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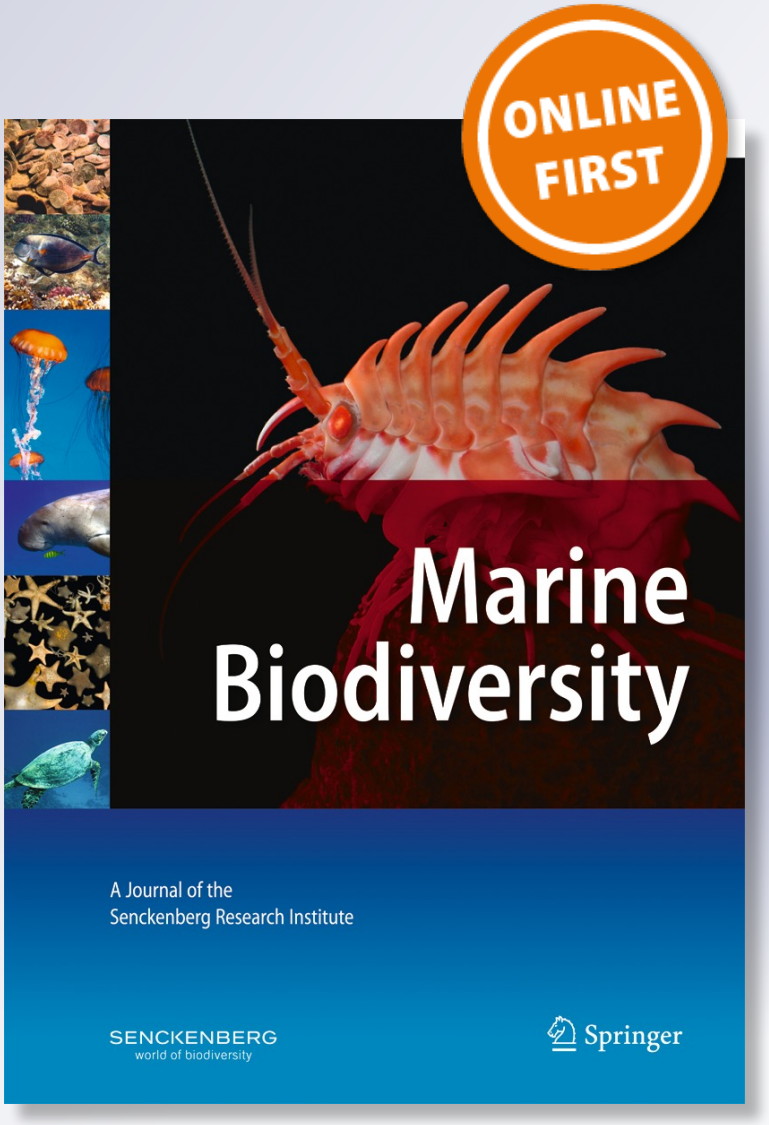

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ORIGINAL PAPER

Poecilostomatoid copepods associated with two species of widely distributed corals, *Galaxea astreata* (Lamarck, 1816) and *Galaxea fascicularis* (Linnaeus 1767), in the South China Sea

Yu-Rong Cheng[1] · **Chang-Feng Dai**[1]

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Abstract Seven species of copepods (Copepoda, poecilostomatoida) including two new species and five new records are described as associates of two widely distributed scleractinian corals, *Galaxea astreata* (Lamarck 1816) and *Galaxea fascicularis* (Linnaeus 1767), from Dongsha atoll (Pratas Island) in the South China Sea (SCS). They are: *Anchimolgus amplius* nov. sp., *Anchimolgus contractus* Humes 1979, *Anchimolgus nasutus* Humes 1996, *Anchimolgus tanaus* Humes 1991, *Clamocus spinifer* Humes 1979, *Karanges hypsorophus* Humes 1979, and *Xarifia dongshensis* nov. sp. *Anchimolgus amplius* nov. sp. can be readily distinguished from its congeners by the following features: (1) the larger body size (1.95 mm), (2) the three digitiform processes on the convex side of the mandible, (3) the third segment of leg 4 exopod arming with four spines, (4) the slender genital double-somite, (5) the caudal ramus with ratio less than 3:1, and (6) the second segment of abdominal somites distinctly shorter than others. *Xarifia dongshensis* nov. sp. can be readily distinguished from its congeners by the possession of (1) the bulge on the second segment of antenna, (2) the body without lateral processes or knobs, (3) the second segment of exopod of leg 1 bearing with one spine, (4) the armature of antennule being 3, 16, 4, 2 + 1 aesthetasc, and 4 + 1 aesthetasc, (5) the caudal ramus with three terminal setae, and (6) the tip of mandible with unilateral spinules. The three records of *Anchimolgus* species seem to have larger body size/appendages and more digitiform lobes on the convex side of the mandible than those from the Great Barrier Reef, New Caledonia, and Moluccas. Until now, 18 species of symbiotic copepods have been known to be associated with *Galaxea* corals.

Keywords Symbiotic copepods · Scleractinian corals · New species · Dongsha atoll

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Introduction

Copepods have been highly successful in forming associations with many marine invertebrates. They have developed more associations with cnidarians (more than 400 species; approximately 28 % of 1500 known species from invertebrate hosts) in their evolutionary history, and the story of their success is best told by observing their presence on so many cnidarians (Humes 1985a, 1994). Within the Cnidaria, the greatest numbers of them (more than 180 species; approximately 41 %) are associates of scleractinian hosts and, in particular, more than 90 % distribute in Indo-Pacific waters (Humes 1979a, 1985a). In contrast, only a few species of coral-associated copepods (<10 %) were discovered from the Atlantic due to several perturbed events reducing the diversity of their host corals, such as the fluctuation of sea levels, low water temperatures, and the isolation in geological histories (Stock 1988). The communities of coral-associated copepods thus showed dramatic changes in various geographic regions and resulted in having varied fauna in the Indian, Pacific, and Atlantic Oceans. For example, the great majority of coral-associated copepods in the Indo-Pacific are Lichomolgidae Kossmann 1877 (ecto-associated) and

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Xarifiidae Humes 1960 (endo-parasitic copepods), while Asterocheridae Giesbrecht 1899 and Corallovexiidae Stock, 1975 are predominant in the Atlantic (Stock 1988). Although the main reason for diverse coral-associated copepods among major oceans is still unknown, the number of new taxa appears to be increasing rapidly in the near future, especially from those rarely explored areas and un-examined host corals. Uncovering the species composition of symbiotic copepods from widely distributed corals might not only contribute to our knowledge on copepod species diversity, but also provide a suitable model for addressing the issues of global distribution of coral-associated copepods and their relationships in evolutionary history.

Galaxea Oken 1815 is a genus of scleractinian corals widely distributed throughout the Indo-Pacific, ranging from the eastern coast of Africa and the Red Sea to the Tuamotus in French Polynesia (Veron 1986). Up to now, a total of 16 species in eight genera of coral-associated copepods from the *Galaxea* corals have been discovered (Humes 1979b, 1985b, 1991, 1996). They are: *Anchimolgus* Humes and Stock, 1972 (six species), *Clamocus* Humes, 1979 (one species), *Hetairosyna* Humes, 1991 (two species), *Hetairosynopsis* Humes 1996 (one species), *Karanges* Humes, 1979 (two species), *Asterocheres* (Humes 1996)(one species), *Pterinopsyllus* Brady, 1880 (one species), and *Xarifia* Humes 1960 (two species) (see Table 1). Although only a few locations in the Indo-Pacific have been surveyed (see Humes 1996, Table 1), this has already provided a preliminary picture for us to understand the distribution of copepods associated with *Galaxea* corals in Indian and southwest Pacific Ocean. However, little is known from the South China Sea (SCS), the largest marginal sea between the Indian and Pacific Oceans. Herein, we examined coral-associated copepods from two widely distributed corals, *Galaxea astreata* (Lamarck 1816) and *Galaxea fascicularis* (Linnaeus 1767), collected from shallow water reefs at Dongsha atoll (also known as the Pratas Island) in SCS. A total of seven poecilostomatoids including two new species and five new records are reported. Combined with the results from previous studies, there are now 18 species of symbiotic copepods known to be associated with *Galaxea* corals.

Materials and methods

Three fragments of *Galaxea astreata* (Lamarck 1816) and 27 fragments of *Galaxea fascicularis* (Linnaeus 1767) colonies (approximately 30 polyps) were collected by scuba diving from coral reefs at Dongsha atoll in 2011 and 2015. Coral fragments were placed in separate bags while in the water, and transported to the laboratory for examination of copepods. Each coral together with sea water in the bag was emptied into a bucket to which sufficient 95 % ethyl alcohol was added to make it approximately a 5 % solution. After several hours, the copepods would leave the corals, and then fell to the bottom of the containers. The water was poured through a fine net (mesh size approximately 100 μm). The copepods were picked from the sediment and preserved in 70 % ethanol. The copepod samples were later cleared in 85 % lactic acid for 1 to 2 h, then dissected on a wooden slide under a dissecting microscope (Humes and Gooding 1964). The removed body parts and appendages were examined under a compound microscope with a series of magnifications up to 1000 times. All drawings were made with the aid of a drawing tube.

Results

Poecilostomatoida Thorell 1859

Anchimolgidae Humes and Boxshall 1996

Anchimolgus Humes and Stock 1972

Anchimolgus amplius nov. sp.

