ISSN 1226-9999 (print)
ISSN 2287-7851 (online)

Korean J. Environ. Biol. 35(1) : 64~82 (2017) https://doi.org/10.11626/KJEB.2017.35.1.064

〈Original article〉

Redescription of Two Species of *Triconia* (Copepoda, Cyclopoida, Oncaeidae) Based on Their First Records in the Tropical Pacific

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Abstract - **Two species of the *minuta*-subgroup within the oncaeid copepod genus *Triconia* Böttger-Schnack, 1999 collected in the equatorial Pacific Ocean are newly recorded. A female *T. minuta* (Giesbrecht, 1893 [“1892”]) and both male and female *T. umerus* (Böttger-Schnack and Boxshall, 1990) from the northeast equatorial Pacific are redescribed with the comparison of its morphological details, which differs from previous studies, in terms of the larger body size, the length to width ratio of the genital double-somite, the relative length of the outer basal seta on P5, and the ornamentation of the appendages. The characters, which are used for identification, such as the length ratio of the outer subdistal and outer spine versus the distal spine on P3-P4, and the outer spine length of the middle exopodal segment on P3 and P4 are reported for the first time. Information on the variations in the endopodal spine lengths of swimming legs 2-4 is also provided for *T. minuta* and *T. umerus*, with the summary of the wide zoogeographical distribution of these two species.**

Key words : taxonomy, *Triconia*, *minuta*-subgroup, variation, equatorial Pacific, zoogeography

INTRODUCTION

The oncaeid genus *Triconia* Böttger-Schnack, 1999 is distinguished by the presence of a distal conical process on the distal margin of the endopods of P2-P4. Three subgroups, the *conifera*-, *similis*-, and *dentipes*-, were proposed by Böttger-Schnack (1999). The *similis*-subgroup currently comprises eight species, identified based on the lacking a dorso-posterior projection (“hump”) on the P2-bearing somite in lateral view and the presence of integumental pockets on the anterior face of the labrum. Recently, a new *minuta*-subgroup of *Triconia* was introduced. The length of the distal endopod spine on P2 in the *minuta*-subgroup is almost same with the length of the conical process. In all species of the *similis*-subgroup including *Triconia similis* (Sars, 1918), *T. hawii* (Böttger-Schnack and Boxshall, 1990), and *T. recta* Böttger-Schnack, 1999, the distal endopod spine on P2 is longer than the conical process (cf. Böttger-Schnack and Machida 2011). A new species, *T. denticula* based on the typical morphological characteristics was assigned to the *similis*-subgroup by Wi *et al.* (2011). The newly established *minuta*-subgroup presently includes four species: *Triconia minuta*, *T. umerus*, *T. parasimilis* Böttger-Schnack, 1999, and *T. gonopleura* Böttger-Schnack, 1999.

A comparison of the spine lengths on the endopods of P2-P4, which is useful information to the reliable identification of species of genus *Triconia*, was provided (e.g., Heron & Bradford-Grieve 1995; Böttger-Schnack 1999; Heron and Frost 2000). But the spine lengths required for unequivocal identification of species of *Triconia* need to reconsider, especially in case of the *minuta*-subgroup species. The proportional lengths of the distal endopod spines on P2-P4 of *Triconia* species were described, although there seems to be an inconsistency between text and table in the publication regarding the length ratio of the outer distal spine on P4

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enp-3 in *T. minuta* (Böttger-Schnack 1999). In Table 3 of the publication, the length of the outer subdistal spine on P4 enp-3 is equal to the length of the outer distal spine (p. 77), but text and figure states "…outer subdistal spine shorter than outer distal spine…" (Böttger-Schnack 1999). In a subsequent publication, she mentioned the outer subdistal spine on P4 enp-3 was slightly shorter than the outer distal spine in *T. minuta*, as in *T. umerus* (Böttger-Schnack 2004, in Table 2). The importance of intraspecific variation was recently noted by Wi *et al.* (2010), who described variations in the morphological characters such as body size, proportional lengths of urosomites, and endopodal and exopodal spines on the swimming legs of *T. conifera* (Giesbrecht, 1891) and *T. borealis* (Sars, 1918). Cho *et al.* (2013) reported intraspecific variability in the spine length proportions on the endopods of swimming legs 2 to 4 in the *dentipes*-subgroup from the equatorial Pacific. Taxonomic studies of the *similis*- and *minuta*-subgroups were primarily carried out in Mediterranean Sea and Red Sea (Boxshall 1977; Krišinić and Malt 1985; Böttger-Schnack and Boxshall 1990; Böttger-Schnack and Huys 1997; Böttger-Schnack 1999, 2001, 2003, 2009; Huys and Böttger-Schnack 2007). There is still insufficient taxonomic data regarding the range of species variations in the *similis*- and *minuta*-subgroups from the world's oceans including the equatorial Pacific Ocean.

During a survey of the zooplankton community in the northeast equatorial Pacific waters of the Korea's mining area, the species diversity of oncaeid copepods was examined. The study was carried out as part of an environmental monitoring program established for the mining site of manganese nodules. *T. minuta* and *T. umerus* were collected by a fine-mesh (60 μm) net in the northeast equatorial Pacific. Here we present the morphological characteristics of these two small *Triconia* species of the *minuta*-subgroup from the equatorial Pacific, including the proportional variations in the lengths of the endopodal spines on P2-P4. We also compare the characters of these specimens with those obtained from previous records of *T. minuta* and *T. umerus* (Böttger-Schnack 1999; Wi *et al.* 2011).

MATERIALS AND METHODS

The *minuta*-subgroup specimens were collected in the northeastern equatorial Pacific (KOMO; KORDI long-term monitoring station, 10°30′N, 131°20′W) using a conical net (mouth diameter 60 cm, mesh size 60 μm) hauled vertically from 100 m to the surface on August 21, 2009 (Fig. 8). The samples were fixed on board in 99.9% ethyl alcohol. Species of the *minuta*-subgroup were sorted from the zooplankton samples under a stereomicroscope (Zeiss Semi 2000-C). Specimens were dissected using tungsten needles, mounted in lactophenol, and sealed with transparent nail varnish. All drawings were made using a drawing tube attached to an Olympus BX51 differential interference contrast microscope. Scale bars in the drawings are given in micrometers (μm).

Total body length and the ratio of the prosome to the urosome were measured along the lateral aspect. Telescoping somites were not considered in the length measurements.

The morphological terminology used in the characterization followed Huys *et al.* (1996). Abbreviations used in the text and figures are as follows: A1, antennule; A2, antenna; ae, aesthetasc; CR, caudal ramus; P1-P6, first to sixth thoracopod; exp, exopod; enp, endopod; and exp (enp)-1 (2, 3) to denote the proximal (middle, distal) segment of a three-segmented ramus. Only the observable pores and other integumental structures (e.g., pits, scales) seen on the body surface under a light microscope were used for the characterizations.

The examined specimens were deposited in the National Marine Biodiversity Institute of Korea (MABIK) at Seocheon-gun in Chungcheongnam-do.

RESULTS

Order Cyclopoida Burmeister, 1835

Family Oncaeidae Giesbrecht, 1893 ["1892"]

Genus *Triconia* Böttger-Schnack, 1999

***Triconia minuta* (Giesbrecht, 1893 ["1892"]) (Figs. 1-3)**

Oncäa minuta Giesbrecht, 1893 ["1892"], 590-604, 756, 774, pl. 47, Figs. 3, 6, 26, 46, 59 (only female).

Triconia minuta Böttger-Schnack, 1999, 70-79, Figs. 14-17.

Triconia minuta Di Capua and Boxshall, 2008, 1410, Figs. 3A, B.

Material examined: Three adult females (MABIK CR00

240689-CR00240691) dissected on 9 or 10 slides.

All specimens collected from sampling locality (10°30′N, 131°20′W) in August 2009 by D.J. Ham. At sampling station, surface temperature and salinities were 28.5°C and 33.5 psu, respectively. Below water column, temperature decreased to 13.6°C at 100 m depth, and salinity remained 34.6-34.7 psu.

Female. Body length (illustrated indiv.): 580 μm [range: 580-605 μm, n = 3].

Exoskeleton weakly chitinized. Prosome about 2 times length of urosome, excluding caudal rami, about 1.8 times urosome length including caudal rami. P2-bearing somite without conspicuous dorsoposterior projection in lateral aspect (Fig. 1B). Integumental pores as figured in Fig. 1A, B. Pleural areas of P4-bearing somite with rounded posterolateral corners.

Genital double-somite about 1.7 times as long as maximum width (measured in dorsal aspect); thin oval-shaped with largest width measured at anterior 3/5, posterior part tapering gradually. Paired genital apertures located at about 2/5 the distance from anterior margin of genital double-somite; armature represented by 1 long spine and minute spinule (Fig. 1C). Pore pattern on dorsal surface as in Fig. 1C.

Anal somite 1.2 times as wide as long; about same length as caudal rami (Fig. 1C). Caudal ramus (Fig. 1C, D) 1.8 times longer than wide. Dorsal seta (VII) shorter than length of terminal accessory seta (VI); seta VI about 2/3 length of seta IV. Dorsal anterior surface (Fig. 1C) with secretory pore near insertion of seta II.

