A NEW SPECIES OF *TORTANUS* (*ATORTUS*) (COPEPODA, CALANOIDA, TORTANIDAE) FROM THE COASTAL WATERS OF NHA TRANG, VIETNAM

BY

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ABSTRACT

A new species of the copepod genus *Tortanus*, subgenus *Atortus*, is described from the coastal waters of Nha Trang, Vietnam. The new species is assigned to the *tropicus* species group sensu Othman (1987) and distinguished from the other members of the group by the morphology of the processes on the fifth pedigerous somite and the genital somite in the female, and the antennule and leg 5 in the male. An analysis of previous records of *Atortus* indicates highly sporadic occurrence, but a large number of species to be distributed in Southeast Asia. This obviously suggests future discovery of even more species, and also the need for sampling with better geographic and ecological coverage in this particular region.

RÉSUMÉ

Une nouvelle espèce du genre de copépode *Tortanus*, du sous-genre *Atortus*, est décrite des eaux côtières de Nha Trang, Vietnam. La nouvelle espèce est attribuée au groupe d'espèces *tropicus* sensu Othman (1987) et se distingue des autres membres du groupe par la morphologie des processus situés sur le somite portant la cinquième patte et le somite génital chez la femelle, et par l'antennule et la cinquième patte chez le mâle. Une analyse des précédents signalements de *Atortus* indique une présence hautement sporadique, mais un grand nombre d'espèces réparties dans le sud-est asiatique. Ceci suggère clairement la découverte future de plus nombreuses espèces, et aussi la nécessité d'un échantillonnage réalisé avec une meilleure couverture géographique et écologique dans cette région particulière.

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INTRODUCTION

The genus *Tortanus* Giesbrecht, 1898 (Calanoida, Tortanidae) is a group of copepods mostly occurring in coastal waters of tropical to temperate regions in the Indo-Pacific and the northwestern Atlantic. It currently comprises 36 nominal species in 5 subgenera (Itoh et al., 2001; Ohtsuka & Conway, 2003; Chen et al., 2004). The subgenus *Atortus*, accommodating 22 nominal species, is regarded as one of the most advanced of the subgenera and is distributed exclusively in the Indo-West Pacific region (Ohtsuka & Reid, 1998). In the course of a study on the biodiversity of the zooplankton in the coastal waters of Southeast Asia, a so far unknown species of *Tortanus* (*Atortus*) was collected from the coastal waters of Vietnam. This species is described herein and the morphological and geographical relationships between this and other, allegedly related species are discussed.

MATERIALS AND METHODS

Zooplankton samples were collected at Nha Trang, southern coast of central Vietnam, by using a hand net (330 μm mesh). The net was towed obliquely from near the bottom to the surface (depth: ca. 2 m) in the nighttime (20:00-20:30 hr) from the pier of the Institute of Oceanography, without light. All samples were fixed and preserved in 2% formaldehyde/seawater. *Tortanus* specimens were sorted from the original sample, stained with methyl blue, dissected with needles in 10% glycerol/distilled water, and body and appendages were observed under a compound microscope and illustrated with the aid of a camera lucida. The morphological terminology follows Huys & Boxshall (1991) and, in particular, Ohtsuka & Reid (1998) for the segmental homology of the antennule in both sexes, and the male leg 5. Prosome length (distance between the anterior to mid-posterior margin) and width, urosome length (distance between the mid-posterior margin of prosome to posterior margin of caudal ramus excluding the distal setae), and width and length of the urosomites (including the telescoped portions) were measured with a calibrated ocular micrometer. Types are deposited in the National Science Museum, Tokyo (NSMT) and the Institute of Oceanography, Nha Trang (ION).

DESCRIPTION

Tortanus (Atortus) vietnamicus n. sp. (figs. 1-3)

Material studied. — Specimens were collected on 30 July 2004 at Nha Trang (12°12.21′N 109°13.26′E), Vietnam. Holotype: female (dissected: NSMT-Cr 16081). Paratypes: 1 dissected female, 2 dissected males, 3 intact females, and 2 intact males (NSMT-Cr 16082); 2 intact females and