(Figs. 1, 2 and 3)

Material examined: All specimens were collected from two corals, *Galaxea astreata* (Lamarck 1816) and *Galaxea fascicularis* (Linnaeus 1767), at Dongsha atoll in the South China Sea. For *G. fascicularis*, 1 ♀ obtained from a colony collected at 4 m depth (20°38′55″N, 116°54′51″E) on 8 April 2011; 13 ♀♀ and 7 ♂♂ from five colonies of the same coral species taken at 7 m depth (20°41′12″N, 116°49′56″E) on 10 April 2011; 1 ♀ and 7 ♂♂ from two colonies taken at 12 m depth (20°35′39″N, 116°45′51″E) on 31 March 2015; 24 ♀♀ and 40 ♂♂ from nine colonies taken at 4–5 m depth (20°42′37″N, 116°49′05″E) on 2 April 2015; 14 ♀♀ and 55 ♂♂ from four colonies taken at 3 m depth (20°42′29″N, 116°44′22″E) on 4 April 2015. For *G. astreata*, 1 ♀ and 2 ♂♂ obtained from a colony taken at 12 m depth (20°35′39″N, 116°45′51″E) on 31 March 2015; 2 ♀♀ and 2 ♂♂ from a colony taken at 4–5 m depth (20°42′37″N, 116°49′05″E) on 2 April 2015. One female holotype (ASIZCR000330) and one male allotype (ASIZCR000331) deposited in the Biodiversity Research Museum, Academia Sinica, Taipei, Taiwan, and all the paratypes deposited in the Institute of Oceanography, National Taiwan University, Taipei, Taiwan.

Female

Body (Fig. 1a, b) large, with moderately broad prosome and slender urosome. Body length of dissected specimen 1.95 mm (1.86–2.03 mm) and greatest width 0.84 mm (0.79–0.88 mm), based on five specimens measured in lactic acid. Segmentation of body distinct. Cephalosome separated from first pedigerous somite by dorsal suture line (Fig. 1a). Urosome (Fig. 1b) 5-segmented. Fifth pedigerous somite (Fig. 1a, b) in dorsal view 144 × 338 μm. Genital double-

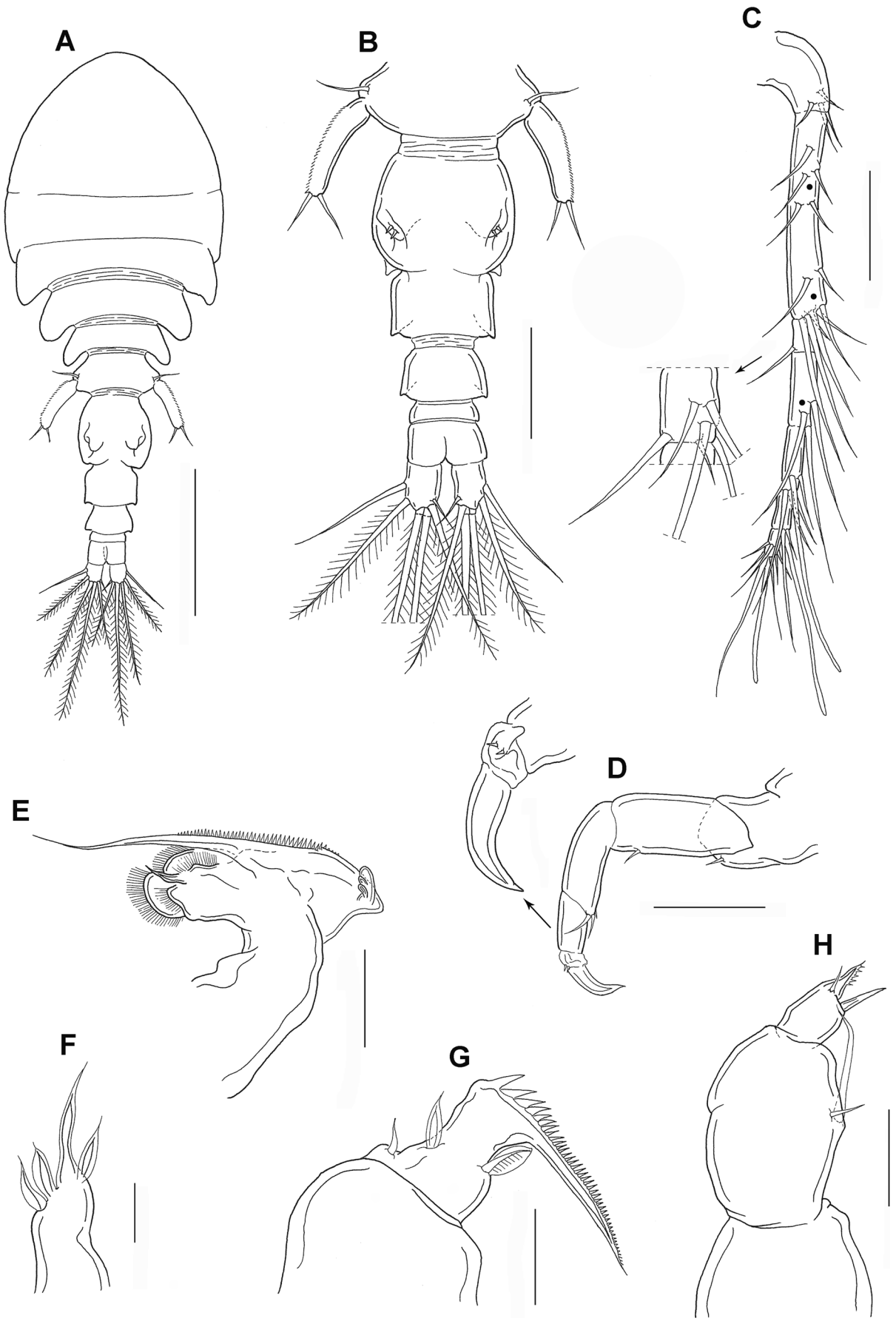
Table 1 Copepods associated with scleractinian corals of the genus *Galaxea*

Copepod symbiont	Host coral	Distribution	Reference
Order Cyclopoida			
Family Pterinopsyllidae			
Pterinopsyllus stirpipes	*Galaxea* sp.	Madagascar	Humes 1996
Order Poecilostomatoida			
Family Anchimolgidae			
Anchimolgus amplius nov. sp.**	*Galaxea astreata* *Galaxea fascicularis*	Dongsha Islands	This study
Anchimolgus abbreviatus	*Galaxea fascicularis*	New Caledonia	Humes 1996
	Galaxea horrescens	Australia	Humes 1991
Anchimolgus compressus	*Galaxea fascicularis*	Moluccas New Caledonia	Humes 1996
*Anchimolgus contractus**	*Galaxea astreata*	Dongsha Islands	This study
	Galaxea fascicularis	Dongsha Islands	This study
		New Caledonia	Humes 1996
		Moluccas	Humes 1979b
Anchimolgus moluccanus	*Galaxea fascicularis*	Moluccas	Humes 1996
*Anchimolgus nasutus**	*Galaxea fascicularis*	Dongsha Islands	This study
		Moluccas New Caledonia	Humes 1996
*Anchimolgus tanaus**	*Galaxea astreata* *Galaxea fascicularis*	Dongsha Islands	This study
	Galaxea horrescens	Australia	Humes 1991
	Galaxea fascicularis	New Caledonia	Humes 1996
*Clamocus spinifer**	*Galaxea astreata* *Galaxea fascicularis*	Dongsha Islands	This study
	Galaxea fascicularis	Moluccas	Humes 1979b
	Galaxea fascicularis	New Caledonia	Humes 1996
Karanges galaxeanus	*Galaxea fascicularis*	Moluccas	Humes 1979b
*Karanges hypsorophus**	*Galaxea fascicularis*	Dongsha Islands Moluccas New Caledonia	This study Humes 1979b
Family Xarifiidae			
Xarifia exserens	*Galaxea fascicularis*	Moluccas	Humes 1985b
Xarifia dongshensis nov. sp.**	*Galaxea fascicularis*	Dongsha Islands	This study
Xarifia sp.	*Galaxea astreata*	Madagascar	Humes 1985b
Order Siphonostomatoida			
Family Asterocheridae			
Asterocheres serrulatus	*Galaxea fascicularis*	Madagascar	Humes 1996
Hetairosyna galaxeae	*Galaxea fascicularis*	Moluccas	Humes 1991
Hetairosyna wedensis	*Galaxea fascicularis*	Moluccas	Humes 1996
Hetairosynopsis bucculentus	*Galaxea astreata* *Galaxea fascicularis* *Galaxea* sp.	Madagascar	Humes 1996

* Refers to the newly recorded species and ** stands for new species in this study

somite (Fig. 1a, b) in dorsal view 325 × 263 μm, with segment notch in anterior two-thirds and areas of attachment of egg sacs located dorso-laterally. Abdomen (Fig. 1b) 3-segmented, three somites from anterior to posterior 100 × 156, 34 × 125,

Fig. 1 *Anchimolgus amplius* new species, female. **a**, habitus, dorsal; **b**, urosome, dorsal; **c**, antennule; **d**, antenna; **e**, mandible; **f**, maxillule; **g**, maxilla; **h**, maxilliped. Scale bar: **a**, 0.5 mm; **b**, 0.2 mm; **c**, **d**, 0.1 mm; **e**, **g**, and **h**, 0.04 mm; **f**, 0.02 mm



