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Four new xarifiid copepods (Poecilostomatoida) associated with the scleractinian coral *Pavona explanulata* (Lamarck) from off Taiwan

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Abstract Four new xarifiid copepods are described. They were found in association with the scleractinian coral *Pavona explanulata* (Lamarck) occurring in shallow water reefs off Yenliao in northern Taiwan. The four species are: *Xarifia capillata* n. sp., *X. parva* n. sp., *X. pavonae* n. sp. and *X. taiwanensis* n. sp. They were found together in a single washing of the host coral. Previously, 13 species of copepods have been found in association with nine species of *Pavona* Lamarck. More than half (7/13) of these symbionts are members of *Xarifia* Humes, 1960.

Introduction

Copepods are a major group of associates on scleractinian corals in the Indo-Pacific (Humes, 1985, 1994). *Pavona* Lamarck is a genus of agariciid coral widely distributed throughout the Indo-Pacific (Veron, 1986).

So far, nine species of copepods have been reported occurring in symbiosis with the species of this genus. They are: *Anchimolgus gracilipes* Kim, 2007 from *P. danai* Milne Edwards & Haime; *Odontomolgus actinophorus* (Humes & Frost, 1964) from *P. angularata* Klunzinger, *P. cactus* (Forsskål), *P. danai*, *P. angularis* Klunzinger and *Pavona? venusta* (Dana); *O. pavonus* Kim, 2007 from *P. danai*; *O. rhadinus* (Humes & Ho, 1967) from *Pavona* sp.; *Paramolgus pavonae* Humes, 1994 from *Pavona praetorta* Dana; *Paramolgus setellus* Humes, 1994 from *Pavona praetorta*; *Xarifia diminuta* Humes & Ho, 1967 from *Pavona* sp.; *X. finitima* Humes, 1985 from *P. cactus* and *P. varians* Verrill; and *X. longipes* Humes, 1962 from *P. angulata*.

Since one coral species may host several species of parasitic copepods, Humes (1994) suggested that the copepod diversity might be higher than the diversity of their host corals. Kim (2006) proposed that the parasitic/symbiotic copepods from corals might be much more diverse than is known, and he also pointed out that the species composition of these coral copepods in different localities around Indo-Pacific might be quite different. This may also be true in regions of the northern Pacific, such as off Taiwan. Although only a few studies have been made so far on the corals of Taiwan, the same trend is already obvious (Cheng et al., 2007, 2008, 2009; Ho et al., 2008, 2010). In this paper, four new poecilostomatoid copepods associated with a colony of *Pavona explanulata* (Lamarck) are described from the shallow water reefs off Yenliao in northern Taiwan.