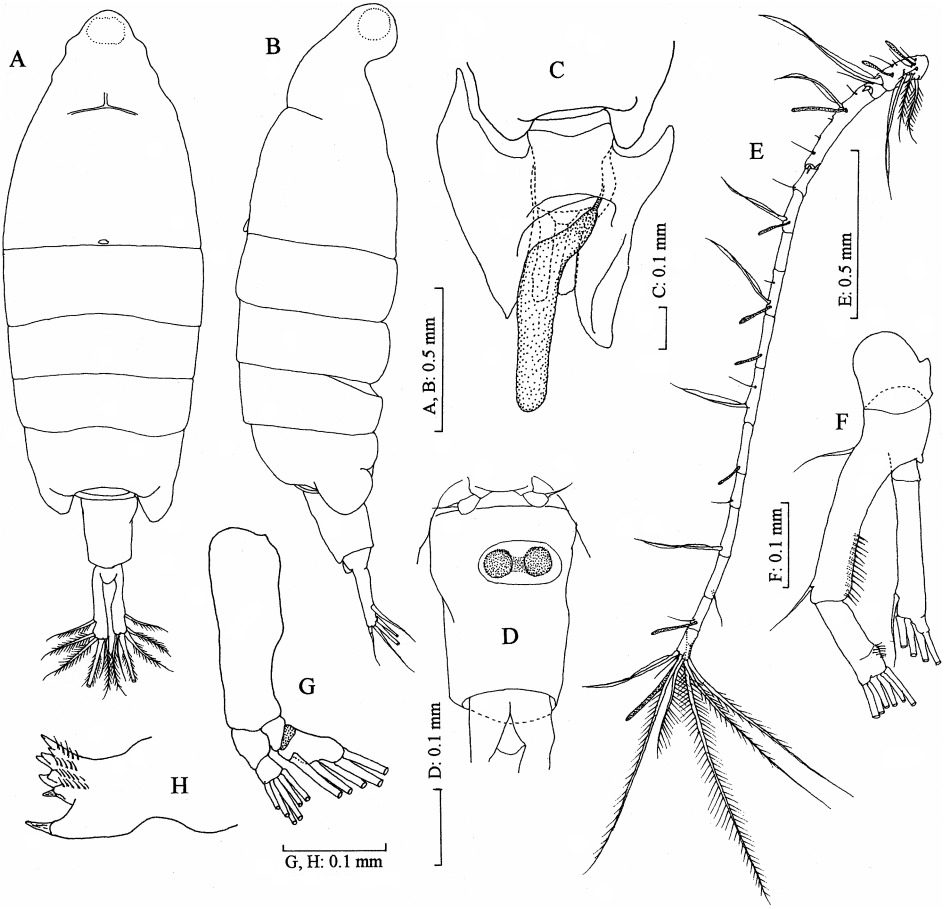

Fig. 1. *Tortanus* (*Atortus*) *vietnamicus*, n. sp., female (A, B, D-H, holotype; C, paratype). A, habitus, dorsal view; B, habitus, lateral view; C, genital complex with spermatophore and coupler, dorsal view; D, pediger 5 and genital complex, ventral view, showing leg 5 and genital operculum; E, antennule; F, antenna; G, mandibular palp; H, mandible, gnathobase.

2 intact males (ION-072004-01). All specimens are preserved in vials in 2% formaldehyde/seawater with a drop of glycerol added.

Female. — Total length 2.12-2.22 mm (mean ± SD = 2.16 ± 0.04, $N = 7$; holotype, 2.19 mm). Prosome length 1.61-1.68 mm (holotype, 1.68 mm), width 0.62-0.70 mm (holotype, 0.70 mm).

Habitus (fig. 1A, B). Prosome about 3.3 times as long as urosome. Cephalosome and first pediger separate; fourth and fifth pediger fused. Fifth pediger asymmetrical, with right posterior corner produced slightly more posteriorly than left, extending to mid-length of genital somite. Urosome 2-segmented, second urosomite completely coalesced with caudal rami. Genital compound somite about 1.5 times as long as wide with right anterolateral margin slightly swollen in dorsal view;