Antennule (Fig. 2A) six-segmented. Armature formula: 1-[3], 2-[8], 3-[5], 4-[3 + ae], 5-[2 + ae], 6-[6 + (1 + ae)].

Antenna (Fig. 2B) three-segmented, distinctly reflexed. Coxobasis with row of long, fine spinules along outer and inner margins with few additional denticles on proximal and distal part of outer margin. Endopod two-segmented, with distal endopod segment shorter than proximal endopod segment; lateral armature consisting of one pectinate, strong spiniform seta III and three curved setae, seta I sparsely pinnate and shorter than setae II-IV; distal armature consisting of five curved setae, setae A-D unipinnate, seta D being shortest, and two slender naked setae (F and G), both setae slightly longer than seta D.

Labrum (Fig. 2G, H) distinctly bilobed. Lobes separated by semicircular vertex covered anteriorly by single straight hyaline lamella. Posterior part of medial incision ornamented with four rounded integumental thickenings and with group of four secretory pores located proximally on each lobe (Fig. 2H). Anterior surface with paired row of long setules and paired integumental pockets lateroposteriorly, free margin of pockets surrounded by minute denticles (Fig. 2G).

Mandible (Fig. 2C) without surface ornamentation; gnathobase with five elements; outer seta (A) a shortest, with row of long fine setules along dorsal margin; ventral blade (B) strong and spiniform, with row of spinules on posterior surface; dorsal blade (C) strong and broad, with dentiform processes along distal margin; dorsal elements setiform, one shorter spinulose (D), one longer multipinnate (E).

Maxillule (Fig. 2D) weakly bilobed, with few spinules. Inner lobe with three elements: outermost one spiniform, with three strong spinules as midregion and distally spinulose, middle element setiform and bipinnate, innermost element sparsely bipinnate, located at some distance from others. Outer lobe with four elements: innermost element setiform and naked, element next to outermost spiniform and strong, with double row of short spinule, two outermost elements setiform and bipinnate, outermost element longest.

Maxilla (Fig. 2E) two-segmented. Syncoxa unarmed, surface ornamented with few spinular rows and one large secretory pore; allobasis produced distally into slightly curved claw bearing two rows of strong spinules along inner margin; stout seta on outer margin reaching below tip of allobasal claw, ornamented with few spinules distally; inner margin with slender spinulose seta and strong basally swollen spine ornamented with two large spinular rows along medial margin and few spinules along outer margin.

Maxilliped (Fig. 2F) four-segmented, comprising syncoxa, basis and two-segmented endopod. Basis robust, with two spiniform bipinnate elements on inner margin, equally long, proximal one more slender than distal one; fringe of long pinnules on anterior surface and additional longitudinal row near outer margin as illustrated in Fig. 2F. Distal endopod segment (claw) with row of pinnules on proximal along 2/3 of concave margin; with minute naked seta on outer proximal margin and unipectinate spine fused basally to inner proximal corner of claw.

Swimming legs 1-4 biramous (Fig. 3A-D), with three-

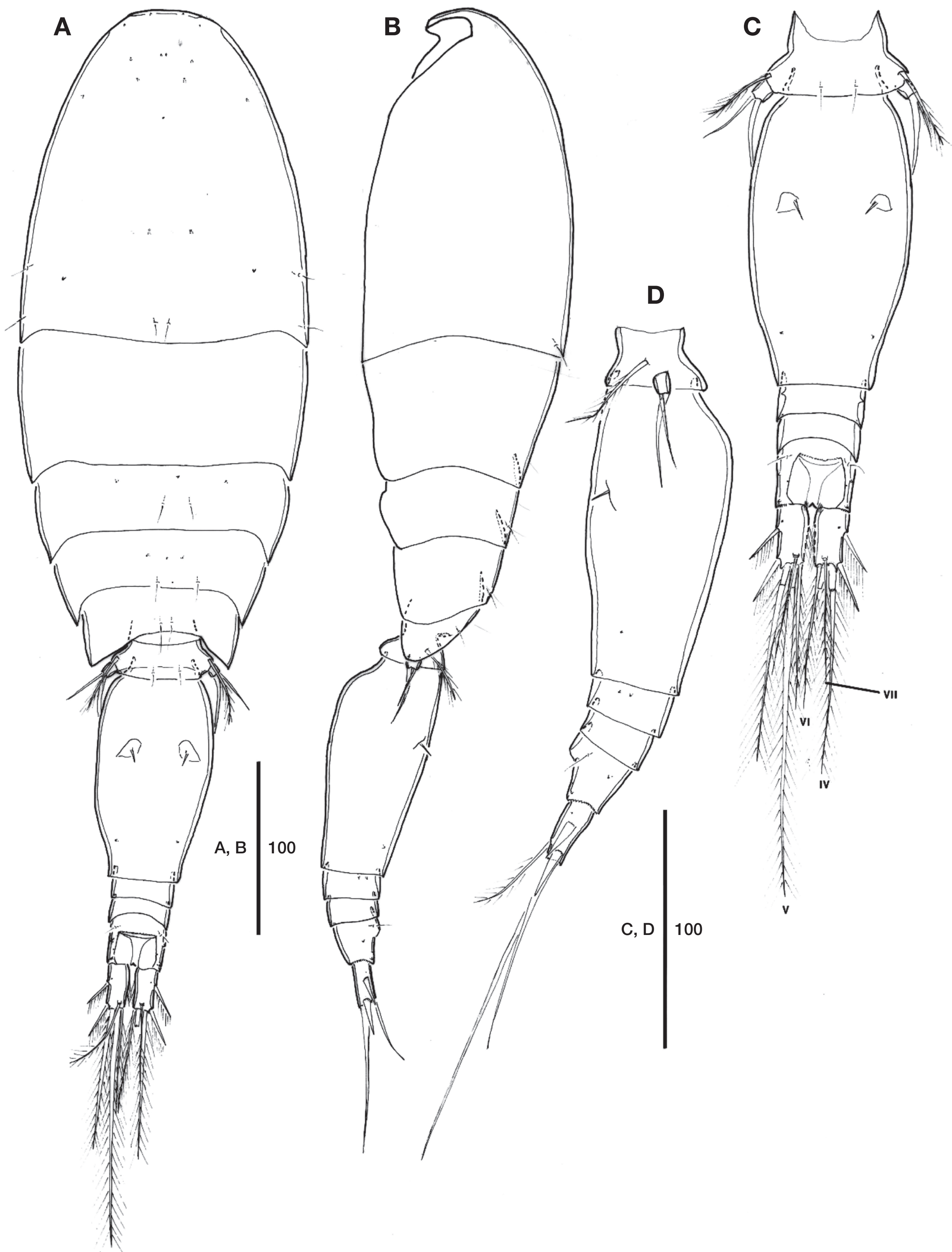

Fig. 1. *Triconia minuta* (Giesbrecht, 1893 ["1892"]), female A habitus, dorsal B same, lateral C urosome, dorsal D same, lateral. Scale bars: µm.

