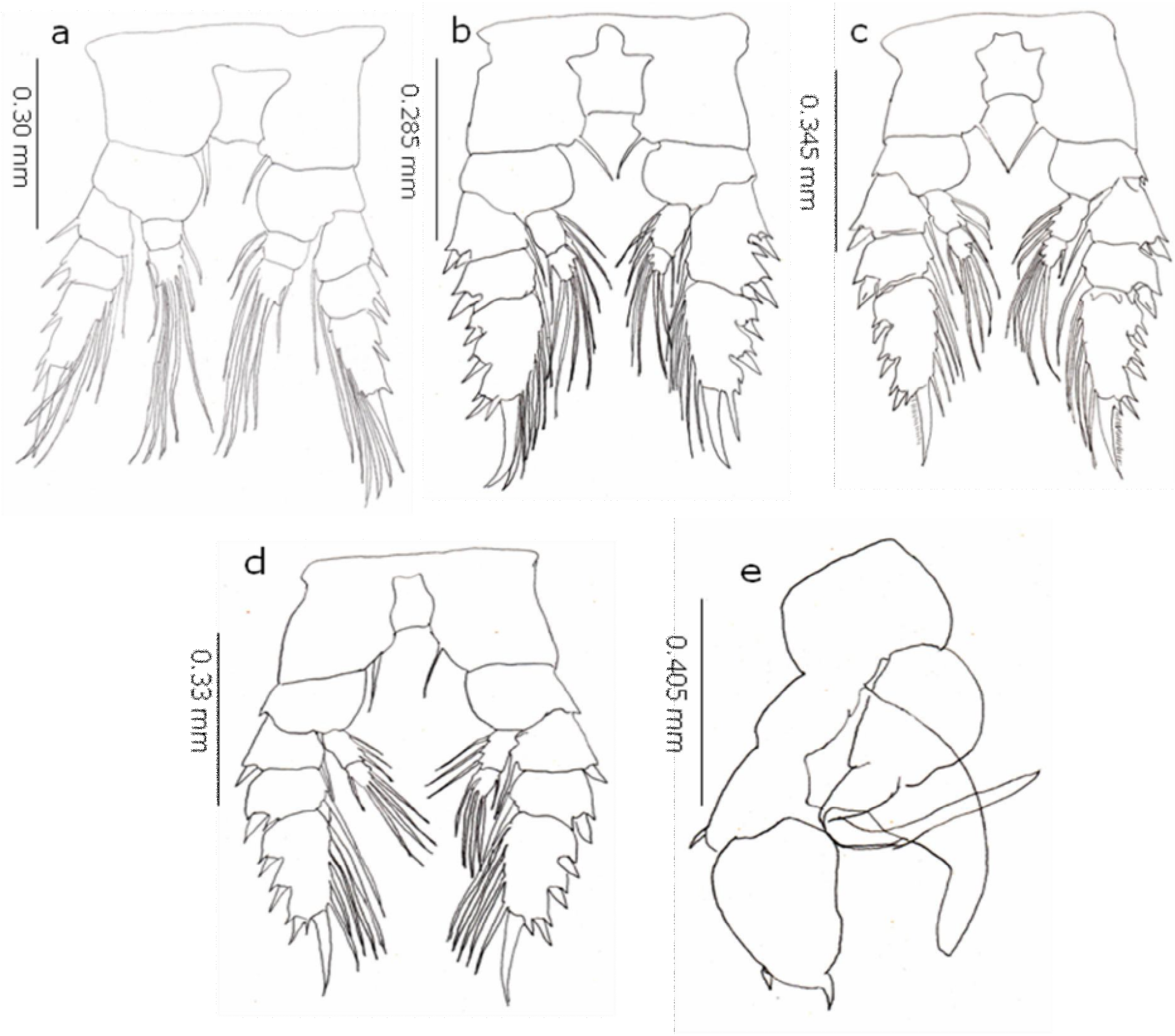

Figure 12. Male swimming (a) leg 1, (b) leg 2, (c) leg 3, (d) leg 4, and (e) leg 5 of *Temora stylifera* Dana.

***Temora turbinata* Dana, 1849**

(Figures 13-18)

Synonym: *Calanus turbinata* Dana, 1849.