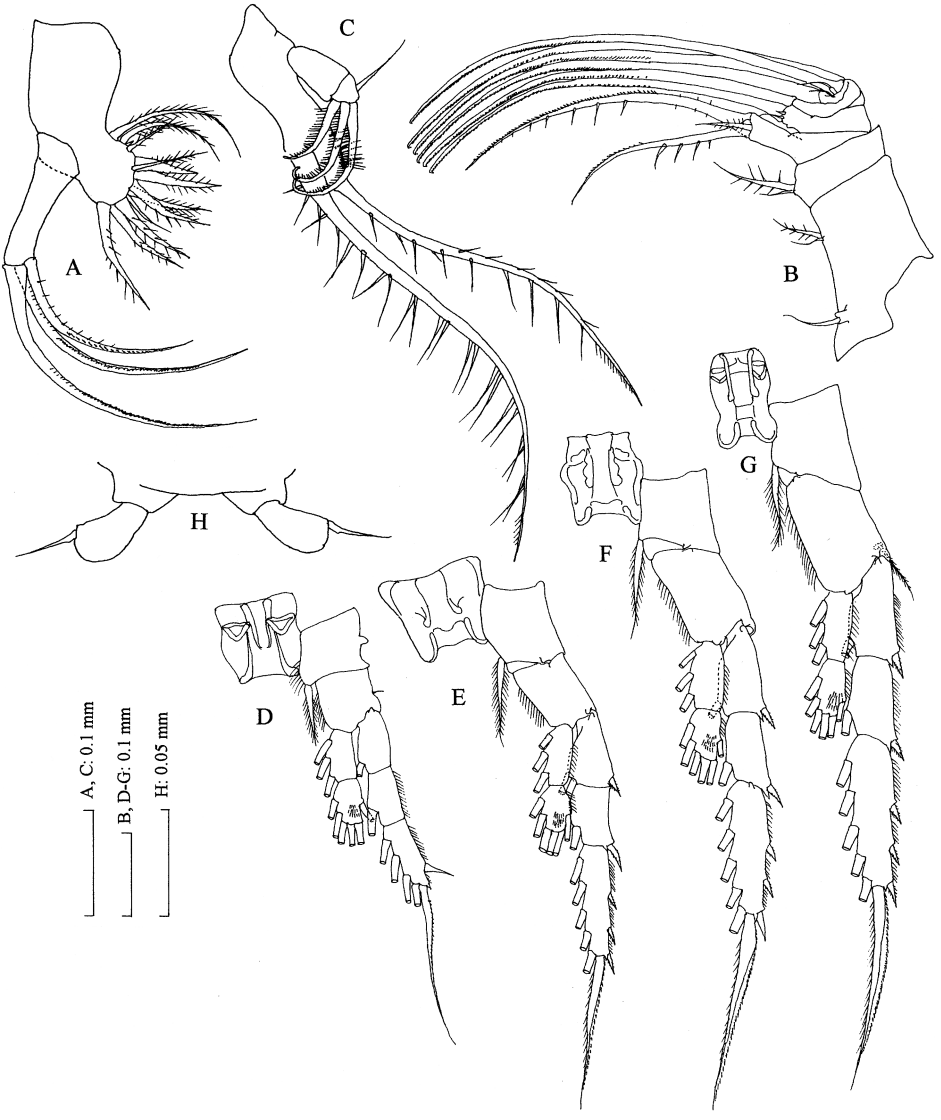

Fig. 2. *Tortanus* (*Atortus*) *vietnamicus*, n. sp., female (A, C-H, holotype; B, paratype). A, maxillule; B, maxilla; C, maxilliped; D, leg 1, anterior view; E, leg 2, anterior view; F, leg 3, anterior view; G, leg 4, anterior view; H, leg 5, anterior view.

genital operculum (fig. 1D) semicircular, located ventrally at anterior 1/3 of genital compound somite. Caudal rami asymmetrical with left ramus slightly longer than right; anteromedial margin of right ramus slightly concave. Three paratype specimens have transparent coupling device (see also Ohtsuka et al., 2000) with left vane larger than right; anterior margin of vanes fitting protuberances of fifth