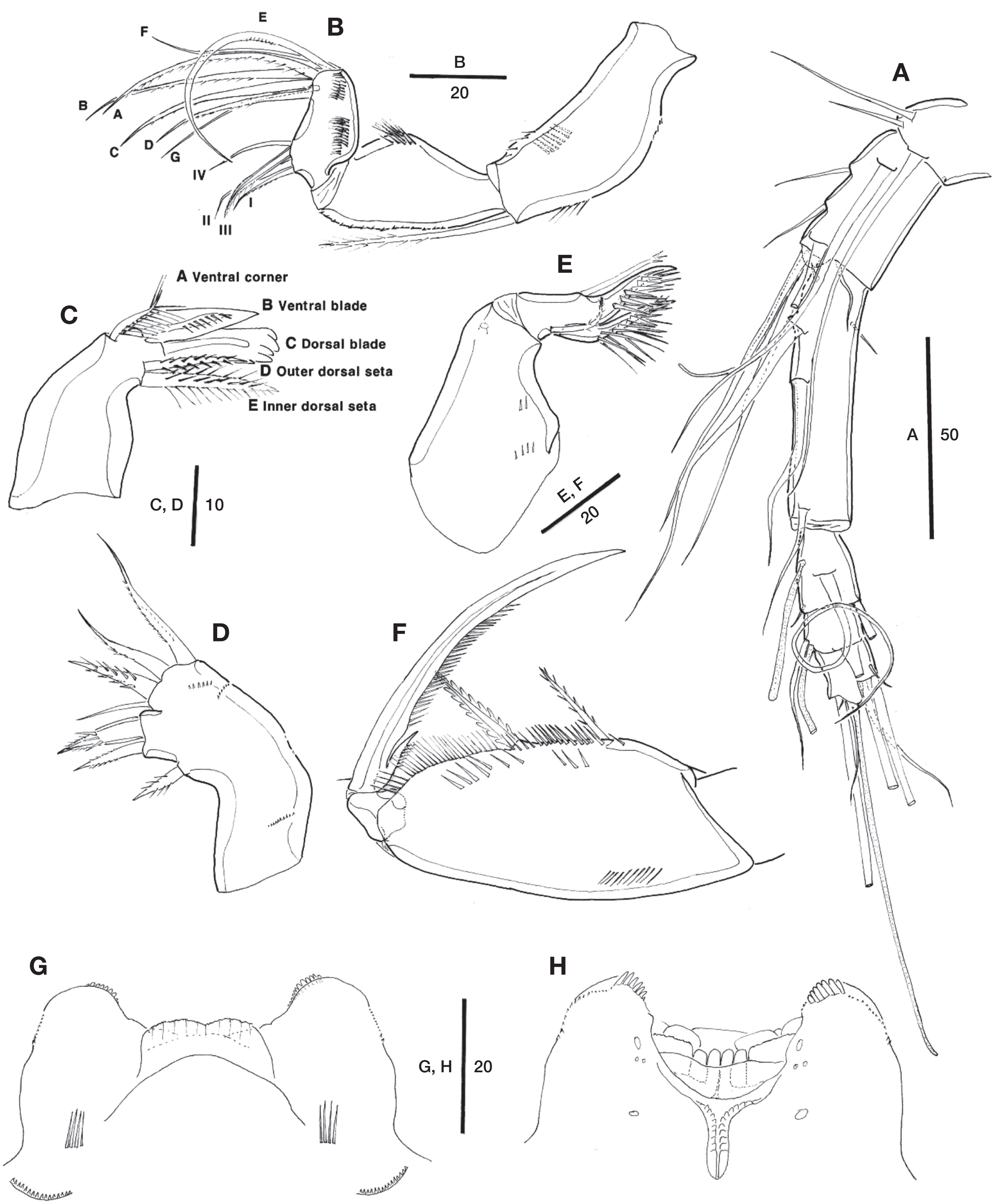

Fig. 2. *Triconia minuta* (Giesbrecht, 1893 [“1892”]), female A antennule B antenna, posterior C mandible D maxillule E maxilla F maxilliped G labrum, anterior H same, posterior. Scale bars: μm.

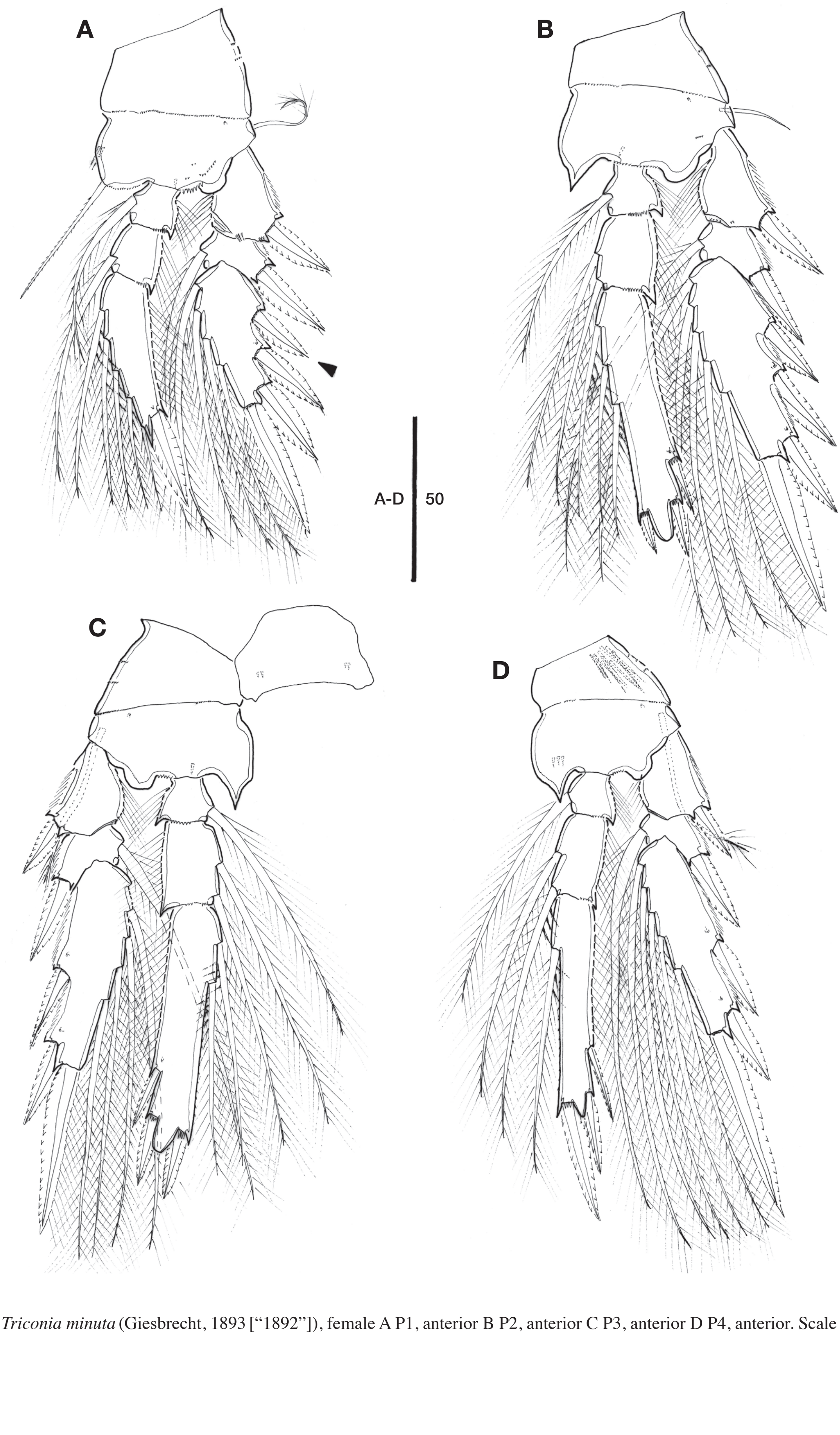

Fig. 3. *Triconia minuta* (Giesbrecht, 1893 ["1892"]), female A P1, anterior B P2, anterior C P3, anterior D P4, anterior. Scale bars: µm.

segmented rami. Intercoxal sclerites well developed, with ornamentation few spinules on posterior face (cf. Fig. 3C). Coxa of P4 with tuft of very long fine setules posteriorly at outer proximal corner; other surface ornamentation of coxae and bases of P1-P4 as shown in Fig. 3A-D. Bases with short (P1, P2) or long (P3, P4) outer seta. Inner basal seta on P1 spiniform and minutely pinnate. Endopod of P1 about same length as exopod, those of P2-P4 longer than exopod.

Leg armature formula (Roman numerals indicate spines, Arabic numerals indicate setae):

	Coxa	Basis	Exopod	Endopod
P1	0-0	1-I	I-0; I-1; III,I,4	0-1; 0-1; 0,I,5
P2	0-0	1-0	I-0; I-1; III,I,5	0-1; 0-2; I,II,3
P3	0-0	1-0	I-0; I-1; II,I,5	0-1; 0-2; I,II,2
P4	0-0	1-0	I-0; I-1; II,I,5	0-1; 0-2; I,II,1

Exopods. Outer margin of exopod segments with well-developed serrated hyaline lamella; inner margin of proximal exopod segments with long setules. Secretory pore located on posterior surface of distal segments hyaline lamellae on outer spines well developed; outer and distal (terminal) spines of P1 exopod with subapical tubular extension, which is lacking on proximalmost spine of exp-3 (arrowed in Fig. 3A). Distal spine almost equal in length to (P1, P4) or shorter (P2, P3) than distal exopod segment.

Endopods. Outer margin of endopod segments with fringe of long setules. Inner seta of proximal endopod segment slightly swollen at base. Distal endopod segments with (P1-P3) or without (P4) single secretory pore on posterior surface. Distal margin of P2-P4 produced into conical projection which is round (P2-P3) or small triangular (P4) shape in distal part (Fig. 3B-D). Length data of endopodal spine of three females as shown in Table 1; length ranges of outer subdistal spine (OSDS) and outer distal spine (ODS) relative to distal spine are as follows: P2 enp-3, OSDS: 137-160%, ODS: 129-153%; P3 enp-3, OSDS: 82-88%, ODS: 97-107%; P4 enp-3, OSDS: 56-71%, ODS: 64-82%.

P5 (Fig. 1C, D) comprising plumose seta arising from lateral surface of somite, and small free unornamented segment representing exopod. Exopod 1.2 times as long as wide, bearing stout curved seta and smaller slender seta. Outer seta shorter than inner seta and outer basal seta. Outer basal seta slightly longer than inner seta.