Occurrence. This species was encountered in the horizontal and vertical waters of all the established sampling stations in Iligan and Macajalar Bays. However, male species was frequently collected in samples from Iligan Bay, while both sexes were common in Macajalar Bay.

Description of adult female and male. Body length: females 1.640 mm, males 1.710 mm. For both sexes (Figures 13 a,b), the body is short and compact and is comprised of the cephalosome, metasome and urosome. The cephalosome has a massive head end and devoid of dorsal eye lenses. The metasome is consists of 4 pedigerous somites or metasomal segments with a rounded posterior margin.

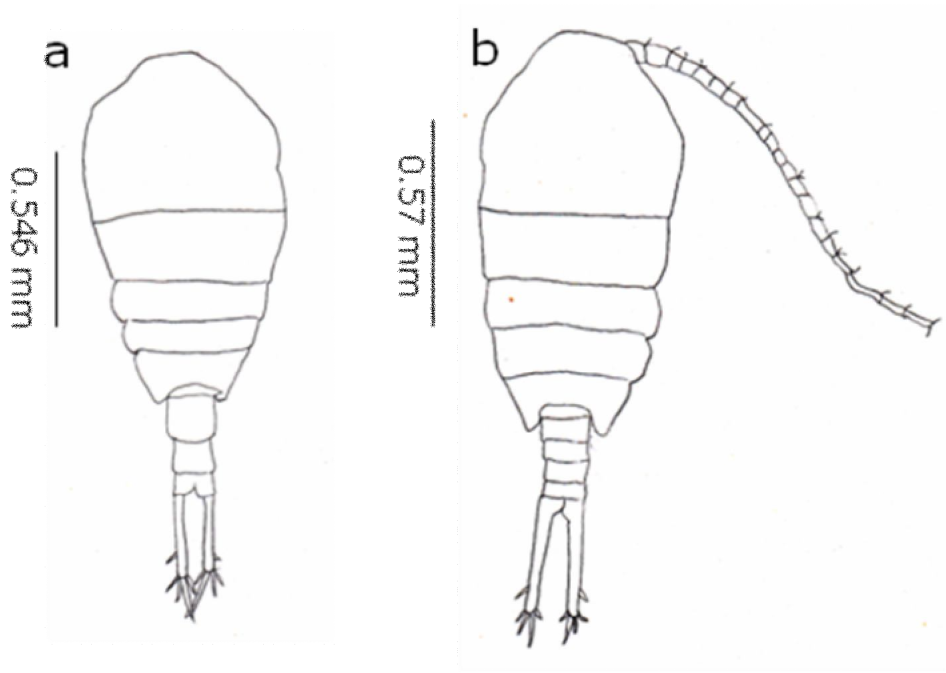

Figure 13. Dorsal view of (a) female and (b) male *Temora turbinata* Dana.

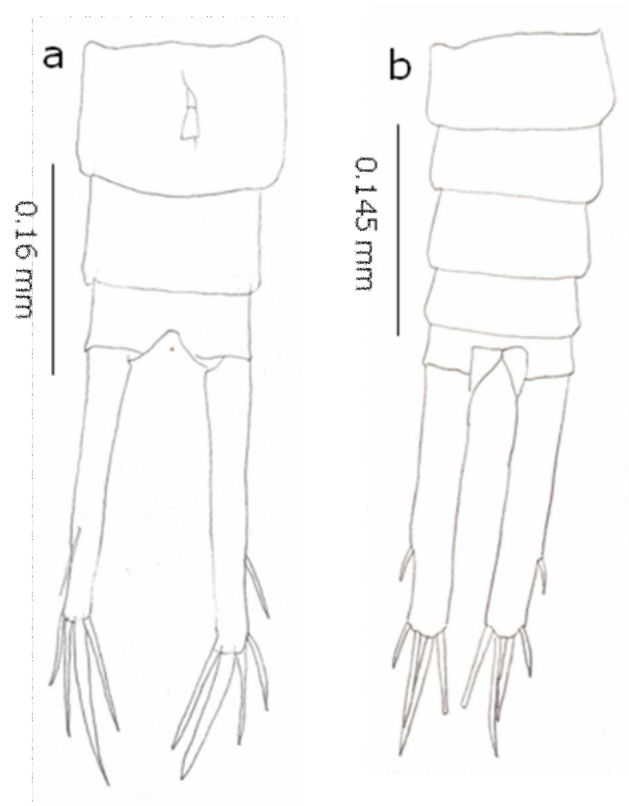

Figure 14. (a) Ventral view of female urosome and (b) dorsal view of male urosome of *Temora turbinata* Dana.