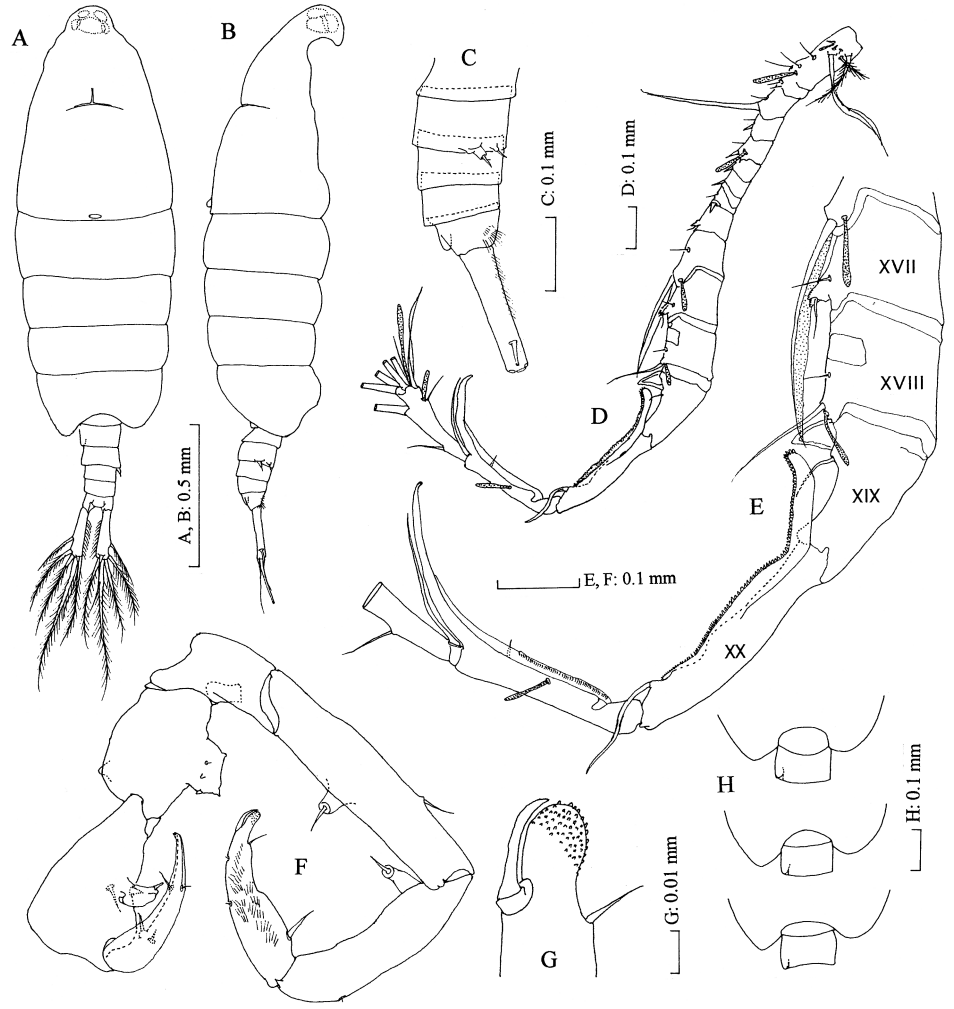

Fig. 3. *Tortanus* (*Atortus*) *vietnamicus*, n. sp., male (paratypes). A, habitus, dorsal view; B, habitus, lateral view; C, urosome, right lateral view; D, right antennule; E, right antennule, Roman numerals denote ancestral-segment numbers; F, leg 5, anterior view; G, left leg 5, tip of distal exopod; H, pediger 5 and urosomite1 from 3 specimens, dorsal view, showing asymmetry of pediger 5 with left side slightly more acute and posteriorly produced than right.

pediger, posterior margins extending beyond posterior end of caudal rami; two of these specimens also have a sausage-like spermatophore (fig. 1C).

Antennule (fig. 1E) symmetrical, reaching mid-length of caudal ramus; ancestral segments I-IX, XI-XIV, XXVI-XXVIII fused. Armature as follows: I, 1; II-IX, 8+2ae (aesthetascs); X, 2; XI, 2+ae; XII, 1; XIII, 1; XIV, 2; XV, 1; XVI, 1+ae; XVII, 0; XVIII, 2+ae; XIX, ae; XX, 2; XXI, ae; XXII, 1; XXIII, 1; XXIV, 1; XXV, 1+1+ae; XXVI-XXVIII, 6+ae. Antenna (fig. 1F) coxa without seta; basis with me-