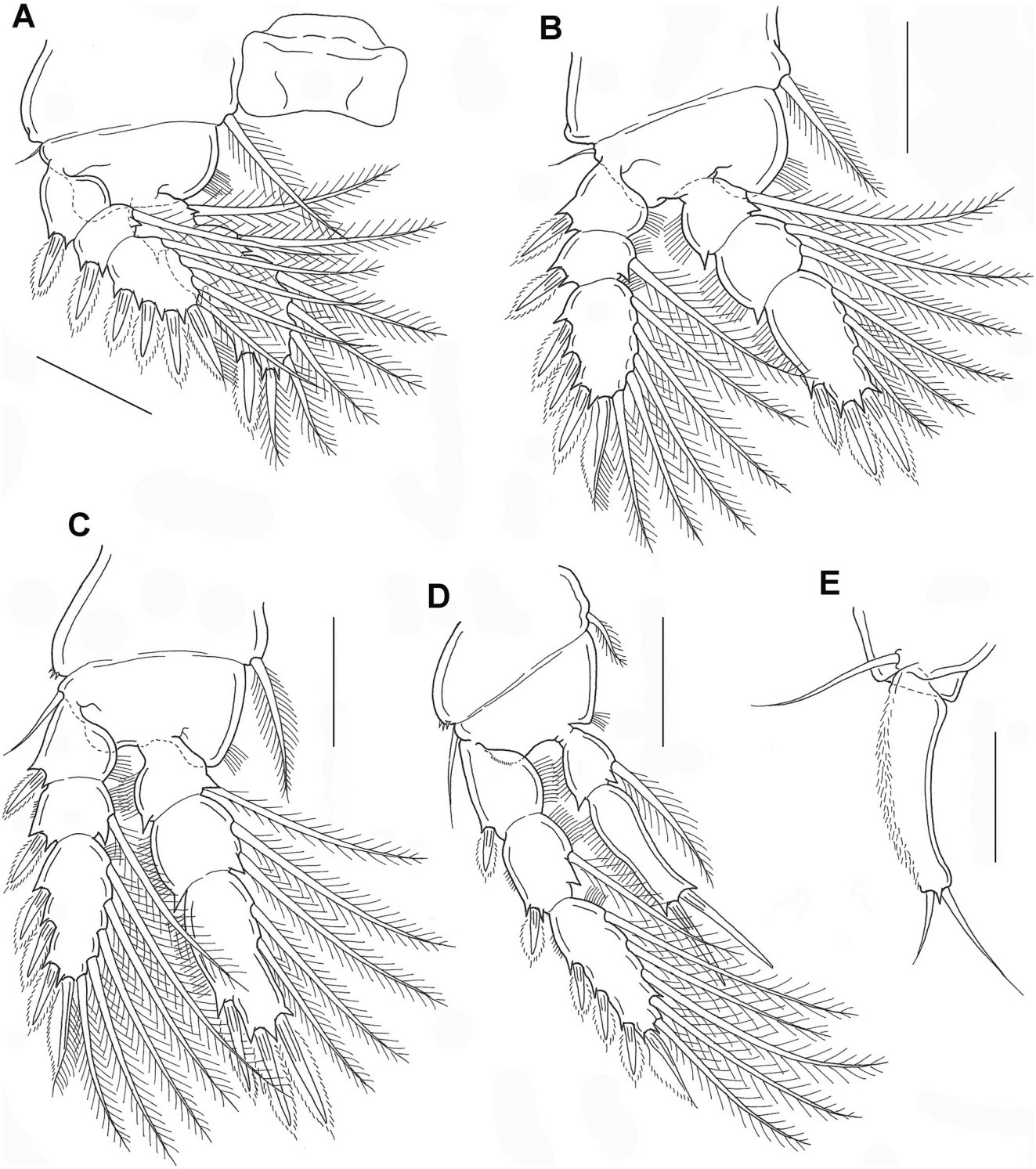


Fig. 2 *Anchimolgus amplius* new species, female. **a**, leg 1; **b**, leg 2; **c**, leg 3; **d**, leg 4; **e**, leg 5. Scale bar: **a**–**e**, 0.05 mm

and 81 × 144 μm, second somite dramatically shorter than others. Caudal ramus (Fig. 1a, b), subquadrate, only a little longer than wide, in dorsal view 81 × 69 μm, armed with six setae. Surface of body without setules (Fig. 1a, b). Egg sac not seen.

Antennule (Fig. 1c) 478 μm long, 7-segmented. Lengths of segments from anterior to posterior: 66, 191, 30, 69, 63, 34, and 25 μm. Armature: 4, 13, 6, 3, 4 + 1 aesthetasc, 2 + 1 aesthetasc, and 7 + 1 aesthetasc. Antenna (Fig. 1d) 399 μm long including claw, 4-segmented, the lengths from first to

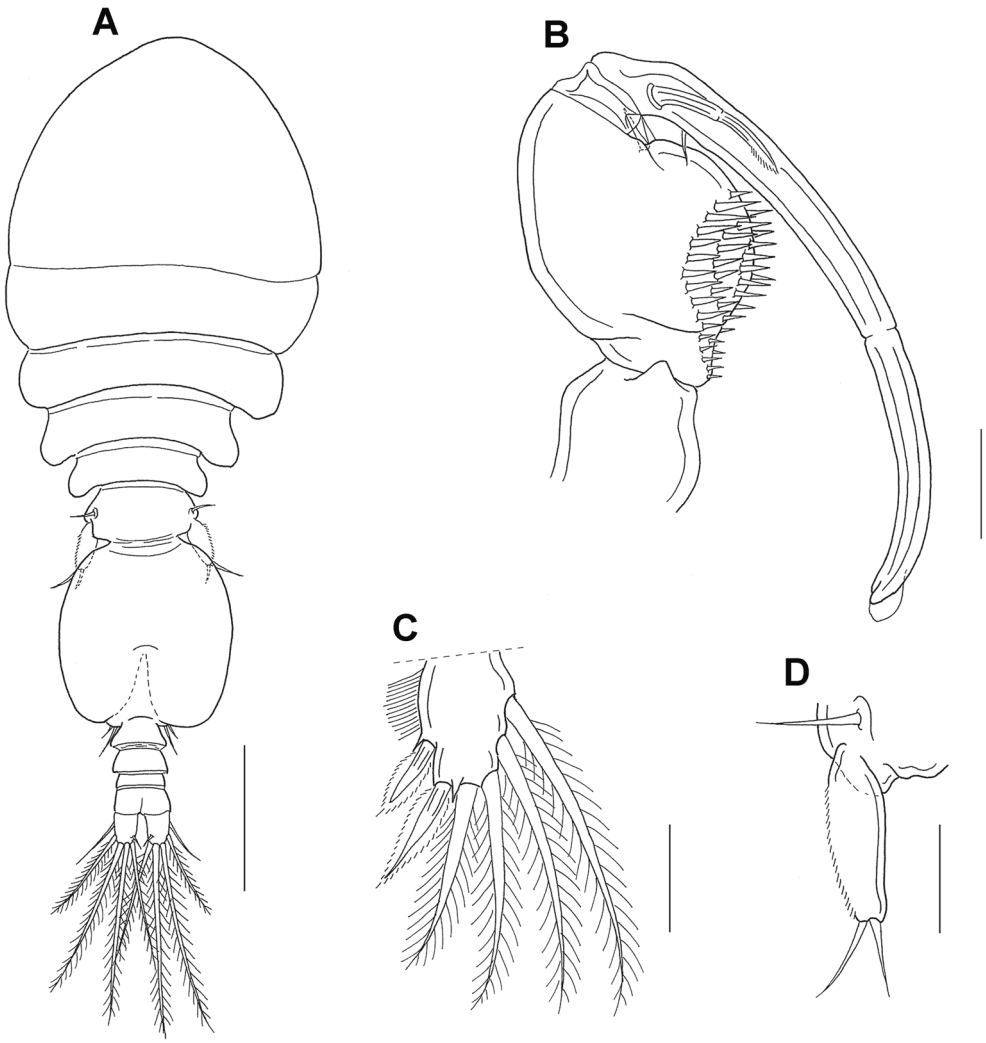


Fig. 3 *Anchimolgus amplius* new species, male. **a**, habitus, dorsal; **b**, maxilliped; **c**, first segment of leg 1; **d**, leg 5. Scale bar: A, 0.1 mm; **b**–**d**, 0.05 mm

fourth segments: 94, 125, 69, 58 μm, respectively. Armature: 1, 1, 3, 2, and one terminal claw 53 μm long. Mandible (Fig. 1e) with deeply proximal notch, inner margin distinctly bilobated with relatively small spinules, proximal lobe prominently protruded; convex side with three digitiform processes; terminal lash very slender and elongated, with spinules on outer margin. Maxillule (Fig. 1f) small, tipped with one subterminal long seta and three small setae. Maxilla (Fig. 1g) 2-segmented, first segment stout and unarmed; second segment armed with broad inner seta (foliaceous) and two setae on outer margin (one relatively larger seta and one proximal seta); distal lash almost at a right angle to segment, elongated, with serrate outer margin. Maxilliped (Fig. 1h) 3-segmented, first segment largest and unarmed; middle segment with slightly convex outer margin and two unequal setae (larger one about 50 μm) on inner side; small third segment tipped with one subterminal naked spine, one terminal spine bearing minute spinules, and one small seta.

Legs 1–4 (Fig. 2a-d) with 3-segmented exopods and 3-segmented endopods (except for leg 4 only with 2-segmented endopod). Armature formula of spines (in Roman numerals) and setae (in Arabic numerals) as follows:

	Coxa	Basis	Exopod	Endopod
Leg 1	0-1	1-0	I-0; I-1; IV + 4	0-1; 0–1; I + 5
Leg 2	0-1	1-0	I-0; I-1; IV + 5	0-1; 0–2; III + 3
Leg 3	0-1	1-0	I-0; I-1; IV + 5	0-1; 0–2; III + 2
Leg 4	0-1	1-0	I-0; I-1; IV + 5	0-1; II

Free segment of leg 5 (Fig. 2e) 190 × 50 μm, proximally expanded, with several rows of spinules on outer margin and 2 terminal setae.

Leg 6 (Fig. 1b) represented by two small setae in genital area.

Male

Body (Fig. 3a) similar to that of the female. Surface of body smooth. Body length of dissected specimen 1.47 mm (1.38–1.52 mm) and greatest width 0.53 mm (0.49-0.55 mm), based on five specimens measured in lactic acid. Urosome 6-

segmented. Abdomen (Fig. 3a) 4-segmented, from anterior to posterior 27 × 55, 22 × 53, 14 × 44, and 23 × 53 μm, third somite slightly shorter than others. Caudal ramus as in the female, but much smaller.

Antennule, antenna, mandible, maxillule, and maxilla like the female, but antennule with three additional aesthetascs (two on second and one on fourth segments, as black dots indicated in Fig. 1c). Maxilliped (Fig. 3b) consisting of three segments and terminal claw; first and third segment unarmed; second segment broadest, with two equal inner setae and longitudinal rows of small spinules on inner margin; terminal claw evenly curved, with one large and one minute naked setae proximally.