The female urosome is 3-segmented (Figure 14a), with the genital aperture located ventrally and is seen as a slit with two small circles. The urosome of the male is 5-segmented (Figure 14b) with urosomal segment 4 longer than anal segment (Bradford-Grieve 1999). The caudal rami of both sexes are symmetrical, long and slender, however in female, the second terminal seta is thicker and asymmetrical (Bradford-Grieve 1999). The length of the urosome including the caudal ramus is 0.480 mm for female and 0.435 mm for male.

Both antennules of the female are 24-segmented (Figures 15 a,b) and measures 1.035 mm for the left antennule and 0.990 mm for the right. For the male, the left antennule is 24-segmented (Figure 16a) and measures 0.915 mm, while the right side (Figure 16b) is 23-segmented, measuring 0.900 mm and geniculates at segment 20.

Swimming legs 1 to 4 of both sexes are biramous (Figures 17 a-d and 18 a-d). In male, swimming legs 1 to 4 consisted of 3-segmented exopodites and 2-segmented endopodites (Figures 17 a-d). In female, only swimming leg 1 (Figure 18 a) is similar with the male, while the rest of the legs had 2-segmented exopodites and endopodites (Figure 18 b-d). Further, legs 1 to 4 in female had shorter spine on the terminal exopod (Bradford-Grieve 1999). The swimming leg 5 for both sexes is uniramous. In female (Figure 18e), it is slightly asymmetrical and is 3-segmented with the terminal segment bearing a shorter and thinner inner spine when compared to the 2 terminal spines (Bradford-Grieve 1999). In male (Figure 17e), the left leg formed into a claw or chela with the thumb of the claw being slender and gradually curved (Al-Yamani et al 2011).

The above descriptions are similar with those described and figured by Giesbrecht (1892), Mori (1937), Kasturirangan (1963), Chen & Zhang (1965), Koga (1984), Bradford-Grieve (1999), Al-Yamani & Prusova (2003), Phukham (2008), and Al-Yamani et al (2011).

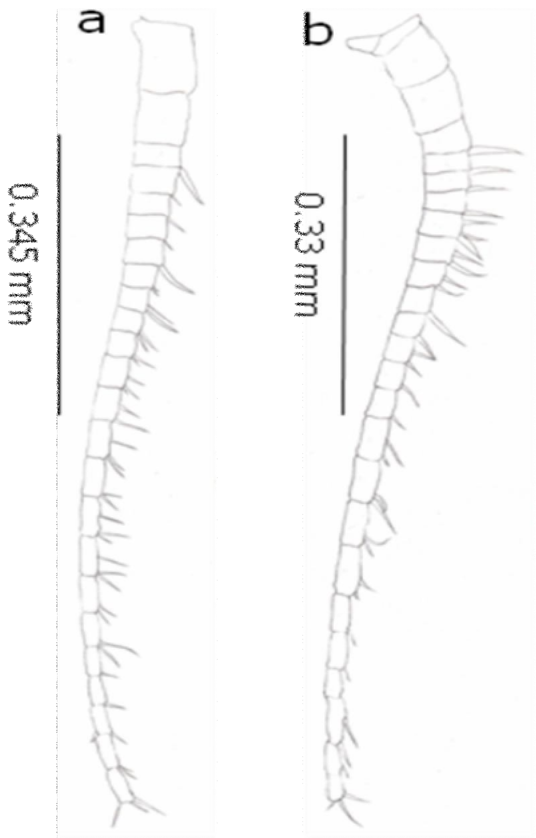

Figure 15. (a) Left and (b) right antennule of female *Temora turbinata* Dana.