dial seta; basis and endopod completely fused; endopod 3-segmented, proximal segment with distomedial seta and distolateral row of spinules, second and distal segments incompletely fused, distal segment with proximolateral tuft of setules and 6 terminal setae; exopod 3-segmented, proximal segment short and unarmed, middle and distal segment incompletely fused, with 3 and 2 setae, respectively. Mandible (fig. 1G, H) gnathobase with 5 cusped teeth, 2 ventralmost teeth with articulated tip, ventralmost tooth monocuspidate while remaining 4 teeth bicuspidate, 3 dorsalmost teeth with 4 longitudinal spinule rows proximally; basis elongate and unarmed; endopod 2-segmented, proximal segment unarmed, distal segment with 6 setae; exopod with 5 setae. Maxillule (fig. 2A) basis and rami completely absent; praecoxal arthrite with 12 spinulose setae and 1 minute seta; coxal endite with 3 stout, spinulose terminal setae. Maxilla (fig. 2B) syncoxal endites with 1, 2, 2, and 3 setae from proximal to distal; basal endite with 1 developed and 2 rudimentary setae; endopod with 5 stout setae with claw-like tip and 2 rudimentary setae. Maxilliped (fig. 2C) syncoxa with two endites, each with spinulose seta; basis unarmed; endopod with 3 medial spinulose setae and lateral seta.

Legs 1-4 (fig. 2D-G) biramous with 3-segmented exopod and 2-segmented endopod; distal endopod segment of legs 1-4 with hair tuft on subdistal, anterior surface. Seta and spine formula as follows:

	Coxa	Basis	Exopod segment 1; 2; 3	Endopod segment 1; 2
Leg 1	0-1	1-0	0-1; 0-1; I, I, 4	0-3; 1, 2, 3
Leg 2	0-1	0-0	I-1; I-1; III, I, 5	0-3; 1, 2, 3
Leg 3	0-1	0-0	I-1; I-1; III, I, 5	0-3; 1, 2, 3
Leg 4	0-1	1-0	I-1; I-1; III, I, 5	0-3; 1, 2, 3

Outer seta on leg 1 basis minute.

Leg 5 (figs. 1D, 2H) uniramous, 2-segmented, and symmetrical with basis of right and left legs fused; ramus long trapezoid, with distal margin broader, with distolateral seta.

Male. — Total length 1.82-1.95 mm (mean $\pm$ SD $= 1.90 \pm 0.05$, $N = 6$). Prosome length 1.32-1.44 mm, width 0.46-0.57 mm.

Habitus (fig. 3A, B). Prosome about 2.8 times as long as urosome. Posterior corners of fifth pediger rounded and asymmetrical, with left posterior margin slightly more acute and produced more posteriorly than right (fig. 3A, H). Urosome 5-segmented. Proportional lengths of urosomites and caudal ramus 18: 16: 15: 14: 13: 24 (= 100); width to length ratios 1.8, 1.4, 1.4, 1.6, 1.4 and 3.8. Genital somite with genital aperture on left posterolateral margin. Second urosomite with posterolateral and posteroventral processes on right side (fig. 3C), of which the latter smaller, each with minute seta on tip. Caudal rami symmetrical.

Appendages similar to those of female except right antennule and leg 5.

Right antennule (fig. 3D, E) geniculate; ancestral segments I-VIII, XXI-XXIII, XXIV-XXVIII completely or incompletely fused; segments XV-XIX expanded. Armature as follows: I, 1; II-V, 5+ae; VI, 1; VII, 2+ae; VIII, 2; IX, 2; X, 2; XI, 2+ae; XII, 1; XIII, 1; XIV, 2; XV, 1; XVI, 2+ae; XVII, 2; XVIII, 2+ae; XIX, 1+p (process); XX, 1+p; XXI-XXIII, 2+ae+2p; XXIV-XXVIII, 9+2ae. Segments XV and XVII with anterodistal, bicuspidate process with serrate margin bearing minute seta. Anteroproximal process on segment XIX large, triangular; process on segment XX serrate anteriorly, retroflexed near base of segment XX, and extending to triangular process of segment XIX. Distal processes on segments XXI-XXIII about as long as the combined segments, curved anteriorly, and bordered by proximal process and distal seta.

Right leg 5 (fig. 3F) coxa semi-trapezoid with small distolateral process and rectangular medial process bearing 4 minute processes each on medial corners, distal margin, and anterior surface, and minute seta on anterior surface; basis triangular and expanded laterally, with rectangular process bearing minute distomedial spine and blunt proximolateral tooth, 2 setae each on posterior surface and at midlength of medial margin; exopod 1-segmented, slightly curved inwards, tapering distally into acute tip, and with 4 setae. Left leg 5 (fig. 3F) coxa unarmed; basis elongate and straight, with lateral seta and cylindrical process bearing seta at midlength of inner margin; exopod 2-segmented, proximal segment with distolateral minute seta and proximomedial, cylindrical process bearing seta, distal segment with patches of setules on anterior surface, 2 medial setae, 2 lateral minute setae, and blunt subdistal seta curved along hemispherical tip of the segment bearing granular processes (fig. 3G).