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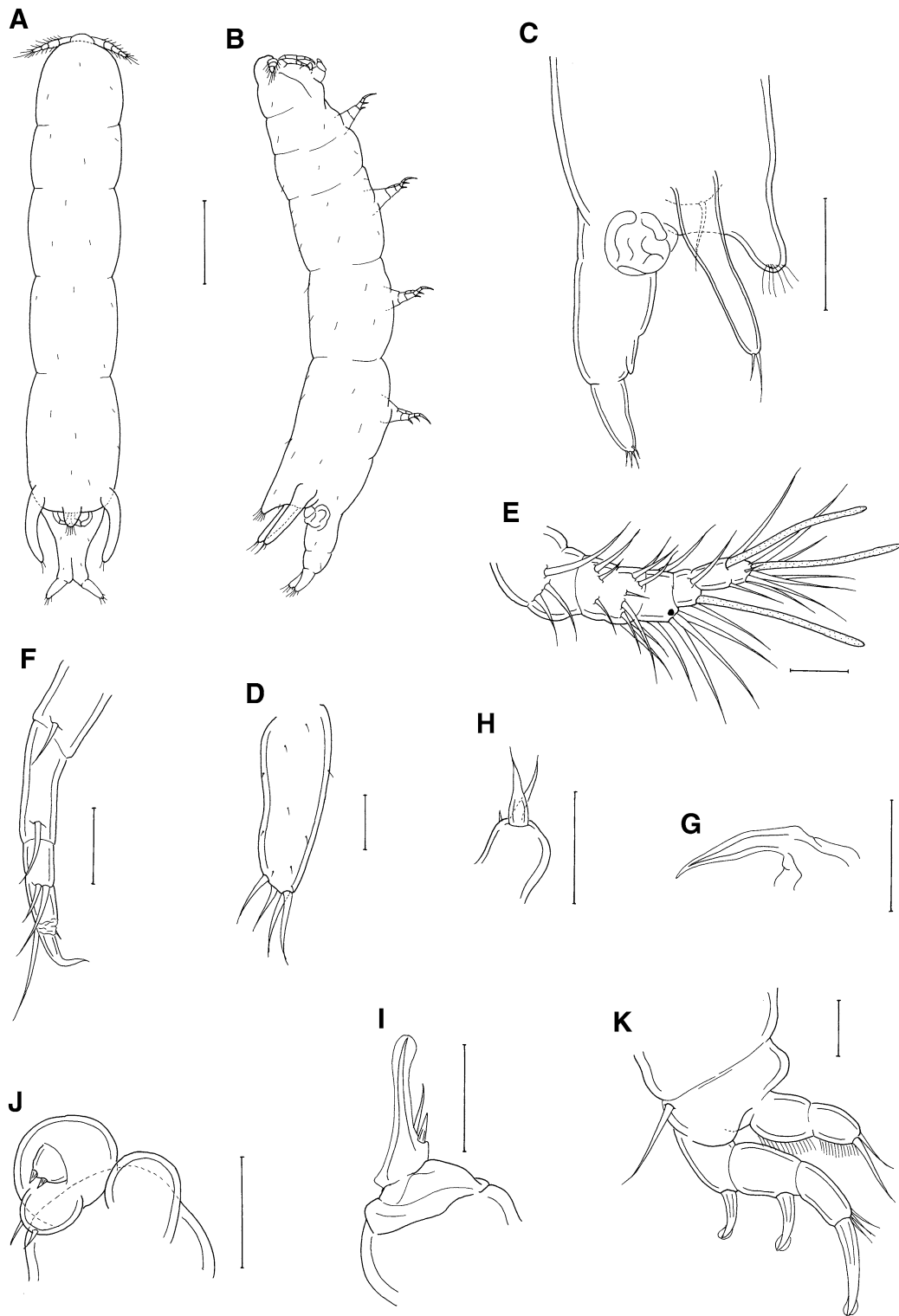


Fig. 1 *Xarifia capillata* n. sp., female. A, habitus, dorsal; B, habitus, lateral; C, urosome; D, caudal ramus; E, antennule; F, antenna; G, mandible; H, maxillule; I, maxilla; J, maxilliped; K, leg I. Scale-bars: A,B, 200 μ m; C, 100 μ m; D–K, 20 μ m

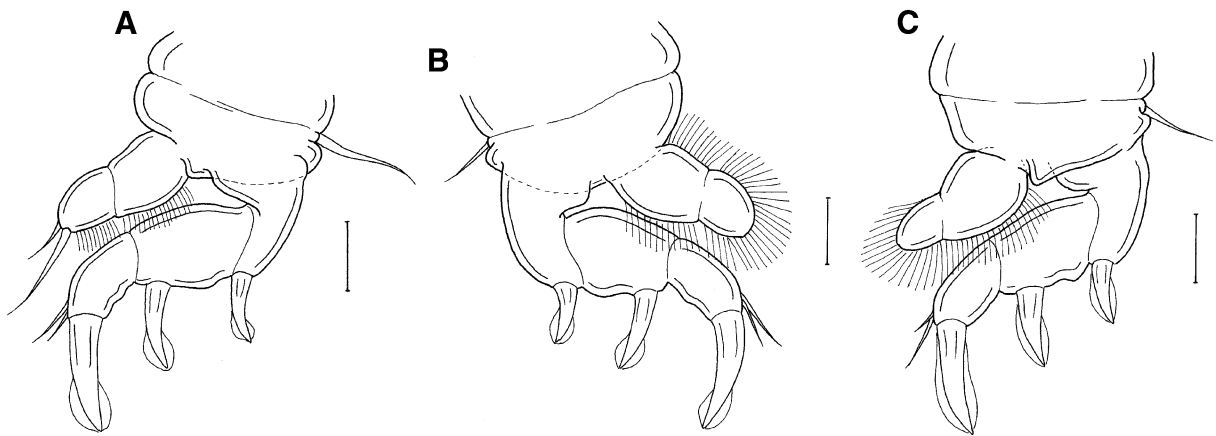


Fig. 2 *Xarifia capillata* n. sp., female. A, leg 2; B, leg 3; C, leg 4. Scale-bars: 20 μ m