Legs 1–4 as in the female, except for sexual dimorphism in endopod of leg 1 with third segment having formula II + 4 (Fig. 3c). Leg 5 (Fig. 3a, d) a small free segment with two setae and one adjacent dorsal seta on outer margin as in the female.

Leg 6 (Fig. 3a) represented by two small setae on posteroventral flap of genital segment.

Spermatophore not seen.

Etymology. The specific name based on the Latin adjective "amplius" which means additional. It alludes to the close relatedness of its congener, *Anchimologus abbreviatus* Humes 1991, but with additional spine on the terminal segment of exopod of leg 4 in this new species.

Remarks

The *Anchimolgus* Humes and Stock 1972 is the largest genus of Anchimolgidae Humes and Boxshall 1996, and it contains at least 34 species in the world (Boxshall and Halsey 2004; WoRMS Editorial Board 2016). Until now, as we are aware, only *Anchimologus abbreviatus* as well as the present new species have been known with the following characters: (1) the body length more than 1.61 mm, (2) the genital double-somite slender, (3) the outer margin of free segment of leg 5 with several spinules, (4) the caudal ramus with ratio less than 3:1, and (5) the second segment of abdominal somites distinctly shorter than others. However, the former species was only parasitic on the *Galaxea horrescens* (Dana 1846), but the latter species can be obtained by washing colonies of *Galaxea astreata* and *Galaxea fascicularis*. In addition, the *Anchimolgus amplius* n. sp. can be readily distinguished from *A. abbreviatus* by: (1) the larger body size (1.95 mm), (2) the convex side of the mandible with three digitiform processes, (3) the large spine on the middle segment of the maxilliped is longer and reaches to the tip of final segment, and (4) the third segment of leg 4 exopod arming with four spines.

Anchimolgus contractus Humes 1979

(Fig. 4)

Anchimolgus contractus Humes, 1979: 507–528, figs. 58–61

Host: *Galaxea fascicularis* (L.)

Localities: New Caledonia and Moluccas

Material examined: All specimens were collected from two corals, *Galaxea astreata* (Lamarck 1816) and *Galaxea fascicularis* (Linnaeus 1767), at the Dongsha atoll in the South China Sea. For *G. fascicularis*, 11 ♀♀ and 6 ♂♂ obtained from two colonies collected at 4 m depth (20°38′55″N, 116°54′51″E) on 8 April 2011; 15 ♀♀ and 5 ♂♂ from three colonies of the same coral species collected at 7 m depth (20°41′12″N, 116°49′56″E) on 10 April 2011; 16 ♀♀ and 5 ♂♂ from a colony taken at 12 m depth (20°35′39″N, 116°45′51″E) on 31 March 2015; 17 ♀♀ and 16 ♂♂ from a colony taken at 4–5 m depth (20°42′37″N, 116°49′05″E) on 2 April 2015; 10 ♀♀ and 6 ♂♂ from two colonies at 3 m depth (20°42′29″N, 116°44′22″E) on 4 April 2015. For *G. astreata*, 8 ♀♀ and 15 ♂♂ obtained from a colony taken at 12 m depth (20°35′39″N, 116°45′51″E) on 31 March 2015; 48 ♀♀ and 38 ♂♂ from two colonies taken at 4–5 m depth (20°42′37″N, 116°49′05″E) on 2 April 2015.

Remarks

Female body (Fig. 4a) with moderately slender prosome and not unusually thickened dorsoventrally. Body length of dissected specimen 0.95 mm (0.92–0.98 mm) and greatest width 0.43 mm (0.41–0.44 mm), based on five specimens measured in lactic acid. Male body (Fig. 4b) similar to that of the female. Body length of dissected specimen 0.86 mm (0.84–0.87 mm) and greatest width 0.35 mm (0.34–0.36 mm), based on five specimens measured in lactic acid.

Anchimolgus contractus can be distinguished easily from its congeners by two features of the female: (1) the shortest fourth segment of antennule (19 × 15 μm, Fig. 4c), and (2) the two spines on the posteroventral margin of the anal somite (Fig. 4e). It should be pointed out here that the specimen from SCS seems to have one more digitiform lobe on the convex side of the mandible (Fig. 4d) than the ones described by Humes (1979b). *Anchimolgus contractus* was first discovered living on *G. fascicularis* collected at Ricaudy Reef, New Caledonia and subsequently obtained from Karang Mie, Halmahera, and Banda, Moluccas. Thus, our discovery of it from *G. astreata* in the SCS constitutes a new host and locality records.

Anchimolgus nasutus Humes 1996

(Figs 5 and 6)

Anchimolgus nasutus Humes 1996: 1–49, figs. 5–9

Host: *Galaxea fascicularis* (L.)

Localities: New Caledonia and Moluccas

Material examined: All specimens were collected from a coral, *Galaxea fascicularis* (Linnaeus 1767), at Dongsha atoll in the South China Sea. 2 ♀♀ and 1 ♂ obtained from a *G. fascicularis* colony collected at 7 m depth (20°41′42″N, 116°47′08″E) on 29 March 2015; 2 ♀♀ and 3 ♂♂ from three

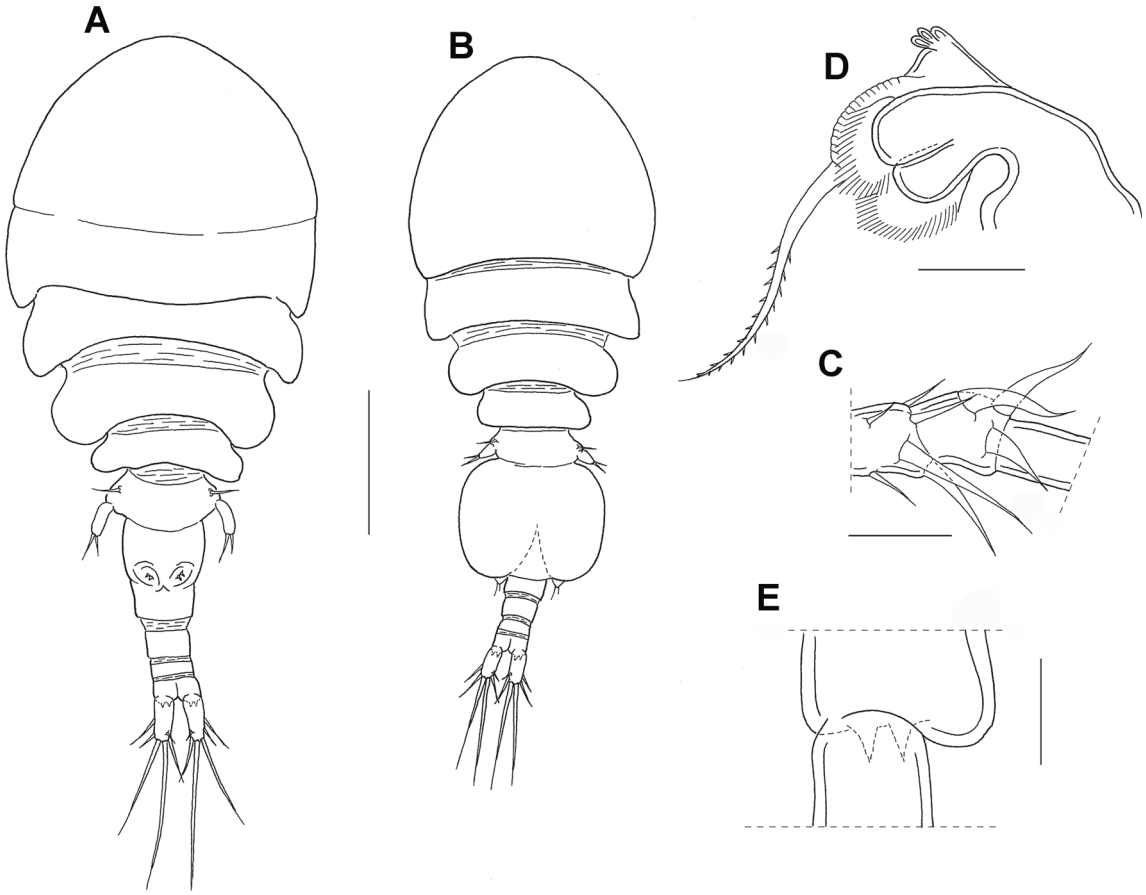


Fig. 4 *Anchimolgus contractus* Humes 1979. **a**, female habitus, dorsal; **b**, male habitus, dorsal; **c**, the fourth segment of antennule; **d**, mandible; **e**, the posteroventral margin of the anal segment. Scale bar: **a** and **b**, 0.2 mm; **c**–**e**, 0.02 mm

colonies of the same coral species taken at 15 m depth (20°35′39″N, 116°45′51″E) on 31 March 2015; 3 ♀♀ and 4 ♂♂ from two colonies taken at 4–5 m depth (20°42′37″N, 116°49′05″E) on 2 April 2015; 1 ♀ from a colony at 3 m depth (20°42′29″N, 116°44′22″E) on 4 April 2015.

Remarks

Female body (Fig. 5a) slender, body surface covered with setules. Body length of dissected specimen 1.64 mm (1.58–1.74 mm) and greatest width 0.59 mm (0.57–0.64 mm), based on five specimens measured in lactic acid. Male body (Fig. 6a) similar to that of the female. Body length of dissected specimen 1.32 mm (1.29–1.37 mm) and greatest width 0.45 mm (0.42–0.47 mm), based on five specimens measured in lactic acid. Maxilliped (Fig. 6b) robust, similar to the original description (see Humes 1996: Fig. 6f).

According to Humes (1996), it can be distinguished from all congeners by the following three features of the female: (1) the long snoutlike rostrum, (2) the long seta located dorsally and adjacent to the base of free segment of leg 5, (3) the setation of antenna, without seta on the second segment, and only two setae on the third segment. However, based on the comparison between the specimens of *A. nasutus* collected from SCS and those described by Humes (1996) from New Caledonia and Moluccas, there seems to have some differences in those three unique features and mandible structure. The specimens from SCS differ from type species in carrying the longer snoutlike rostrum (310 μm, Fig. 5b), the armature formula of antenna (1, 1, 3, 2, and one claw; second segment with many minute scalelike knobs on inner surface, Fig. 5c), three digitiform lobes on the convex side of mandible (Fig. 5d), and the longer seta (290 μm) adjacent to the free segment of leg 5 (Fig. 5e). Otherwise, they are identical.