Taxonomic remarks. — The new species belongs to the *tropicus* species complex within the subgenus *Atortus* Ohtsuka, 1992 (cf. Bowman, 1971; Othman,1987; Ohtsuka & Kimoto, 1989). This species complex is defined by the combination of the following characters: (1) the second urosomite of the male with a process on the right side, (2) the anterior end of the serrate margin of the ancestral segment XX of right antennule of the male produced proximally over segment XIX, and (3) the distal segment of leg 5 of the female either slender and asymmetrical or subquadrate. The following 10 species are the current members of this species complex: *Tortanus brevipes* A. Scott, 1909, *T. tropicus* Sewell, 1932, *T. longipes* Brodsky, 1950, *T. rubidus* Tanaka, 1965, *T. giesbrechti* Jones & Park, 1968, *T. bowmani* Othman, 1987, *T. ryukyuensis* Ohtsuka & Kimoto, 1989, *T. digitalis* Ohtsuka & Kimoto, 1989, *T. taiwanicus* Chen & Hwang, 1999, and *T. vietnamicus* as described above, of which *T. brevipes* is known only from the female. While Ohtsuka & Kimoto (1989) proposed the name "*brevipes* species complex"

for this assemblage of species, the name "*tropicus*" proposed by Othman (1987) is followed here, since the male of *T. brevipes* has not yet been described.

The female of *T. vietnamicus* is distinguished from the other members of the *tropicus* species complex, except *T. brevipes* and *T. tropicus*, by the asymmetrical fifth pediger with the right posterior corner produced more posteriorly than the left; the fifth pediger in the other 7 species is either symmetrical, asymmetrical with the left corner more produced than the right, or of specific shape. The female *T. brevipes* is distinguished from *T. vietnamicus* by the highly asymmetrical fifth pediger in which the left side is much shorter than the right and directed almost at a right angle to the body (Scott, 1909), and the female *T. tropicus* differs from *T. vietnamicus* in the genital compound somite with a process on the left side and the elongated, asymmetrical leg 5. The male *T. vietnamicus* is distinguished from *T. giesbrechti*, *T. longipes*, *T. ryukyuensis*, and *T. tropicus* by the presence of a prominent process on the basis of the right leg 5, which is lacking in the latter four species. The males of the other four species of the complex all have a long, sharply pointed process on the base of the ancestral segment XIX of the right antennule, whereas the process is blunt and triangular in *T. vietnamicus*. The following characters may also be useful in identifying *T. vietnamicus*: the shape of the coupling device associated with the spermatophore in the female (fig. 1C); the well-developed cylindrical processes on the basis and the proximal exopod segment and the semispherical tip of the distal exopod segment with granular processes in the right leg 5 of the male.

Ecological remarks. — The temperature and salinity in Nha Trang Bay observed slightly offshore of the sampling site fluctuated between 24.1 and 29.4°C and 32.3-34.0 (water-column average), respectively, during the year (Department of Marine Plankton, ION, unpubl. monthly obs. for 2003). The present samples were collected in late July in the dry season with the prevailing South-West Monsoon, and the temperature (27.4°C) and salinity (33.9) were relatively higher than in the rainy season (September-December). The bottom substrate of the sampling site is sand and rock, scattered with massive corals (*Porites*) and patches of seagrasses [*Halophia ovalis* (R. Brown) Hooker f., *Enhalus acoroides* (L. f) Royle, *Thalassia hemprichii* (Ehrenb.) Aschers.] and seaweeds (*Sargassum, Padina, Turbinaria, Halymenia*). These environmental conditions are consistent with the previous observation that *Atortus* tends to occur in more or less oligotrophic high-salinity waters, sometimes strongly influenced by warm currents or in coral reefs (Ohtsuka & Reid, 1998).