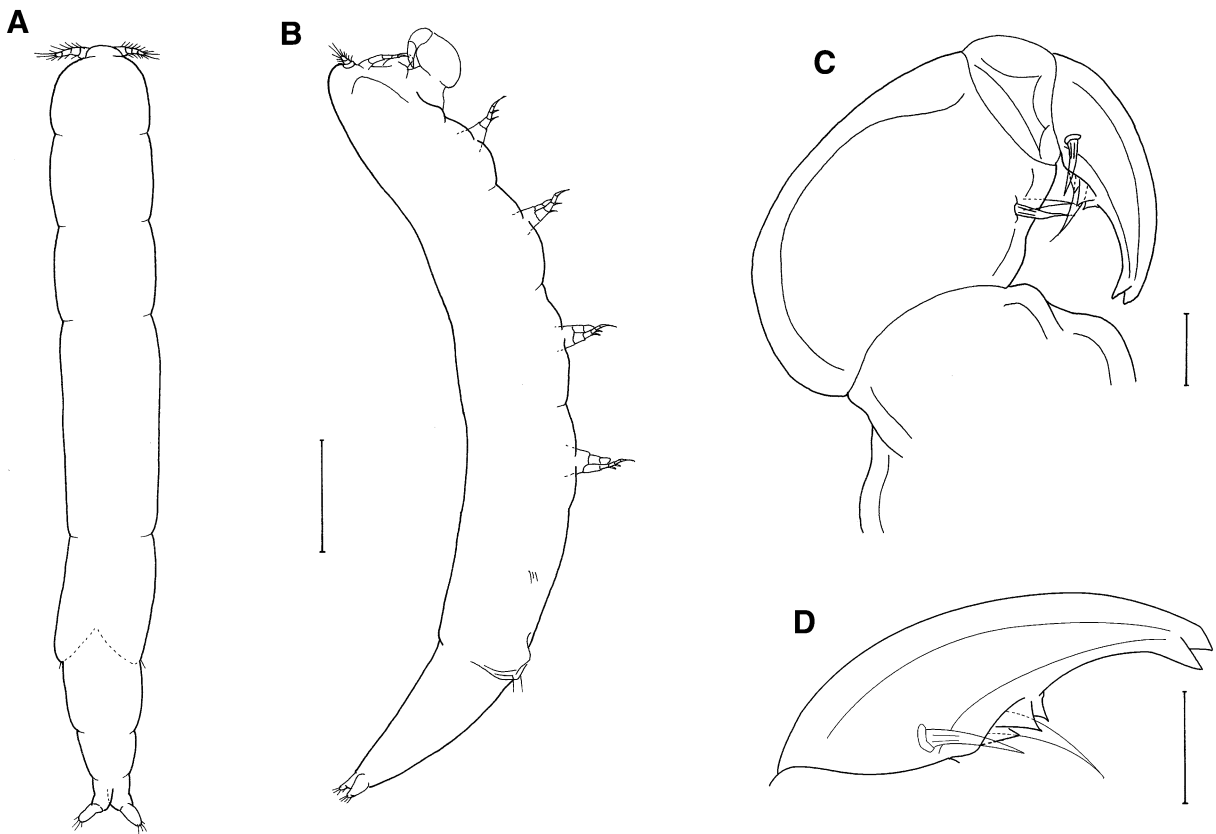


Fig. 3 *Xarifia capillata* n. sp., male. A, habitus, dorsal; B, habitus, lateral; C, maxilliped; D, claw of maxilliped. Scale-bars: A,B, 200 μ m; C,D, 20 μ m

Materials and methods

Fragments from one leaf coral colony, *Pavona explanulata*, were collected by SCUBA diving, placed in a bag while in the water, and then

transported to the laboratory to be examined for copepod parasites. To collect the parasitic copepods, the coral together with the seawater in the bag was emptied into a bucket, to which sufficient 95% ethyl alcohol was added to make it approximately a 5%