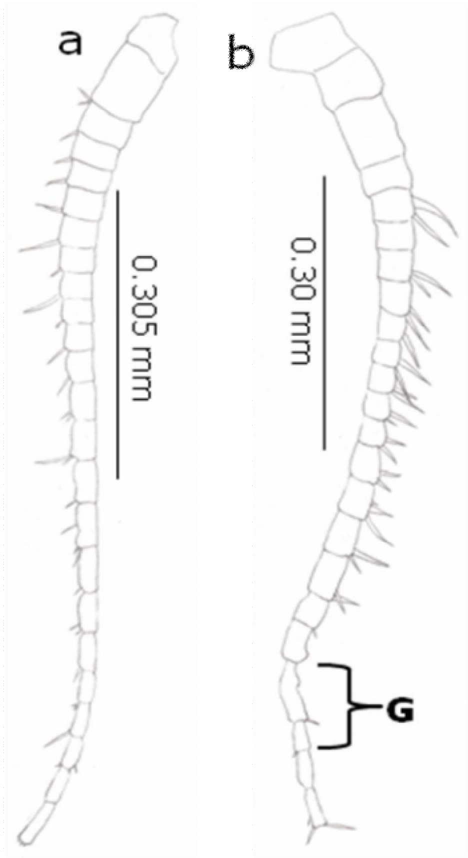

Figure 16. (a) Left and (b) right antennule of male *Temora turbinata* Dana.

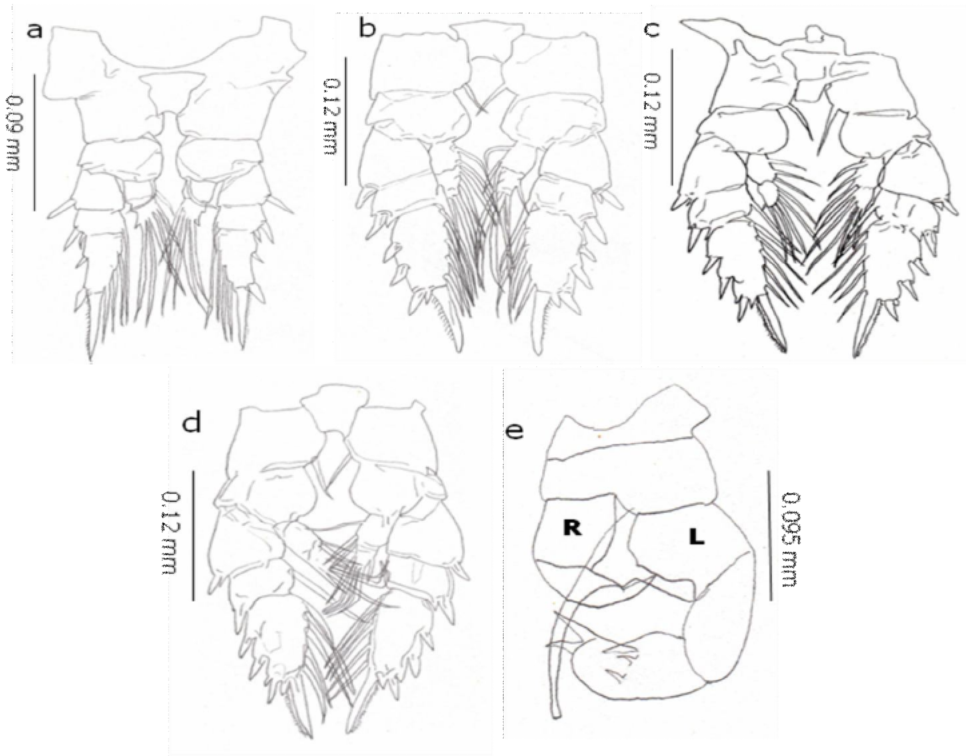

Figure 17. Male swimming (a) leg 1, (b) leg 2, (c) leg 3, (d) leg 4 and (e) leg 5 of *Temora turbinata* Dana. Legend: L – left, R - right.