DISCUSSION

Ohtsuka & Kimoto (1989) distinguished two species groups within the *tropicus* species complex: the *longipes* group (*T. giesbrechti* and *T. longipes*) and the

rubidus group (*T. bowmani*, *T. digitalis*, and *T. rubidus*), of which the *longipes* group has the following characters (characters for the *rubidus* group in parentheses): (1) the posterior corner of the fifth pediger produced more posteriorly on the left side in both sexes (asymmetrical in female, left side bearing irregularly pointed ventro-lateral processes and right side with rounded or pointed lobe; symmetrical in male); (2) the anterior process of ancestral segment XX of male right antennule strongly retroflexed and extending over distal half of segment XIX, and the proximal process of segment XIX not reaching the distal end of the segment (the latter process slender and extending over half of the segment); in male leg 5, (3) the right coxa without processes (with inner subterminal process), basis massive and bearing bulbous medial protuberance with 2 setules (with broad inner medial projection with 2 short setae along posterior half), small exopod segment claw-like and tapering distally (exopod about as long as basis); (4) the left basis with sinuate inner margin bearing large acute proximal process and 3 or 4 small blunt or pointed processes (without such processes); (5) left exopod segment 1 without large cylindrical processes proximally (with such a process). In addition, (6) the female leg 5 of the *rubidus* group is reduced and 2-segmented with lamellate terminal segment bearing outer plumose seta, but *T. longipes* also has this character. The more recently described species *Tortanus taiwanicus* may be assigned to the *rubidus* group in these respects (Ohtsuka et al., 2000). *Tortanus vietnamicus*, however, cannot be assigned to either group, since it is referable to the *longipes* group in character no. 2, to the *rubidus* group in characters nos. 4-6, but to neither in character no. 1, and character no. 3 in *T. vietnamicus* is more or less a mixture of those of the two groups. Hence, the relationship of *T. vietnamicus* to the two groups is not clear at present, solely on the basis of morphological information, as well as for the other three species of the complex, *T. brevipes, T. ryukyuensis*, and *T. tropicus* (cf. Ohtsuka & Kimoto, 1989).

The previous, reliable records of the *brevipes* species complex [fig. 4: modified from Ohtsuka & Kimoto (1989) with addition of *T. taiwanicus* and *T. vietnamicus*] clearly show the highly sporadic occurrence of species, in which only *T. longipes* and *T. rubidus* have been recorded from multiple localities. This may reflect the potentially high endemism in this group, but is also attributable to the sampling methods applied in many previous studies, coupled with the ecological characteristics of *Atortus*, as suggested by Ohtsuka & Kimoto (1989) for the absence of recent records of *Atortus* from the northern Indian Ocean. As summarized by Ohtsuka & Reid (1998) and Ohtsuka et al. (2000), the species of *Atortus* inhabit shallow (often less than 10 m), clear waters of relatively high salinity, such as coral reefs, inlets with sandy or rocky bottoms, and their vicinities. They form swarms often close to the substrate, suggesting an effective antipredation/foraging strategy (Ohtsuka