P6 (Fig. 1C) represented by operculum closing off each

Table 1. Variation of morphometric data among individuals of *Triconia minuta* and *T. umerus* from the northeastern equatorial Pacific: comparison of the length of spines on P2-P4 enp-3 (unit: μm)

		Triconia minuta						*Triconia umerus*													
		Female						Female								Male					
		Specimen 1		Specimen 2		Specimen 3		Specimen 1		Specimen 2		Specimen 3		Specimen 4		Specimen 1		Specimen 2		Specimen 3	
		L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R
P2	OSDS	19.1	18.8	17.6	16.9	17.6	16.9	23.5	23.2	22.1	27.7	21.3	22.1	23.2	22.8	19.1	19.1	20.2	18.4	18.0	17.6
	ODS	18.0	19.1	17.3	16.5	16.9	15.8	22.4	23.2	22.4	22.1	21.0	22.1	23.9	24.3	17.6	18.8	17.6	18.4	18.0	18.4
	DS	14.0	12.9	12.5	11.4	11.0	11.4	16.9	16.9	16.2	15.1	16.2	16.2	16.9	16.2	13.6	13.2	12.9	12.5	13.2	14.0
P3	OSDS	19.1	18.4		18.0	16.9	18.0			23.5	23.5	23.5	23.5	23.5	24.6	19.1	19.9	21.7	21.0	18.0	19.5
	ODS	21.0	21.7	Damaged	21.3	21.0	22.1	Damaged	Damaged	28.3	27.2	27.6	27.9	29.8	31.6	23.5	23.5	24.3	23.5	22.4	22.4
	DS	21.7	21.7		20.6	20.6	20.6			25.0	24.3	24.3	25.7	26.8	28.7	21.0	20.2	20.2	21.0	21.0	23.2
P4	OSDS	22.1	22.1	22.1		21.3	20.6	28.7	27.9	26.8	25.7	27.2	25.0	27.6	28.3	24.3	22.8	22.4	21.0	19.5	21.7
	ODS	26.1	25.7	25.7	Damaged	24.6	25.4	31.6	32.7	33.5	30.5	33.1	31.6	34.6	34.6	27.9	27.9	27.6	27.9	28.7	27.6
	DS	36.8	39.0	31.3		38.2	36.0	38.2	37.5	38.2	36.8	39.0	39.7	43.0	43.0	33.8	33.5	33.1	33.8	35.3	34.9

DS = distal spine; ODS = outer distal spine; OSDS = outer subdistal spine; L = left, R = right genital aperture; armed with long spine and minute spinule.

Male. Not found.

Remarks. The collected specimens, *Triconia minuta* and *T. umerus*, showed the typical morphological characteristics of the *minuta*-subgroup: the absence of a dorsal projection on the prosome of the female, the presence of integumental pockets on the anterior face of the labrum of both sexes, and the presence of a distal spine on the distal endopodal segment of P2.

Within the *minuta*-subgroup, *T. minuta* is closely related to *T. umerus* and *T. parasimilis*, which share a short distal spine on P2 enp-3 and the relatively long seta VI, which is longer than seta VII. *T. minuta* can be differentiated from the other two species by (i) the proportional lengths of elements on the basis of maxilliped, which is equal in size in *T. minuta*, while the distal element is 1.5-times longer than the proximal element in *T. umerus* and *T. parasimilis*; (ii) the surface unornamentation of the genital double-somite of *T. minuta* in the light microscope; and (iii) the length ratio of exopodal setae and outer basal seta on P5.

The proportional lengths of the endopodal spines on P2-P4 reported for *T. minuta* from the Red Sea (calculated from Böttger-Schnack 1999, fig. 16B-D) fall within the range of variation determined in our specimens from the equatorial Pacific (cf. Table 1), except for the outer distal spine on P3 enp-3 (ODS : DS = 1.13 : 1), which is slightly longer than that of our specimens (ODS : DS = 0.97-1.07 : 1) (Table 2). Also, the ODS/DS ratio for P4, as calculated from Giesbrecht, 1893 [“1892”] (0.57 : 1, plate 47, fig. 59), is smaller than that of our specimens (ODS : DS = 0.64-0.82 : 1) (Table 2). Böttger-Schnack (1999) already pointed out the variation between specimens from the Red Sea (in Böttger-Schnack’s study) and those from the Gulf of Naples (in Giesbrecht’s study) with regard to the proportional lengths of the endopodal spines on P4. According to Böttger-Schnack (1999), in specimens from the Gulf of Naples, the outer subdistal spine is as long as the outer distal spine, while in specimens from the Red Sea, this spine is slightly smaller than the outer distal spine.

Females of *T. minuta* from the equatorial Pacific resemble females of species from the Red Sea (Böttger-Schnack 1999), except for variations in (i) body size (580-605 μm), as our specimens are larger than those from the Red Sea (500-560 μm according to Böttger-Schnack 1999) and the Gulf of Naples (560-580 μm according to Giesbrecht 1893 [“1892”]); (ii) the length ratio of the prosome to the urosome (including and excluding the caudal rami), which is smaller (1.8 and 2.0) in our specimens than in the Red Sea specimens (2.1 and 2.4); and (iii) the ornamentation of the basal setae on P1 (inner) and P3 (outer): in the Pacific specimens, the inner basal seta on P1 is spiniform and minutely pinnate, and the outer basal seta on P3 is plumose (Fig. 3A, C), while in the Red Sea specimens, these setae on P1 and P3 are naked.

Triconia umerus (Böttger-Schnack and Boxshall, 1990) (Figs. 4-7)

Oncaea umerus Böttger-Schnack and Boxshall, 1990, 861-865. Figs. 1A-H, 2A-F (female only).

Triconia umerus Böttger-Schnack, 1999, 91-97, Figs. 24-26.

Triconia umerus Di Capua and Boxshall, 2008, 1410, Figs. 3C, D, 4A.

Triconia umerus Wi, Shin and Soh, 2011, 595-601, Figs. 5-8, 9C-E, G.

Material examined: Four adult females (MABIK CR00 240692-CR00240695) each dissected on 9 or 10 slides. Three adult males (MABIK CR00240696-CR00240698) each dissected on 9 or 10 slides.

All specimens collected from sampling locality (10°30′N, 131°20′W) in August 2009 by D.J. Ham. At sampling station, surface temperature and salinities were 28.5°C and 33.5 psu, respectively. Below water column, temperature decreased to 13.6°C at 100 m depth, and salinity remained 34.6-34.7 psu.

Female. Body length (illustrated indiv.): 694 μm [range: 694-778 μm, n = 4].

Exoskeleton well chitinized. Prosome about 1.9 times length of urosome, excluding caudal rami, 1.7 times urosome length including caudal rami. P2-bearing somite without conspicuous dorsoposterior projection in lateral aspect (Fig. 4B). Integumental pores on prosome as indicated in Fig. 4A, B. Pleural areas of P4-bearing somite with rounded posterolateral corners.

Genital double-somite about 1.5 times as long as maximum width (measured in dorsal aspect, largest width measured at half of genital double-somite, with rounded lateral

Table 2. Comparison of morphometric ratios for *Triconia minuta* and *T. umerus* from the equatorial Pacific (the present study) with those for specimens from other regions

		Triconia minuta				*Triconia umerus*					
		Gulf of Naples[1)]	Red Sea[2)]	Equatorial Pacific	Red Sea[2)]	Red Sea[2)]	NW Pacific[3)]	Equatorial Pacific	Red Sea[2)]	NW Pacific[3)]	Equatorial Pacific
		Female			Male	Female			Male		
Size range (mm)		0.56-0.58	0.5-0.56	0.58-0.61	0.39-0.41	0.57-0.62	0.65-0.71	0.69-0.78	0.52	0.52-0.57	0.56-0.63
Prosome : Urosome (including CR)		1.7 : 1†	2 : 1	1.8 : 1	1.9 : 1†	2 : 1	1.6 : 1	1.7 : 1	1.4 : 1†	1.7 : 1	1.6 : 1
Genital (double-)somite (dorsal view)	L : W ratio	2†	1.8	1.7	1.4†	1.3	1.7	1.5	1.4†	1.5†	1.4
L ratio spines P2 enp-3	OSDS : DS		1.49 : 1†	1.37-1.6 : 1		1.25 : 1†	1.42 : 1†	1.32-1.44 : 1		1.26/1.4 : 1**	1.26-1.57 : 1
	ODS : DS		1.49 : 1†	1.29-1.53 : 1		1.17 : 1†	1.42 : 1†	1.3-1.5 : 1		1.16/1.30 : 1**	1.3-1.47 : 1
L ratio spines P3 enp-3	OSDS : DS		0.88 : 1†	0.82-0.88 : 1		1 : 1†	1.09 : 1†	0.86-0.97 : 1		0.97/-:1**	0.84-1.07 : 1
	ODS : DS		1.13 : 1†	0.97-1.07 : 1		1.12 : 1†	1.24 : 1†	1.09-1.14 : 1		1.17/-:1**	0.97-1.2 : 1
L ratio spines P4 enp-3	OSDS : DS	0.57 : 1†	0.64 : 1†	0.56-0.71 : 1		0.57 : 1†	0.71 : 1†	0.63-0.75 : 1		0.60/0.59 : 1**	0.55-0.72 : 1
	ODS : DS	0.57 : 1†	0.68 : 1†	0.64-0.82 : 1		0.73 : 1†	0.83 : 1†	0.8-0.88 : 1		0.75/0.76 : 1**	0.79-0.84 : 1
P5-bearing somite	W : L ratio	1.67†	1.2†	1.2		1.1†	1.2†	1.28			
	L ratio seta BS : IS : OS	2.12 : 1.5 : 1†	1.24 : 1.08 : 1†	1.45 : 1.36 : 1	1.7 : 1.43 : 1†	1.73 : 1.46 : 1	1.55 : 1.06 : 1†	1.81 : 128 : 1	1.83 : 1.25 : 1†	1.5 : 1.3 : 1†	2 : 1.3 : 1
AS	W : L	1.4†	1.2	1.2	1.6	1.3	1.7	1.3	1.5†	2.0†	1.3
CR	L : W	2†	1.7	1.8	1.4	2†	1.75	2	1.4	1.6	1.3