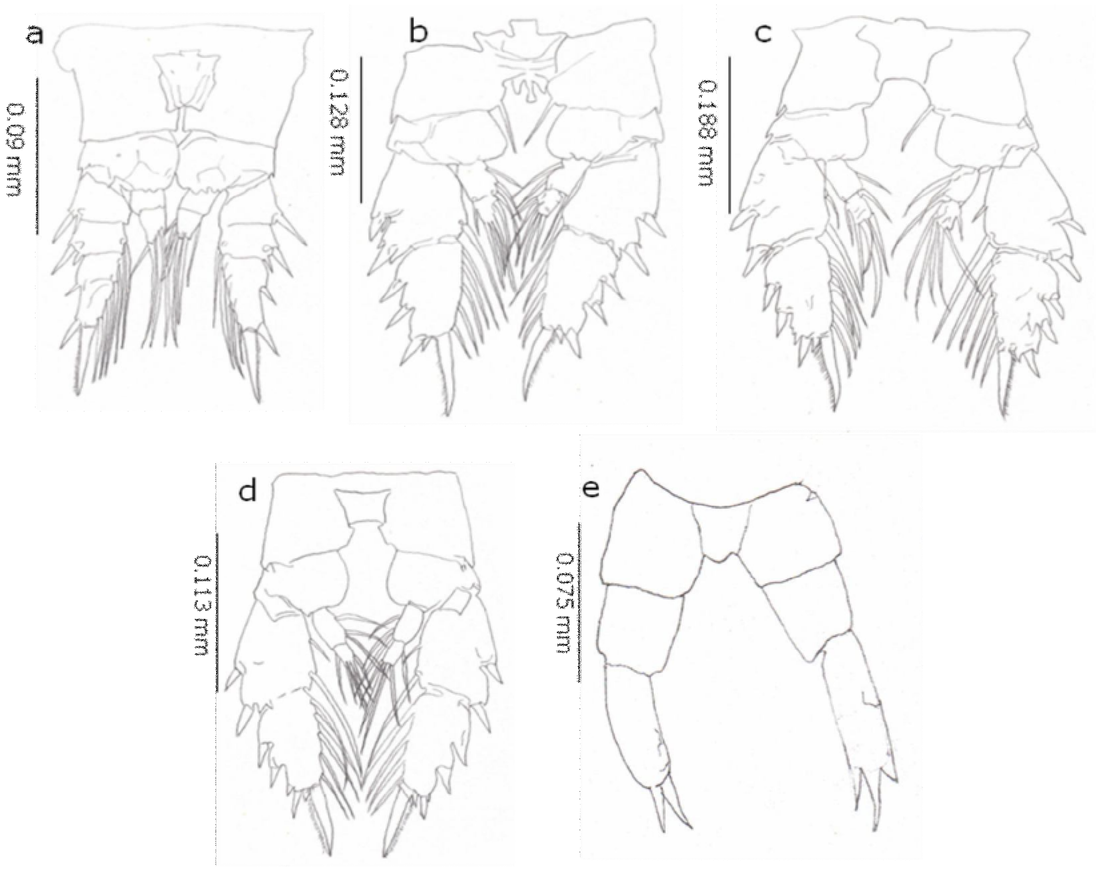

Figure 18. Female swimming (a) leg 1, (b) leg 2, (c) leg 3, (d) leg 4 and (e) leg 5 of *Temora turbinata* Dana.

Remarks. Wilson (1950) also reported this species in Iloilo Straits, Philippine Islands.

Pacific Ocean Records: Farran (1936), Dakin & Colefax (1933), Kasturirangan (1963), Chen & Zhang (1965), Jillett (1971), Bradford (1977), Greenwood (1978), Koga (1984), Bradford-Grieve (1999), and Phukham (2008).

Conclusions. Copepods of the same species may vary morphologically depending on the place or area. In the case of *T. turbinata*, our figures on leg 5 of the male is devoid of setules on the setae, however these were seen on the same organism from the Indian and Florida waters. Further, our figures revealed geniculation on the right antennule of the male species, whereas those same organisms found in the Florida waters showed geniculation on the left antennule. These variations exhibited between the same calanoid species from different places may be interpreted as an evidence of some kind of genetic switch mechanism (Huys & Boxshall 1991) which may allow control in the reversal of either asymmetric or symmertric structures that may result to their successful survival, reproduction and existence.

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