Anchimolgus tanaus Humes 1991

(Figs. 7 and 8)

Anchimolgus tanaus Humes 1991: 1171–1231, figs. 22–24

Host: *Galaxea horrescens* (Dana, 1846) and *Galaxea fascicularis* (L.)

Localities: New Caledonia and Great Barrier Reef

Material examined: All specimens were collected from two corals, *Galaxea astreata* (Lamarck 1816) and *Galaxea fascicularis* (Linnaeus 1767), at Dongsha atoll in the South China Sea. For *G. fascicularis*, 2 ♂♂ obtained from a colony taken at 12 m depth (20°35′39″N, 116°45′51″E) on 31 March 2015; 3 ♀♀ and 3 ♂♂ from a colony taken at 3 m

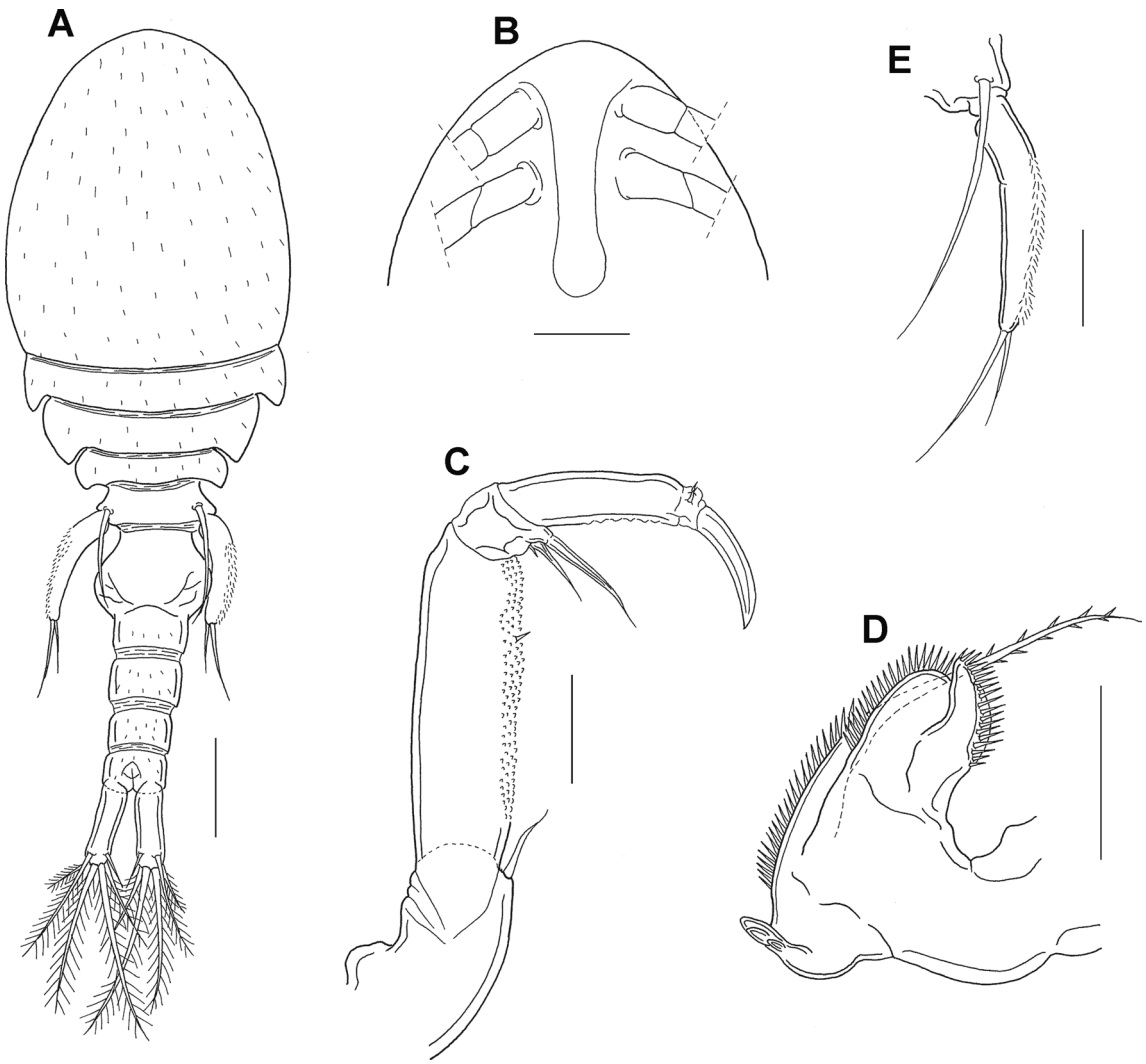


Fig. 5 *Anchimolgus nasutus* Humes 1996, female. **a**, habitus, dorsal; **b**, rostrum, ventral; **c**, antenna; **d**, mandible; **e**, leg 5. Scale bar: **a**, 0.2 mm; **b** and **e**, 0.1 mm; **c** and **d**, 0.04 mm

depth (20°42′29″N, 116°44′22″E) on 4 April 2015. For *G. astreata*, 1 ♀ and 1 ♂ obtained from a colony taken at 12 m depth (20°35′39″N, 116°45′51″E) on 31 March 2015.

Remarks

Female body (Fig. 7a) elongate and slender. Body length of dissected specimen 1.08 mm (1.04–1.12 mm) and greatest width 0.28 mm (0.27–0.30 mm), based on three specimens measured in lactic acid. Male body (Fig. 8a) similar to that of the female. Body length of dissected specimen 1.12 mm (1.06–1.14 mm) and greatest width 0.30 mm (0.28–0.32 mm), based on three specimens measured in lactic acid.

As in the case of *A. contractus* and *A. nasutus*, some differences are noted when comparing the specimens between our collections and previous studies. In our female specimens, the caudal ramus (265 × 25 μm, Fig. 7b) and free segment of leg 5 (168 × 48 μm, Fig. 7d) are longer than those from the Great Barrier Reef and New Caledonia. In addition, the specimens collected from SCS have four digitiform lobes (Fig. 7c) on the convex side of the mandible instead of only a single small process as shown in Humes (1991) and three minute lobes in the New Caledonian specimens (Humes 1996). In terms of male specimens, the antennule, antenna, mandible, maxillule, and maxilla of our specimens are similar to those described by Humes (1991). A similar concordance can also be observed in the structure of maxilliped (Fig. 8c), although the length of the claw is 197 μm (150 μm in Great Barrier Reef materials). However, some drastic differences are also noted, particularly in the caudal ramus (ratio 5.33:1, Fig. 8b) and the first segment of endopod of leg 1 (armature: II + 4, Fig. 8d). Such dissimilarities probably reflect local variation in geographically separated populations rather than providing evidence for specific distinctiveness. Pending analysis of molecular sequence data is necessary to address this issue.

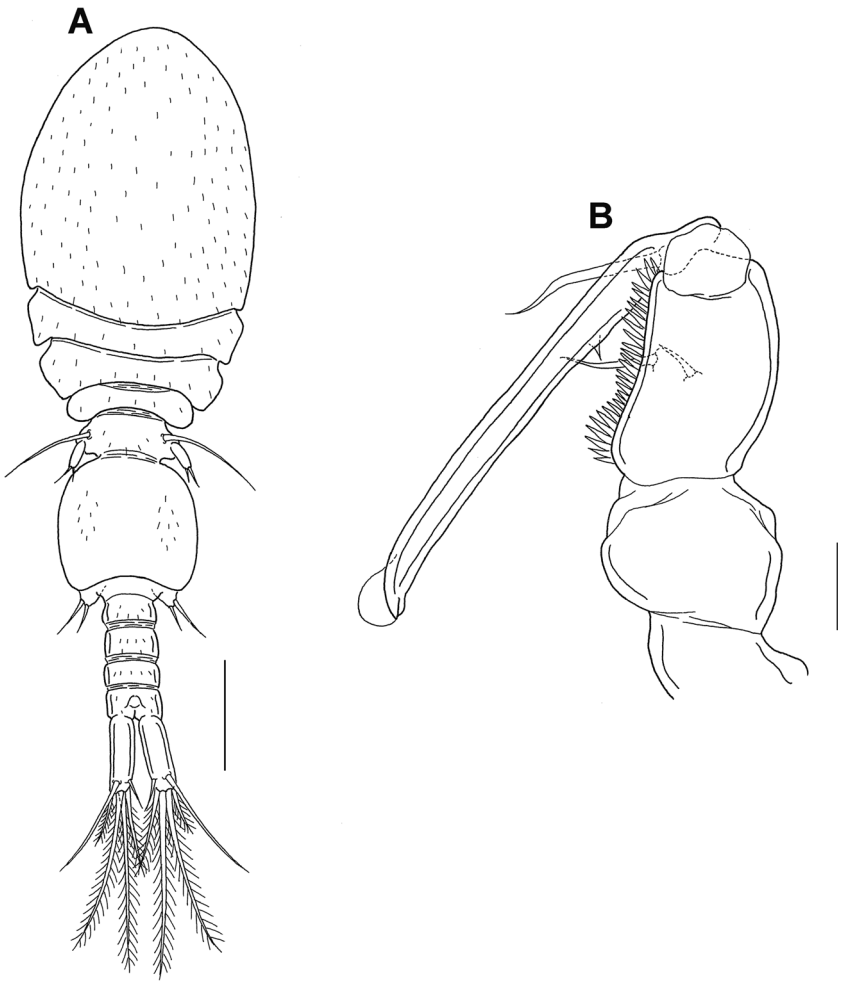


Fig. 6 *Anchimolgus nasutus* Humes 1996, male. **a**, habitus, dorsal; **b**, maxilliped. Scale bar: **a**, 0.2 mm; **b**, 0.04 mm

Anchimolgus tanaus has previously been found from *G. horrescens* collected at Big Broadhurst Reef, Great Barrier Reef and from *G. fascicularis* collected at Ricaudy Reef, New Caledonia. Our discovery of it from *G. astreata* in the SCS constitutes a new host and stretches the northern limit of this species to the western Northern Pacific.