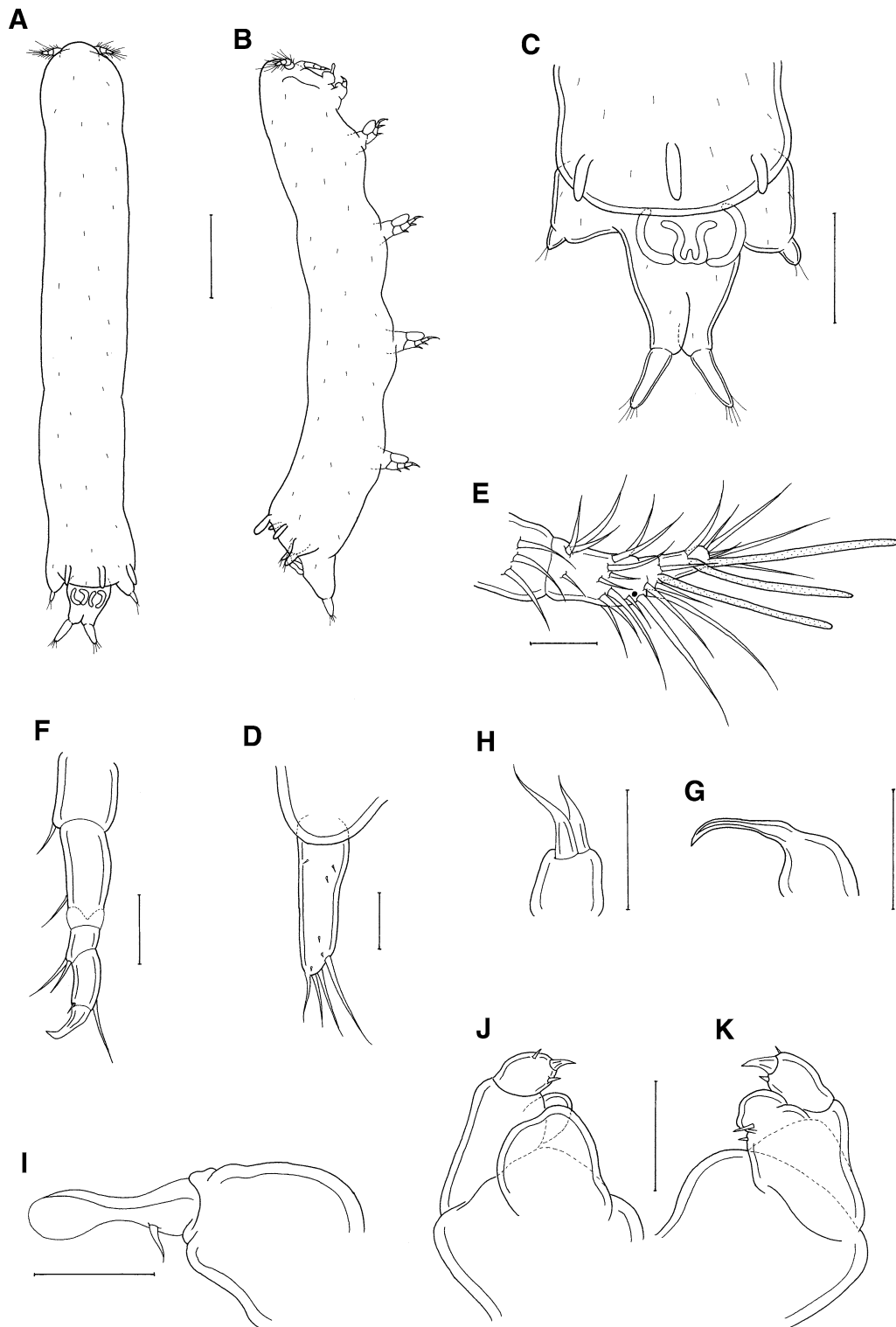


Fig. 4 *Xarifia parva* n. sp., female. A, habitus, dorsal; B, habitus, lateral; C, urosome; D, caudal ramus; E, antennule; F, antenna; G, mandible; H, maxillule; I, maxilla; J, maxilliped, lateral view; K, maxilliped, medial view. Scale-bars: A,B, 200 μ m; C, 100 μ m; D–K, 20 μ m