1)Giesbrecht, 1893, 2)Böttger-Schnack and Boxshall, 1990; Böttger-Schnack, 1999, 3)Wi *et al*. 2011
† = calculated from reference papers' figures
* = for the number of specimens measured, see Table 1
** = values from re-examination of specimen of Korean waters (Left/Right)
AS = anal somite; BS = outer basal seta; CR = caudal ramus; DS = distal spine; IS = inner exopodal seta; L = length; OS = outer exopodal seta; ODS = outer distal spine; OSDS = outer subdistal spine; W = width

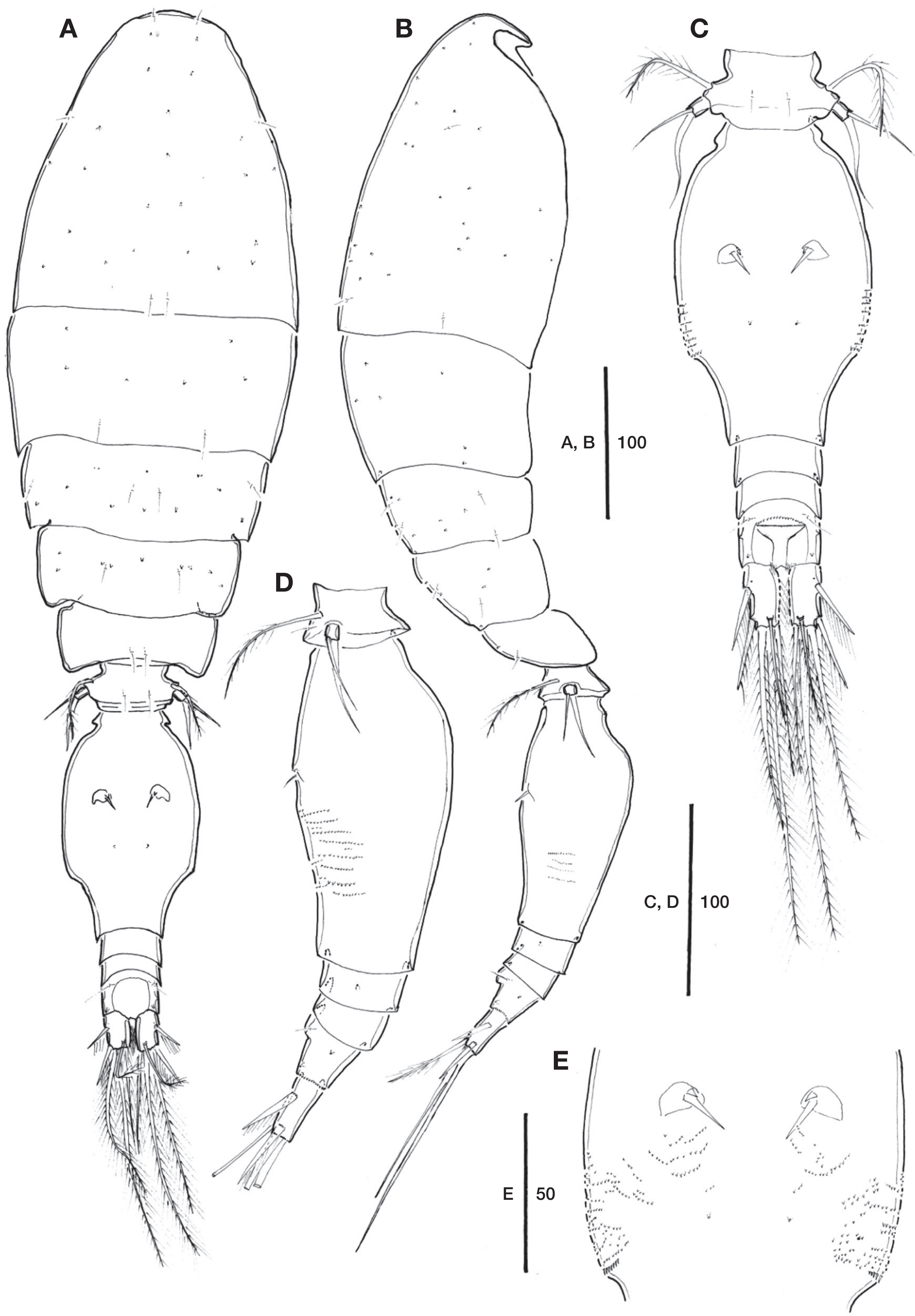

Fig. 4. *Triconia umerus* (Böttger-Schnack and Boxshall, 1990), female A habitus, dorsal B same, lateral C urosome, dorsal D same, lateral E genital-double somite, middle part, dorsal. Scale bars: µm.

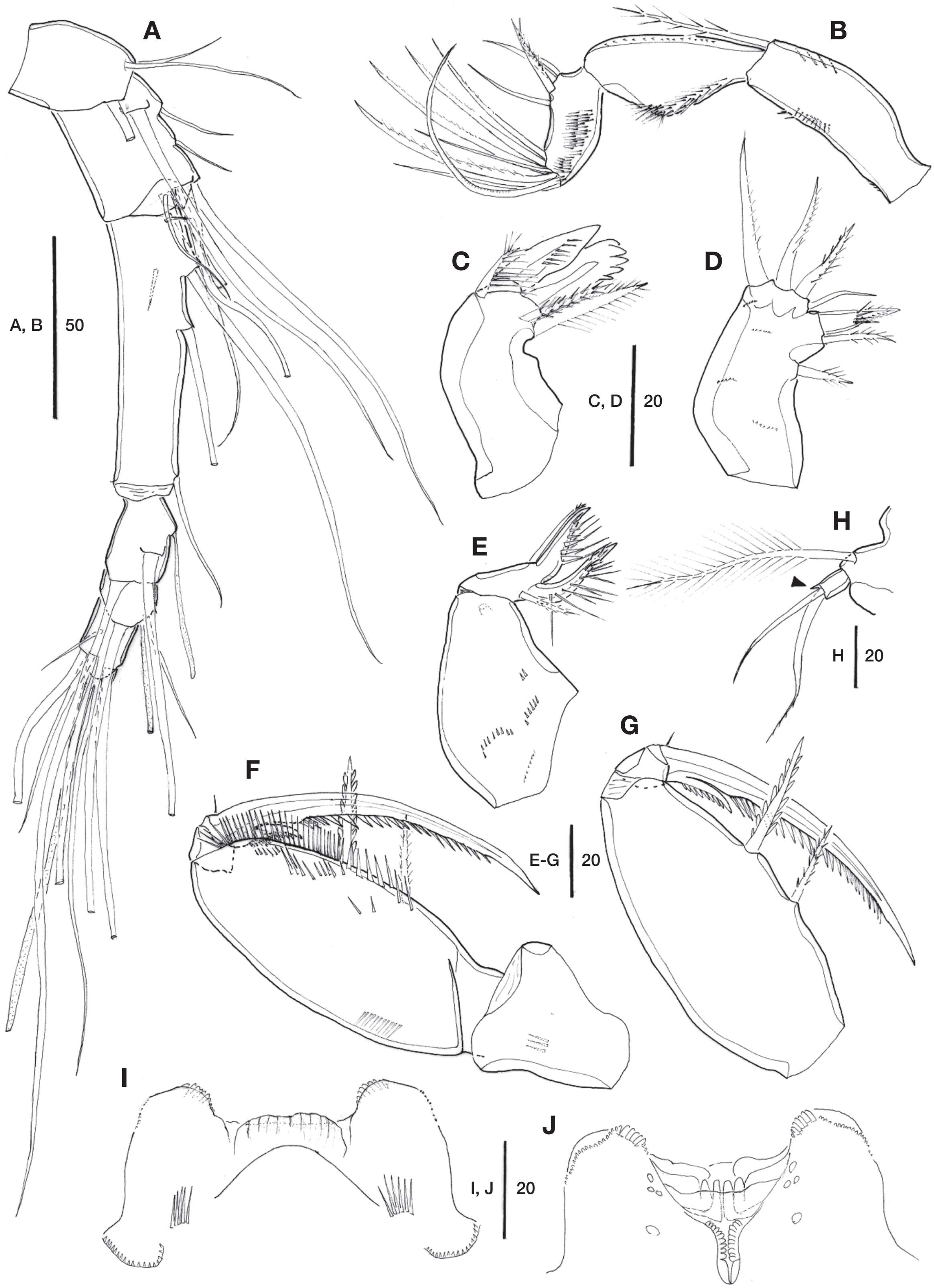

Fig. 5. *Triconia umerus* (Böttger-Schnack and Boxshall, 1990), female A antennule B antenna, posterior C mandible D maxillule E maxilla F maxilliped, anterior G same, posterior H P5 I labrum, anterior J same, posterior. Scale bars: μm.