Clamocus spinifer Humes, 1979

(Fig. 9)

Clamocus spinifer Humes, 1979: 507–528, figs. 1–28

Host: *Galaxea fascicularis* (L.)

Localities: New Caledonia and Halmahera

Material examined: All specimens were collected from two corals, *Galaxea astreata* (Lamarck 1816) and *Galaxea fascicularis* (Linnaeus 1767), at the Dongsha atoll in the South China Sea. For *G. fascicularis*, 2 ♀♀ and 1 ♂ obtained from a colony collected at 4 m depth (20°38′55″N, 116°54′51″E) on 8 April 2011; 2 ♂♂ from a colony of the same coral species taken at 7 m depth (20°41′12″N, 116°49′56″E) on 10 April 2011; 5 ♀♀ and 3 ♂♂ from a colony taken at 15 m depth (20°35′39″N, 116°45′51″E) on 31 March 2015; 4 ♀♀ and 3 ♂♂ from three colonies taken at 4–5 m depth (20°42′37″N, 116°49′05″E) on 2 April 2015; 5 ♀♀ and 2 ♂♂ from three colonies taken at 3 m depth (20°42′29″N, 116°44′22″E) on 4 April 2015. For *G. astreata*, 3 ♀♀ and 2 ♂♂ obtained from a colony taken at 12 m depth (20°35′39″N, 116°45′51″E) on 31 March 2015; 4 ♀♀ and 1 ♂ from a colony taken at 4–5 m depth (20°42′37″N, 116°49′05″E) on 2 April 2015.

Remarks

Female body (Fig. 9a) with prosome moderately broad. Body length of dissected specimen 0.86 mm (0.82–0.88 mm) and greatest width 0.39 mm (0.37–0.40 mm), based on five specimens measured in lactic acid. Male body (Fig. 9b) similar to that of the female. Body length of dissected specimen 0.83 mm (0.80–0.86 mm) and greatest width 0.34 mm (0.33–0.35 mm), based on five specimens measured in lactic acid. The maxilliped of our specimens (Fig. 9e) is similar to that described by Humes (1979b).

The two median terminal setae on the caudal ramus (Fig. 9c) and the two thorn-like setae on the fourth segment of the antennule (Fig. 9d) serve as a useful recognition character for *C. spinifer*. Our discovery of it from *G. astreata* in the

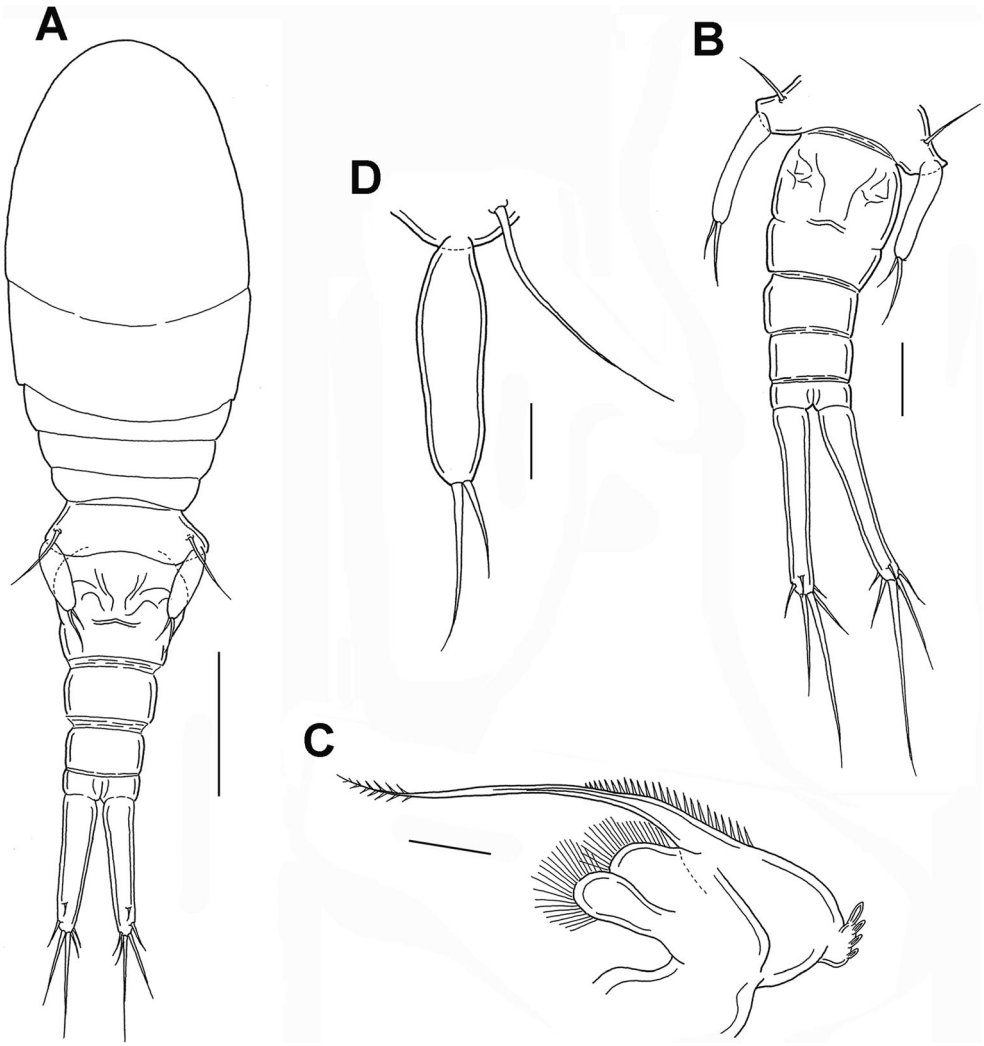


Fig. 7 *Anchimolgus tanaus* Humes 1991, female. **a**, habitus, dorsal; **b**, urosome, dorsal; **c**, mandible; **d**, leg 5. Scale bar: **a**, 0.2 mm; **b**, 0.1 mm; **c**, 0.02 mm; **d**, 0.05 mm

SCS constitutes a new host and stretches the northern limit of this species to the northern West Pacific.

Karanges hypsorophus Humes, 1979

Karanges hypsorophus Humes, 1979: 507–528, figs. 47–57

Host: *Galaxea fascicularis* (L.)

Localities: New Caledonia and Halmahera

Material examined: Only one female specimen was collected from a colony of *Galaxea fascicularis* (Linnaeus 1767) taken at 15 m depth (20°35′39″N, 116°45′51″E), at the Dongsha atoll, on 31 March 2015.

Remarks

This species has been known from *G. fascicularis* collected from Halmahera (Humes 1979b) and New Caledonia (Humes 1996). Our specimen is similar to the description of previous studies, except for the smaller body size (length 0.86 mm and greatest width 0.27 mm). Although only one female was found in the present study, our discovery of it from *G. fascicularis* in the SCS extends the northern limit of this species to the northern West Pacific.

Family Xarifiidae Humes 1960

Genus *Xarifia* Humes 1960

Xarifia dongshensis nov. sp.

(Figs. 10, 11 and 12)

Material examined: 3 ♀♀ and 2 ♂♂ obtained from washings of a colony of *Galaxea fascicularis* (Linnaeus 1767) collected at 4 m depth (20°38′55″N, 116°54′51″E) at the Dongsha atoll, on 8 April 2011. One female holotype (ASIZCR000332) and one male allotype (ASIZCR000333) deposited in the Biodiversity Research Museum, Academia Sinica, Taipei, Taiwan, and all the paratypes deposited in the Institute of Oceanography, National Taiwan University, Taipei, Taiwan.

Female

Body (Fig. 10a, b) slender, about 6–7 times longer than wide. Length 2.50 mm (2.46-2.55 mm) and greatest width 0.40 mm (0.39-0.41 mm), based on three specimens measured in lactic acid. Segmentation of somites indistinct. Region