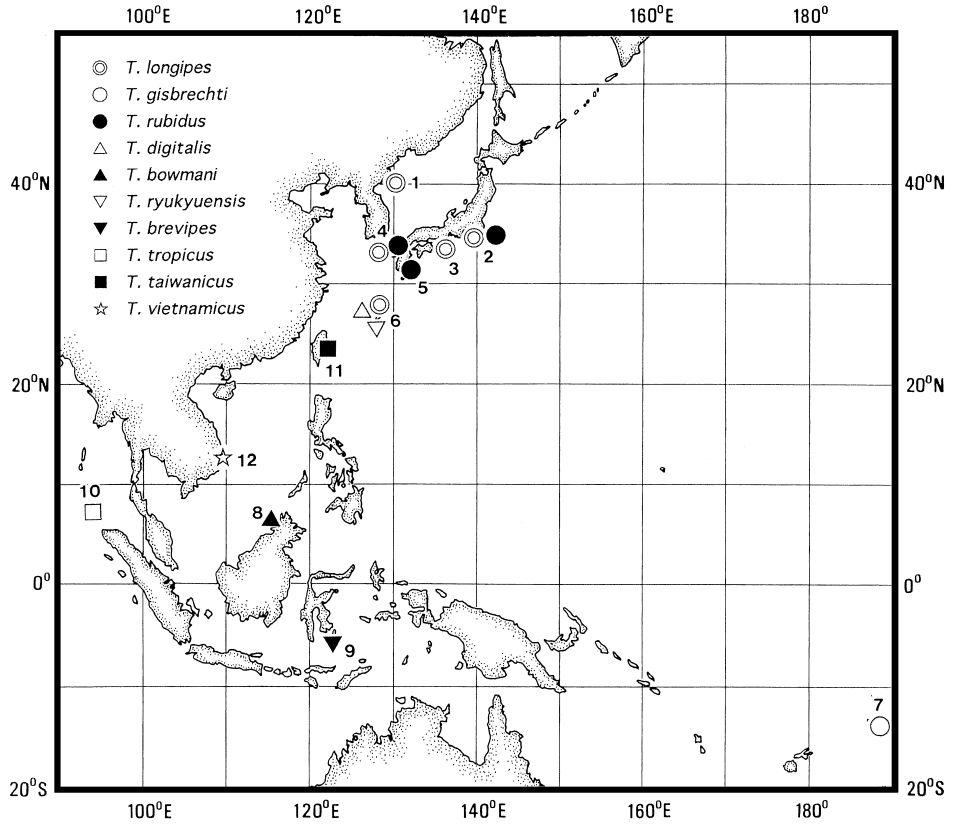

Fig. 4. Occurrence records of the *tropicus* species complex (Othman, 1987) of the subgenus *Atortus* (modified from Ohtsuka & Kimoto, 1989). Localities and references: 1, Poseta Bay (Brodsky, 1950); 2, Sagami Bay (Tanaka, 1965); 3, Tanabe Bay (Ohtsuka et al., 1987); 4, Shijiki Bay (Ohtsuka & Kimoto, 1989); 5, Shibushi Bay (Ohtsuka & Kimoto, 1989); 6, Ryukyu Islands (Ohtsuka & Kimoto, 1989); 7, Pago Pago Harbor, American Samoa (Jones & Park, 1968); 8, Pulau Tiga, Sabah (Othman, 1987); 9, Saleyer Anchorage (Scott, 1909); 10, Nankauri Harbor, Nicobar Islands (Sewell, 1932); 11, Hualien, Taiwan (Chen & Hwang, 1999); 12, Nha Trang, Vietnam (present study).

et al., 2000). While accidental collection may be possible through extensive sampling by conventional methods, such as surface- or vertical tows of nets, the use of more specific methods such as SCUBA diving (Ohtsuka & Kimoto, 1989) and night-time collection, with or without light (Jones & Park, 1968; Bowman, 1971; this study), would be recommended for more effective sampling of this group of copepods. These difficulties are shared by some other groups of copepods, such as the pseudodiaptomids and pontellids, in which still many new species have been discovered in recent years (see, e.g., Walter et al., 2002; Mulyadi, 1997).

Despite the above limitation in sample collection, it is apparent that relatively large numbers of allegedly closely-related species are distributed within a restricted area of Southeast Asia. This suggests an extensive speciation of this group

through geological vicariance events in this particular region, such as changes in sea-level, salinity, and water temperature coupled with the complex topography encompassing many island chains and marginal basins bordered with shallow sills, as proposed for pontellids (Fleminger, 1986) and other groups in the tortanids (Ohtsuka et al., 1992; Ohtsuka et al., 1995; Itoh et al., 2001; Ohtsuka & Conway, 2003).

From the Vietnamese coast, three species of *Tortanus* (*Atortus*), *T.* (*A.*) *brevipes*, *T.* (*A.*) *murrayi* A. Scott, 1909, and *T.* (*A.*) *recticauda* (Giesbrecht, 1889) have been recorded from Nha Trang by Rose (1956), but with no morphological description. Of these species, the occurrence of *T. recticauda* is questionable, since the type locality, Red Sea, and the subsequent reliable locality, the Arabian Gulf, are far from the Vietnamese coast, as suggested for the record by C. B. Wilson (1950) from the Philippines (Ohtsuka & Kimoto, 1989). The occurrence of the other two species should also be re-examined, since their reliable records are only from the waters south of Borneo and the Philippines (Scott, 1909; Bowman, 1971), while a great dispersal ability of *Atortus* under natural conditions is also suggested (Ohtsuka & Conway, 2003) and possibility of synanthropic dispersal cannot totally be excluded (see, e.g., Orsi & Walter, 1991). The present samples contained none of these species, but instead *T. vietnamicus*, a close relative of *T. brevipes* on the basis of female characters. Considering the state of our present knowledge and the potentially large number of species to be discovered in *Atortus*, a situation that applies to the whole Indo-West Pacific, further research should be based on a sample series with better geographic and ecological coverage, coupled with phylogenetic analysis using molecular genetic approaches next to conventional anatomical characters.

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