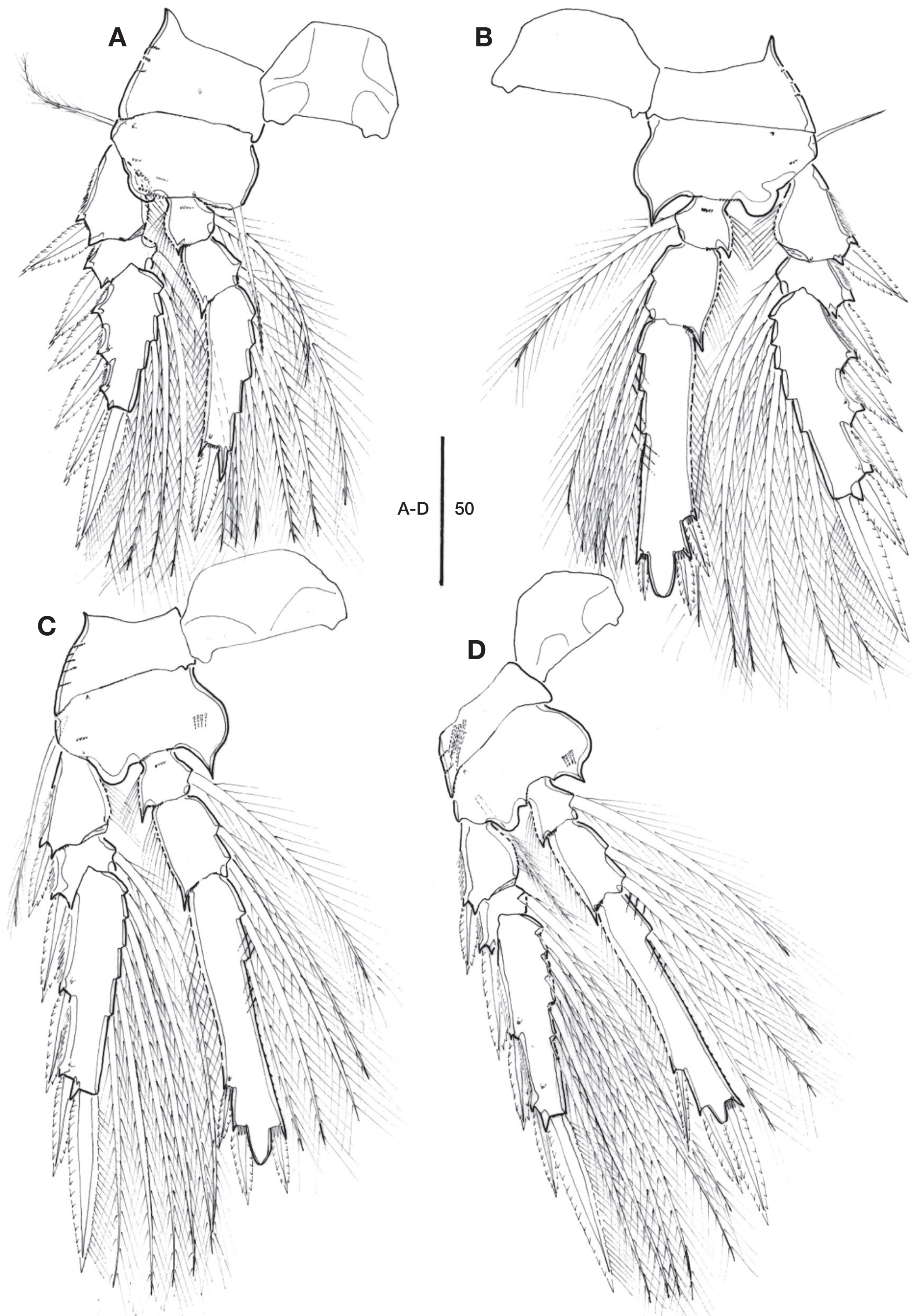

Fig. 6. *Triconia umerus* (Böttger-Schnack and Boxshall, 1990), female A P1, anterior B P2, anterior C P3, anterior D P4, anterior. Scale bars: µm.

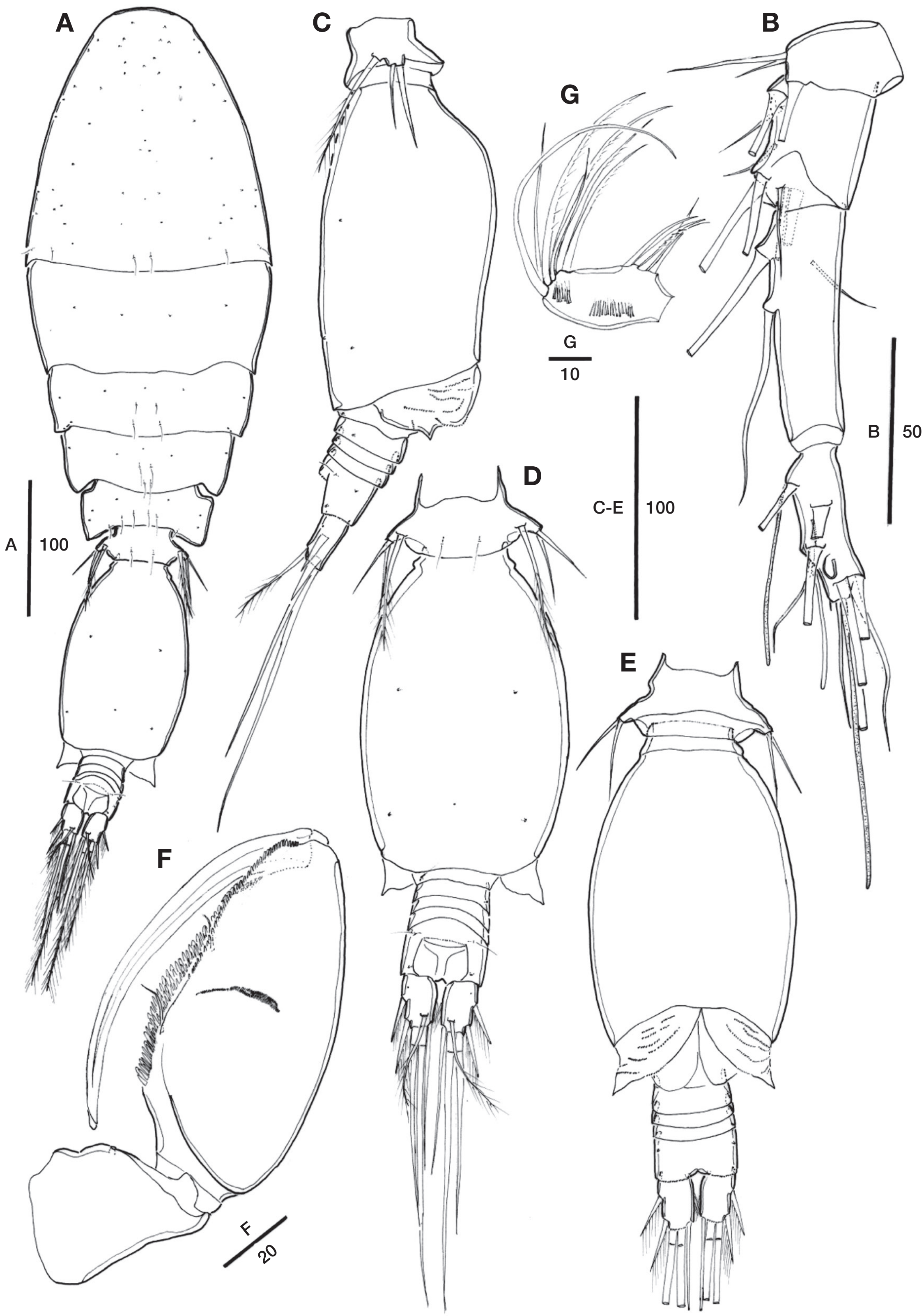

Fig. 7. *Triconia umerus* (Böttger-Schnack and Boxshall, 1990), male A habitus, dorsal B antennule C urosome, lateral D same, dorsal E same, ventral F maxilliped, anterior G antenna, distal endopod segment. Scale bars: μm.

margins, posterior part gradually tapering, with conspicuous angular edge ('bottle-neck') at anterior 2/3 (Fig. 4C, E). Dorsal surface of genital double-somite covered with small denticles, especially under genital apertures, surface area near edges ornamented with linear row of spinules dorsolaterally (Fig. 4E). Paired genital apertures located at 2/5 distance from anterior margin of genital double-somite; armature represented by 1 long spine and minute spinule (Fig. 4E). Secretory pores on dorsal surface as indicated in Fig. 4C, E.