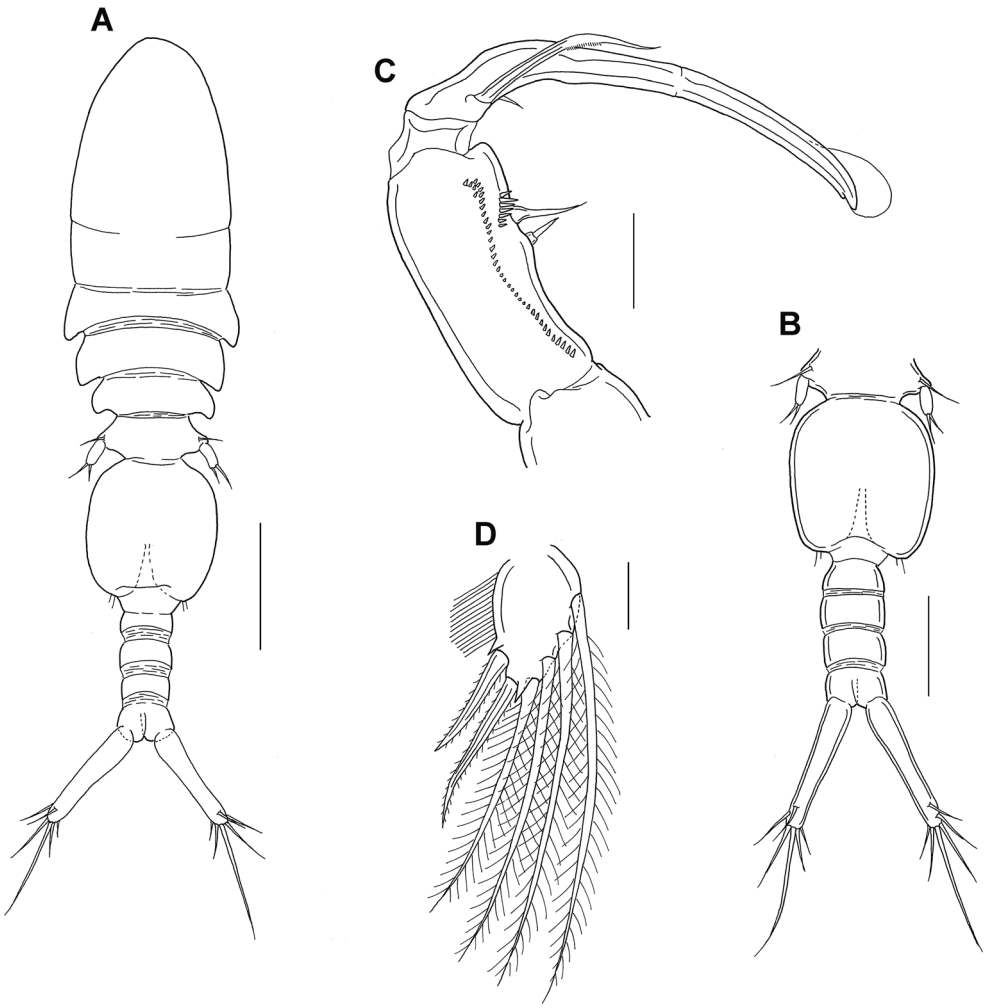


Fig. 8 *Anchimolgus tanaus* Humes 1991, male. **a**, habitus, dorsal; **b**, urosome, dorsal; **c**, maxilliped; **d**, the first segment of endopod of leg 1. Scale bar: **a**, 0.2 mm; **b**, 0.05 mm; **c**, 0.02 mm

dorsal to fifth legs rounded and smooth, without lateral processes or knobs (Fig. 10c). Genital and postgenital somites (Fig. 10b) slightly recurved upward. Postgenital somites (Fig. 10c) small, segmentation indistinct, only little longer than wide (128 × 116 μm). Areas of attachment of egg sacs located dorso-laterally. Egg sac not seen. Caudal ramus (Fig. 10d) elongate and pointed, 100 μm long, 25 μm wide near base, bearing three terminal setae and one lateral seta. Surface of body densely covered with long setules (Fig. 10a-c).

Antennule (Fig. 10e) 5-segmented; first to fifth segments 25 × 30, 34 × 21, 10 × 11, 10 × 9, 13 × 7 μm, respectively, from anterior to posterior. Armature: 3, 16, 4, 2 + 1 aesthetasc, and 4 + 1 aesthetasc. All setae naked. Antenna (Fig. 10f) 3-segmented; second segment with prominent posterodistal bulge; third segment bearing with a claw. Formula 1, 1, 2 + I + 1. Mandible (Fig. 10g) blade, tipped with unilateral spinules. Maxillule (Fig. 10h) tipped with two unequal setae and one small anterior process. Maxilla (Fig. 10i) 2-segmented; first segment unarmed but with three minute spiniform process; second segment drawn out into a pointed process with lamella and one medial seta. Maxilliped (Fig. 11a) 3-segmented; first segment with one large, distal protuberance; second segment with two medial inner setae; small third segment tipped with three small spines.

Legs 1–4 (Fig. 11b-d) with 3-segmented exopod and 2-segmented endopod. Formula of spines (in Roman numerals) and setae (in Arabic numerals) as follows:

	Coxa	Basis	Exopod	Endopod
Leg 1	0-0	1-0	0-0; I-0; I + 2	0-0; 2
Leg 2	0-0	1-0	I-0; 0–0; I + 2	0-0; 2
Legs 3	0-0	1-0	I-0; 0–0; I + 1	0-0; 1
Legs 4	0-0	1-0	I-0; 0–0; I + 1	0-0; 1

Leg 5 (Fig. 10a-c) 146 μm long, 85 μm wide near base, bearing two terminal setae. Dorsal seta hard to see.

Male:

Body (Fig. 12a, b) slender, similar to that of the female, about 7.5 times longer than wide. Length 2.75 mm (2.74-2.76 mm) and greatest width 0.36 mm (0.35-0.37 mm), based on two specimens measured in lactic acid. Caudal ramus as in the female. Body surface with long setules as in the female.

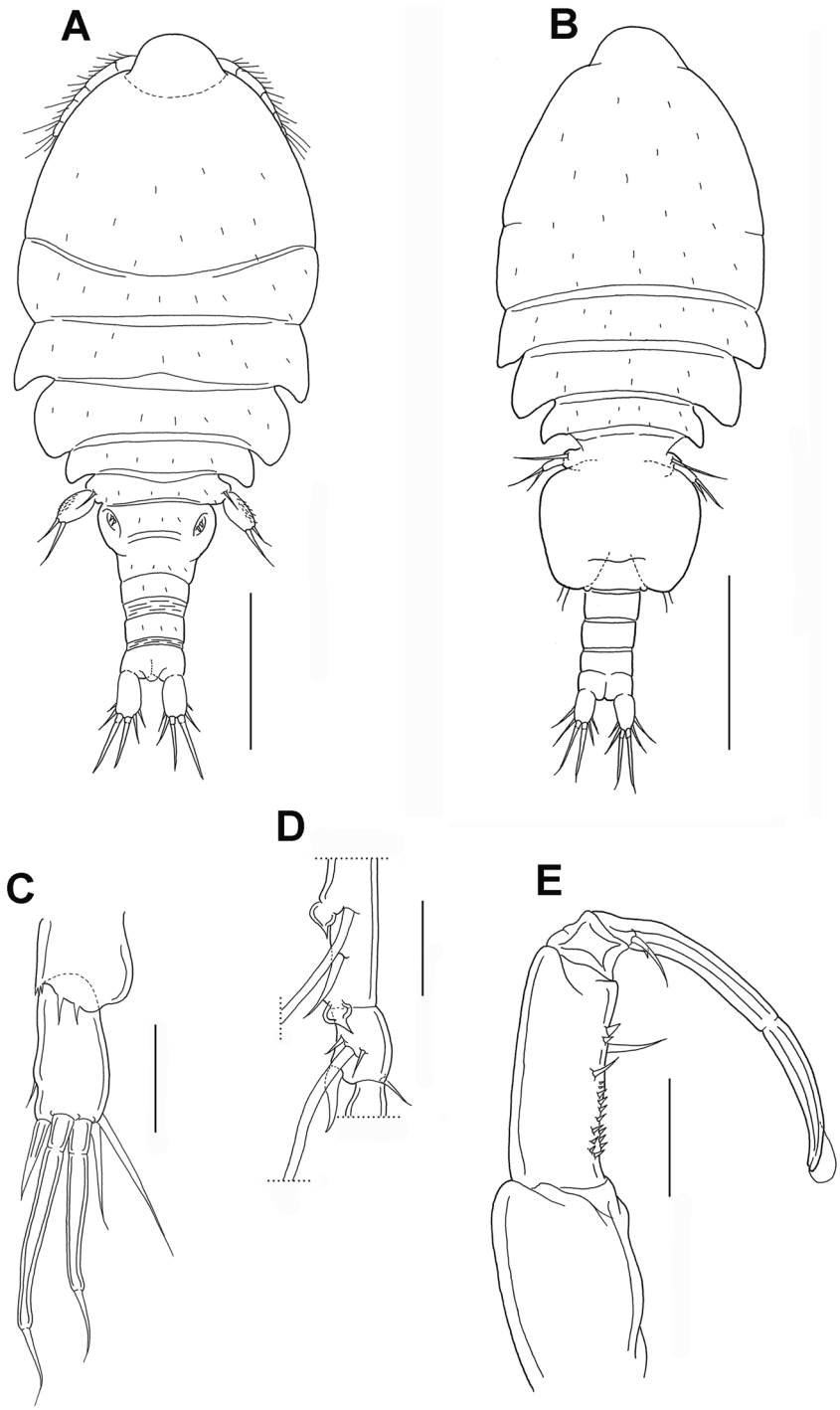


Fig. 9 *Clamocus spinifer* Humes 1979. **a**, female habitus, dorsal; **b**, male habitus, dorsal; **c**, the posteroventral margin of the anal segment; **d**, the fourth segment of the antennule; **e**, maxilliped of male. Scale bar: **a** and **b**, 0.2 mm; **c** and **e**, 0.04 mm; **d**, 0.02 mm

Antennule, antenna, mandible, maxillule, and maxilla like those in the female, but antennule with two aesthetasc added on second and third segment (at point indicated by a dot in Fig. 10e). Maxilliped (Fig. 12c) 4-segmented; first and third segment unarmed; second segment with two medial equal setae; fourth segment a claw with trifurcate tip, bearing two proximal setae and three basally located teeth on concave surface.

Legs 1–4 as in the female

Leg 5 (Fig. 12d) minute, with two terminal setae and one adjacent dorsal seta.

Leg 6 (Fig. 12b) represented by two small setae on posteroventral flap on genital somite.

Spermatophore not seen

Etymoology: The species is named after the type-locality Dongsha atoll.