Anal somite about 1.3 times wider than long and slightly shorter than caudal rami (Fig. 4C).

Caudal ramus 2 times longer than wide. Seta VII slightly longer than half length of seta IV and 2/3 length of seta VI (Fig. 4C).

Antennule (Fig. 5A) six-segmented. Armature formula as for *T. minuta*.

Antenna (Fig. 5B) three-segmented. Distal endopod segment with armature and ornamentation as in *T. minuta*, except for seta F almost equal in length to seta D, seta G shorter than setae D and F.

Labrum (Fig. 5I, J) similar to *T. minuta*.

Mandible (Fig. 5C) similar to *T. minuta*, except for inner dorsal seta bipinnate.

Maxillule (Fig. 5D) similar to *T. minuta*.

Maxilla (Fig. 5E) similar to *T. minuta*.

Maxilliped (Fig. 5F, G) similar to *T. minuta*. Surface of syncoxa ornamented with few spinule. Distal element on basis 1.5 times longer than proximal elements. Distal endopod segment (claw) with strong pinnules along proximal 5/6 of concave margin, decreasing in size distally.

Swimming legs (Fig. 6A-D), with armature and ornamentation as in *T. minuta*, except for intercoxal sclerites without ornamentation. Coxae and bases of legs 1-4 with surface ornamentation as in Fig. 6A-D.

Exopods similar to *T. minuta*, except for terminal spine of P4 shorter than distal exopod segment and the outer spine length on middle exopod segment on P3 and P4, reaching over the insertion of the proximalmost spine on exp-3 of P3 and P4.

Endopods. Length ratios of spines different from *T. minuta* with length data of spines of four specimens as shown in Table 1; length ranges of outer subdistal spine (OSDS) and outer distal spine (ODS) relative to distal spine are as follows: P2 enp-3, OSDS: 132-144%, ODS: 130-150%; P3 enp-3, OSDS: 86-97%, ODS: 109-114%; P4 enp-3, OSDS: 63-75%, ODS: 80-88%.

P5 (Fig. 5H) with outer basal seta long and distally plumose; exopod segment with one denticle on distal margin (arrowed in Fig. 5H). Exopod slightly longer than wide, bearing short naked seta (outer) and long seta (inner) ornamented with few denticles along inner distal margin. Outer seta slightly shorter than inner seta, and almost half the length of outer basal seta.

P6 (Fig. 4E) represented by operculum closing off each genital aperture; armed with long spine and minute spinule.

Male. Body length (illustrated indiv.): 628 μm [range: 557-628 μm, n = 3]. Sexual dimorphism in antennule, antenna, maxilliped, P5-P6, caudal ramus and in genital segmentation.

Prosome 1.8 times the length of urosome, excluding caudal rami, about 1.6 times urosome length, including caudal rami (Fig. 7A). Integumental pores on prosome and urosome as figured (Fig. 7A).

Caudal rami 1.3 times longer than wide, shorter than in female; seta VII shorter than seta VI. Dorsal surface of genital somite with 5 secretory pores as indicated in Fig. 7D. Surface of genital flaps ornamented with several rows of small spinules (Fig. 7E). Anal somite about 1.3 times wider than long as in female.

Antennule (Fig. 7B) four-segmented with distal segment corresponding to fused segments 4-6 of female. Armature formula 1-[3], 2-[8], 3-[4], 4-[11 + 2ae + (1 + ae)].

Antenna (Fig. 7G) as in female, except for lateral armature on distal endopod segment, with seta II being relatively longer than in female.

Maxilliped (Fig. 7F) three-segmented, comprising syncoxa, basis and 1-segmented endopod. Syncoxa without surface ornamentation, with single secretory pore at inner distal margin. Basis robust, particularly inflated in proximal half bulbous swelling; anterior surface with 1-2 transverse spinule rows in addition to row of very small flap spinules along distal part of inner margin (Fig. 7F); posterior surface with rows of short spatulate setules of graduated length along palmar margin; with 2 small naked setae within longitudinal cleft, proximal seta slightly longer than distal one. Endopod drawn out into long curved claw, concave margin unornamented; accessory armature consisting of short, unipectinate spine basally fused to inner proximal corner of claw; claw with minute hyaline apex (Fig. 7F).

Swimming legs with armature and ornamentation as in female, length data of endopodal spines of three males as shown in Table 1; length ranges of outer subdistal spine (OSDS) and outer distal spine (ODS) relative to distal spine are as follows: P2 enp-3, OSDS: 126-157%, ODS: 130-147%; P3 enp-3, OSDS: 84-107%, ODS: 97-120%; P4 enp-3, OSDS: 55-72%, ODS: 79-84%.

P5 (Fig. 7C, D) exopod not delimited from somite, shorter than in female; proportional lengths of outer basal seta and exopodal setae as in female.

P6 (Fig. 7E) represented by posterolateral flap closing off genital aperture on either side; covered by pattern of spinules; posterolateral corners protruding laterally so that they discernible in dorsal aspect (Fig. 7A, D).

Remarks. Females of *T. umerus* from the northeast equatorial Pacific were identified by the shape of the lateral margin and the conspicuous surface ornamentation of the genital double-somite, which showed a 'bottle-neck' or 'shoulder-like' edge, small denticles near genital apertures, and spinules near edges (Böttger-Schnack and Boxshall 1990). The morphological characters of *T. umerus* from the northeast equatorial Pacific are similar to those from the Red Sea (Böttger-Schnack and Boxshall 1990; Böttger-Schnack 1999), except for the following characters: (i) the bod larger body length in our specimens (females: 694-778 μm) than those from in the Red Sea (female: 590 μm); (ii) the length ratio of the prosome and urosome (including the caudal rami) is smaller (1.7) than that in the Red Sea specimens (2.1); (iii) the length to width ratios of the caudal rami and genital somite are larger than those in the Red Sea specimens; and (iv) in the Pacific specimens, antennary seta G is somewhat shorter than seta D (Fig. 5B), whereas in the Red Sea specimens seta G is almost the same length as seta D.

Recently, Wi *et al.* (2011) described both sexes of *T. umerus* from the Korean waters. In their description, they pointed out several variations between those specimens and the Red Sea specimens, such as the length ratio of the prosome to the urosome, the length to width ratio of the caudal rami, and the genital somite. However, specimens from the Korean and the equatorial Pacific waters differ in the following characters: (i) the length of the antennary seta A (Fig. 5B), which in the equatorial Pacific specimens is as long as seta B, whereas in the Korean specimens, seta A is longer than seta B (not described in Wi *et al.* 2011, but shown in their fig. 6B), and (ii) the plumose ornamentation of the outer basal seta on P5 (Fig. 5H), in contrast to the naked seta of the Korean waters specimens. In addition, the ornamentation of the stout seta on the outer margin of the maxilla differs slightly: in Wi *et al.*'s description, the stout seta is naked, as in *T. denticula* (cf. Wi *et al.* 2011, their fig. 3G), whereas in specimens from the equatorial Pacific, it is armed with a few spinules distally. To resolve the discrepancy between specimens from the Korean waters and those from the equatorial Pacific waters, we obtained a female specimen from the Korean waters, loaned from the collections of the National Institute of Biological Resources (NIBR), Incheon. The results disproved Wi *et al.*'s description, because this seta on the outer margin of the maxilla was ornamented with a few spinules.

Other morphological differences in micro-structure were identified between females from the equatorial Pacific and those from coastal waters (e.g., the Red Sea and the Korean waters). These include (i) the spinnular row on the concave margin of the distal segment (claw) of the maxilliped, which runs along the proximal 5/6 of the concave margin in the Pacific specimens (Fig. 5F, G) but extends along the entire length of the concave margin in the Red Sea and the Korean specimens; (ii) the additional ornamentation on the maxillule surface (Fig. 5D); (iii) the ornamentation on the P5-bearing somite, with a denticle on the distal part of the exopod (arrowed in Fig. 5H), while the exopod segment on P5 is unornamented in the two specimens; and (iv) the pinnate ornamentation of the inner basal seta on P1 in the Pacific specimens (Fig. 6A) compared with the naked structure in the Red Sea and Korean specimens.

The proportional lengths of the spines of P2-P4 enp-3 reported for females of *T. umerus* from the Red Sea (calculated from Böttger-Schnack and Boxshall 1990, fig. 2D-F) and the Korean waters (calculated from Wi *et al.* 2011, fig. 7B-D) are within the range of values determined for our specimens from the equatorial Pacific, whereas those of P2 and P4 (the Red Sea) and P3 (the Korean waters) are not. The proportional spine lengths of OSDS and ODS compared with DS on the endopods of P2 and P4 were smaller in our specimens than in the Red Sea specimens [OSDS/DS (1.25 :

1) and ODS/DS (1.22 : 1) on P2; OSDS/DS (0.57 : 1) and ODS/DS (0.73 : 1) on P4, in Böttger-Schnack and Boxshall 1990, fig. 2D, F], whereas for P3 the spine lengths were larger in our specimens than in those from the Korean waters [OSDS/DS (1.09 : 1) and ODS/DS (1.24 : 1), in Wi *et al*. 2011, fig. 7C] (Table 2). Wi *et al*. (2011) reported that the distal spine on P2 enp-3 was much shorter in the male compared with the female. In their specimen, the distal spine barely reached the tip of the conical process (their fig. 8I). We found individual variation in the proportional spine length of the distal spine on P2 enp-3 in the male specimens from the equatorial Pacific. In some specimens, the distal spine on P2 enp-3 was clearly longer than the length of the conical process, as in the female, while it was almost equal in or slightly shorter than the length of the conical process in some other specimens.

Triconia umerus males are most similar to *T. minuta* males. Males were identified by the following characters: (i) the length of the outer subdistal spines on P4 enp-3, which in *T. umerus* is shorter than the outer distal spine, while in *T. minuta* the two spines are roughly equal in length; (ii) the length ratio of the outer exopodal seta to the inner seta on P5, which is longer in males of *T. umerus* than of *T. minuta*; (iii) the pore pattern on the dorsal surface of the genital double-somite, with five pores in *T. umerus* compared with three in *T. minuta* (Böttger-Schnack 1999). Males of both the *similis*- and *minuta*-subgroups can be distinguished by the pore pattern on the dorsal surface of the genital double-somite, as already stated by Böttger-Schnack (1999). However, there are only two pores on the genital somite in the figure published by Wi *et al*. (2011, their fig. 8A), because they are sometimes difficult to discern.

Males from the equatorial Pacific showed minor morphological differences compared with specimens from the Red Sea and the Korean waters: (i) a larger size (557-628 μm) than males from either the Red Sea (520 μm) or the Korea waters (515-565 μm); (ii) the additional ornamentation of antennary setae C and D, which are unipinnate in the Pacific specimens (Fig. 7G), compared with the naked setae in the Red Sea and the Korean specimens; and (iii) the relative length of the outer seta on P5, which is as long as the inner seta (Fig. 7C) in our Pacific samples but shorter in the Red Sea and the Korean samples. However, in male specimens from all three areas, the outer basal seta is twice as long as the inner exopodal seta on P5.

DISCUSSION

The genus *Triconia* is one of the most difficult taxa to identify because of similar morphological characteristics of species, especially in the case of males (Böttger-Schnack and Schnack 2013). Endopodal spine length was used to distinguish species of the *similis*-subgroup (Böttger-Schnack 1999). However, in *T. minuta* from the equatorial Pacific, the outer subdistal spine is almost equal in length to (P2) or shorter than (P3-P4) the outer distal spine, but it shares this characteristic with *T. umerus* from the equatorial Pacific. In present study, we found additional morphological differences to identify these two species: (i) the length ratio of the outer subdistal and outer spine in relation to the distal spine on the endopodal segment of P3-P4 is larger in *T. umerus* than in *T. minuta* (Table 2). (ii) The tip of spine of the middle segment on P3 and P4 exopods reaches as far as the insertion of the proximal-most spine on the distal segment of *T. minuta*, but this spine is long, extending beyond the insertion of the proximal-most spine on the distal segment, in *T. umerus* (Fig. 3C, D and Fig. 6C, D). Morphometric characters, specifically, the proportional lengths of the exopodal outer spines on P3-P4, were used to distinguish *Oncaea cristata* from *O. crypta* (Böttger-Schnack 2005). Exopodal spine length was also used in the key developed by Heron & Bradford-Grieve (1995) to distinguish *T. conifera* from *T.* quadrata (Heron & Bradford-Grieve 1995).

Oncaeidae copepods are the most dominant smaller meso-zooplankton in equatorial Pacific (Kang *et al*. 2004, 2007). However, copepods have historically been underestimated, due to the use of nets with meshes ＞200-333 μm, which fail to capture the smallest species (Hopcroft *et al*. 2001). Recently in the study area, taxonomic study with fine net of 60 μm mesh size shows that many oncaeid copepods are smaller than 0.5 mm in body length (Cho 2011). To overcome the numerous loss, as yet undescribed microcopepod species in the collection, in particular the oncaeid copepods, using fine-mesh net would be desirable.

After the detailed descriptions and illustration of *Triconia* species by Böttger-Schnack (1999), *T. minuta* and *T. umerus* are known from the Mediterranean Sea (Krišinić and Grbec

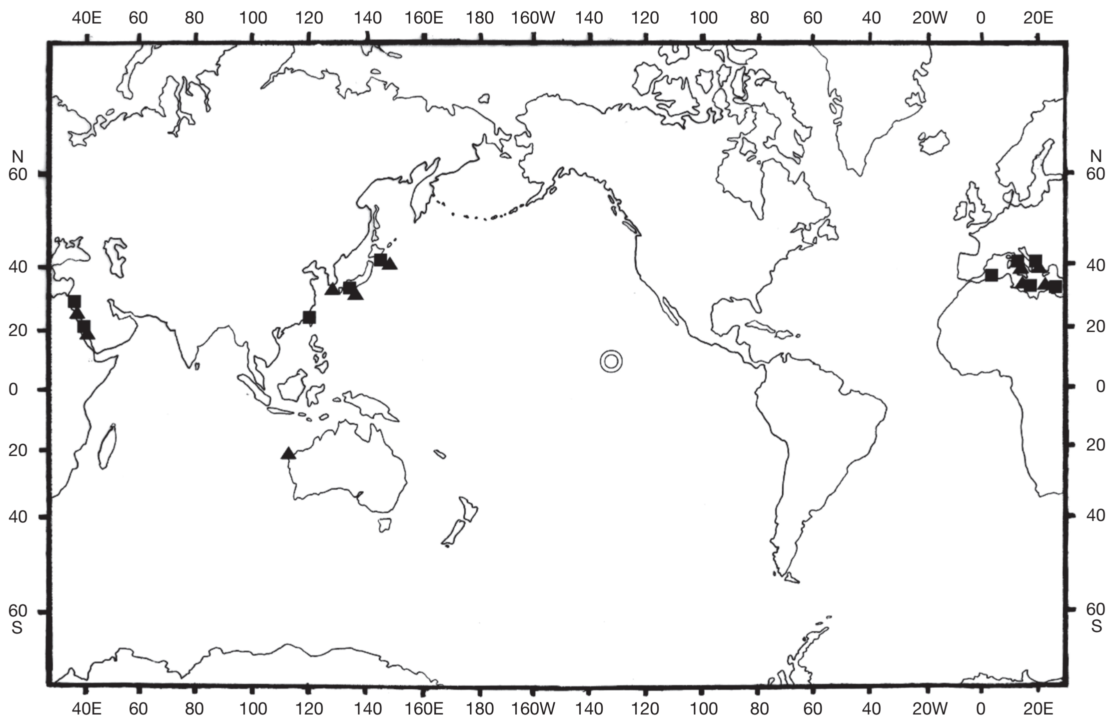

Fig. 8. Distribution of *Triconia minuta* and *T. umerus* based on previous records and on the present study (◎ - KOMO). References are: *T. minuta* (■) Böttger-Schnack (1999), Böttger-Schnack *et al*. (2001), Krišinić and Grbec (2002), Hsieh *et al*. (2004), Nishibe and Ikeda (2004), Di Capua and Boxshall (2008), Böttger-Schnack *et al*. (2008), Böttger-Schnack and Schnack (2009), Nishibe *et al*. (2009); *T. umerus* (▲) Böttger-Schnack and Boxshall (1990), Böttger-Schnack (1999), Böttger-Schnack *et al*. (2001), Krišinić and Grbec (2002), Nishibe and Ikeda (2004), Di Capua and Boxshall (2008), Böttger-Schnack *et al*. (2008), McKinnon *et al*. (2008), Böttger-Schnack and Schnack (2009), Nishibe *et al*. (2009), Wi *et al*. (2011).

2002; Di Capua and Boxshall 2008; Böttger-Schnack *et al*. 2001; Böttger-Schnack and Schnack 2009) and the northwest Pacific (Nishibe and Ikeda 2004; Nishibe *et al*. 2009), *T. umerus* from the northeast Indian Ocean (Mckinnon *et al*. 2008), and *T. minuta* from the northeast Taiwan Strait (Hsieh *et al*. 2004), Recently, *T. umerus* was also identified in the southern part of Korean waters (Wi *et al*. 2011). This study reports the distribution of *T. minuta* and *T. umerus* in the tropical Pacific for the first time. These studies demonstrate the world-wide distribution of these two species from coastal to oceanic waters.

ACKNOWLEDGEMENT

We thank two anonymous referees for the constructive comments that improved the quality of this manuscript. This research was supported by the Ministry of Oceans and Fisheries of Korea (PM59352).

CORRECTIVE NOTE

In the article by Wi *et al*. 2011, the following corrections should be made: p 596, the legend of figure 5: Instead of "*Triconia denticula* sp. nov. Female (holotype): (A) P1, posterior ..." it should read "*Triconia umerus*. Female: (A) Habitus, dorsal view; (B) same, lateral view; (C) P5-bearing somite and genital double-somite, lateral view; (D) P6, dorsal."

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Received: 17 February 2017
Revised: 21 March 2017
Revision accepted: 21 March 2017