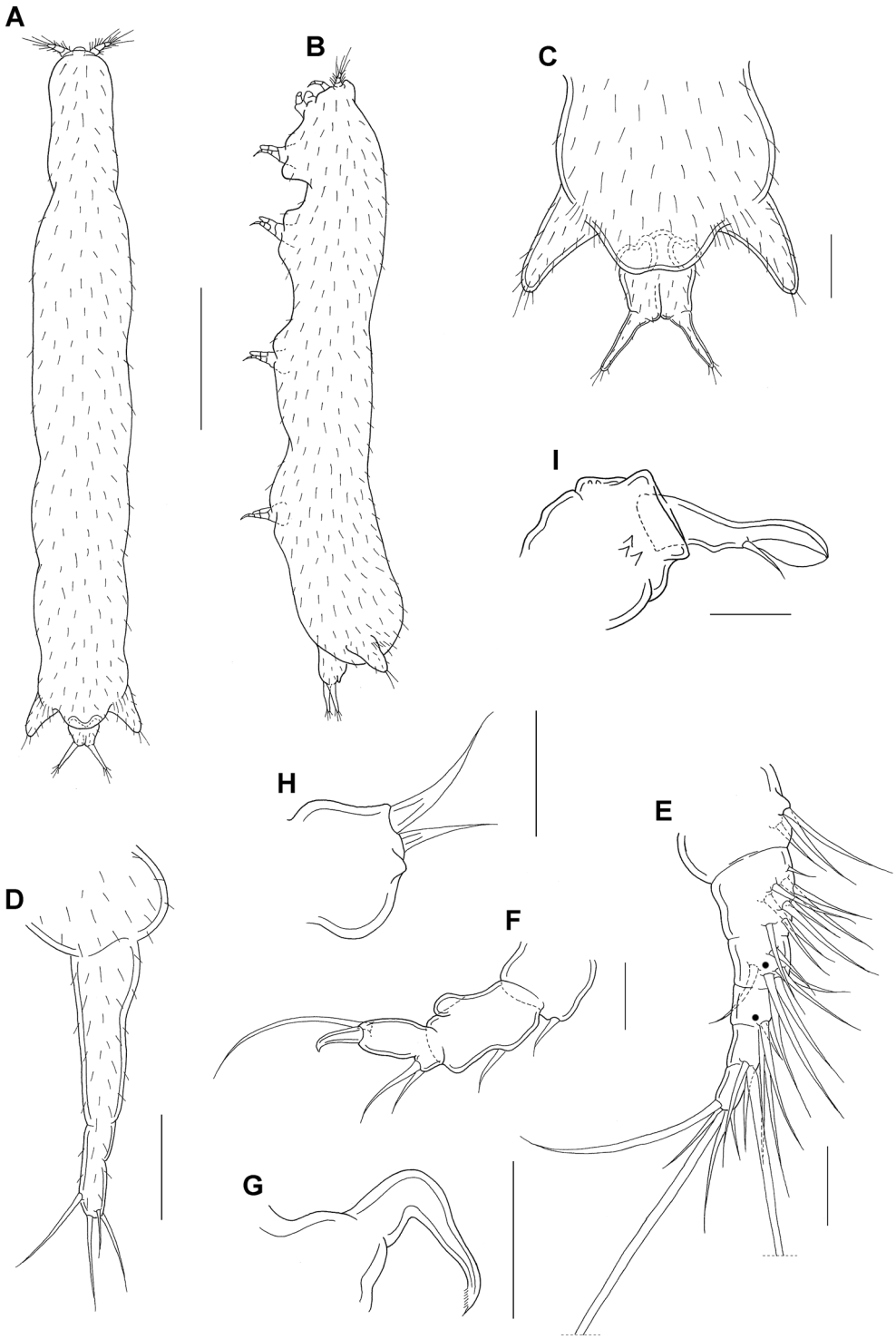


Fig. 10 *Xarifia dongshensis* new species, female. **a**, habitus, dorsal; **b**, habitus, lateral; **c**, urosome, dorsal; **d**, caudal ramus; **e**, antennule; **f**, antenna; **g**, mandible; **h**, maxillule; **i**, maxilla. Scale bar: **a** and **b**, 0.5 mm; **c**, 0.1 mm; **d**, 0.04 mm; E–I, 0.02 mm

Remarks

Among 86 species of xarifid copepods reported occurring in symbiosis with scleractinian corals (Walter and Boxshall 2016), only *Xarifia exserens* Humes, 1985 is similar to the present new species in possessing a bulge on the second segment of antenna in the female. However, the new species, *Xarifia dongshensis* nov. sp., can be readily distinguished from its congener by the following features: (1) without lateral processes or knobs, (2) the second segment of exopod of leg 1 bearing with one spine, (3) the armature of antennule being 3, 16, 4, 2 + 1 aesthetasc, and 4 + 1 aesthetasc, (4) caudal ramus with three terminal setae, and (5) tip of mandible with unilateral spinules.

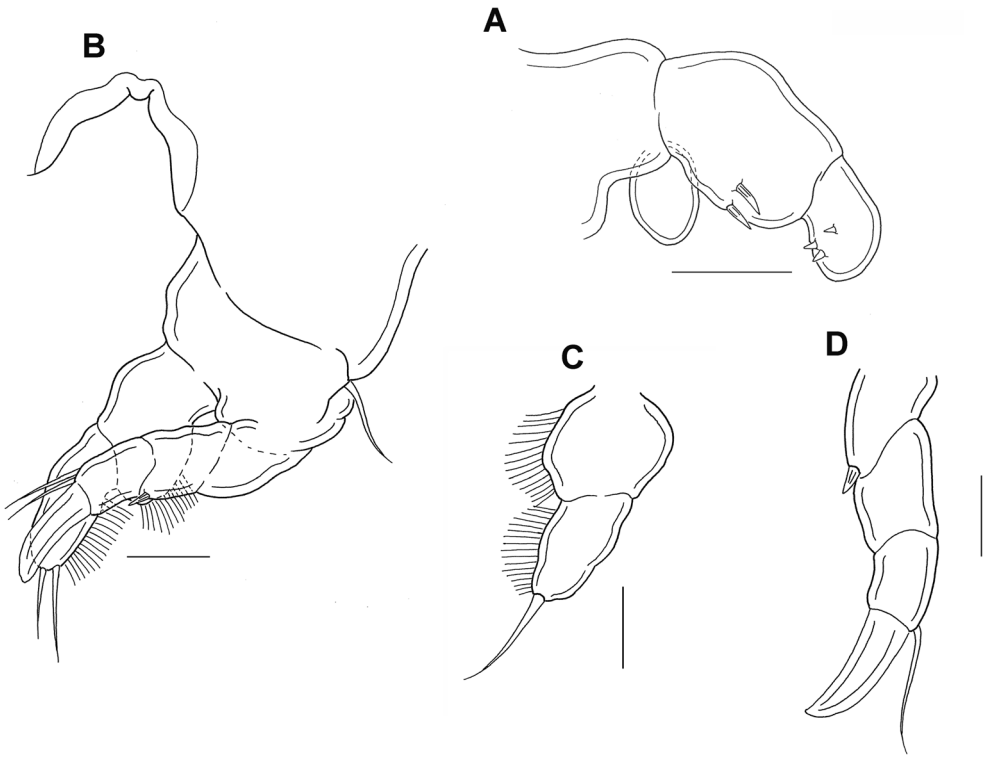


Fig. 11 *Xarifia dongshensis* new species, female. **a**, maxilliped; **b**, leg 1; **c**, endopod of leg 3; **d**, exopod of leg 4. Scale bar: **a**–**d**, 0.02 mm

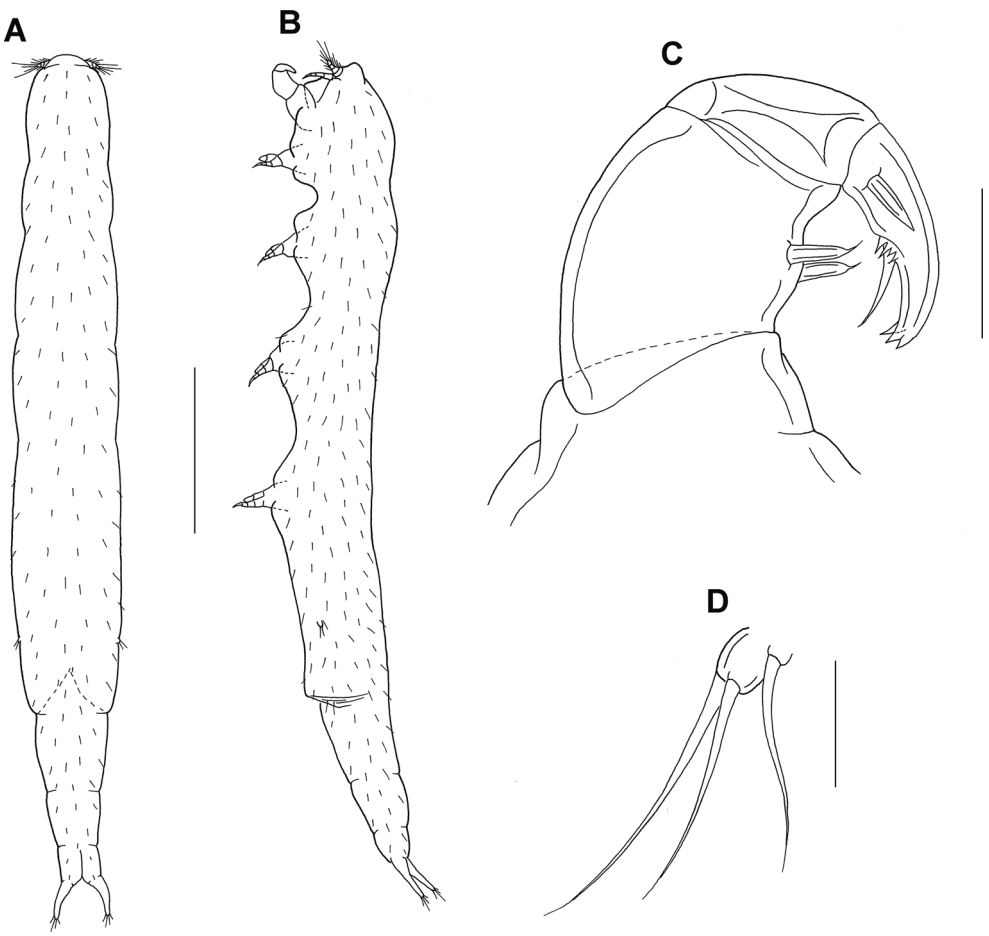


Fig. 12 *Xarifia dongshensis* new species, male. **a**, habitus, dorsal; **b**, habitus, lateral; **c**, maxilliped; **d**, leg 5. Scale bar: **a** and **b**, 0.5 mm; **c**, 0.04 mm; **d**, 0.02 mm

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