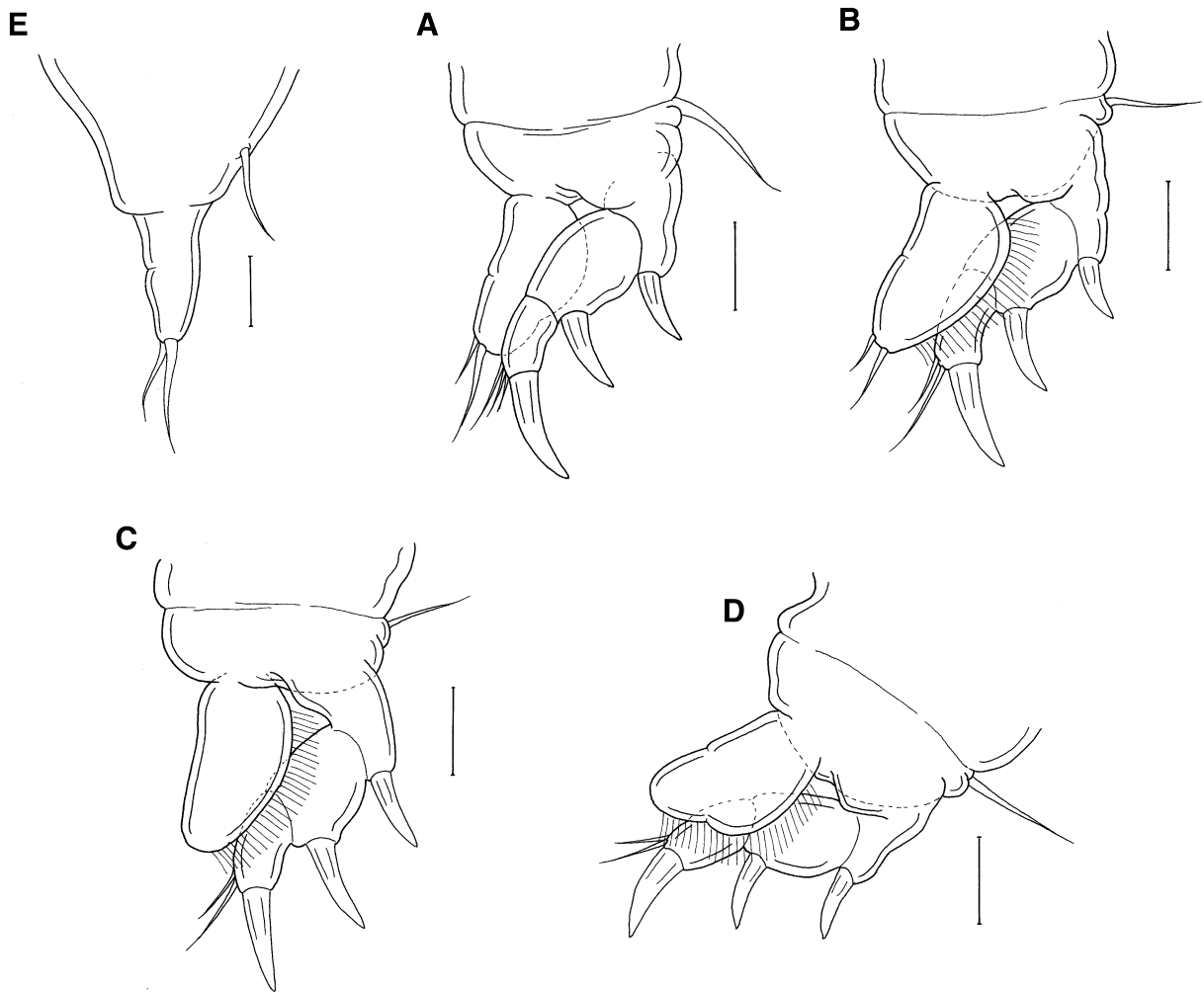


Fig. 5 *Xarifia parva* n. sp., female. A, leg 1; B, leg 2; C, leg 3; D, leg 4; E, leg 5. Scale-bars: 20 μ m

solution. After several hours, the water was poured through a fine net (mesh size *c.*100 μ m). The copepods were picked from the sediment retained in the net and preserved in 70% ethanol. They were later cleared in 85% lactic acid for 1 to 2 h and dissected on a wooden slide under a dissecting microscope (Humes & Gooding, 1964). The removed body parts and appendages were examined under a compound microscope with a series of magnifications up to 1,000 \times . All drawings were made with the aid of a drawing tube.

Order Poecilostomatoida Thorell, 1859
Family Xarifiidae Humes, 1960
Genus *Xarifia* Humes, 1960

***Xarifia capillata* n. sp.**

Type-host: *Pavona explanulata* (Lamarck) (family Agariciidae).

Site: Inside polyps.

Type-locality: Off Yenliao, Taiwan.

Etymology: The specific name *capillata* an adjective based on the Latin “capillus,” which means hair. It refers to the apical tuft of setules on the central process located between and above the fifth legs.

Type-material: Three ♀♀ and 4 ♂♂ obtained from washings of a coral colony collected at 5 m depth on 12 August, 2010. Female holotype (NTUIO-COPEPOD 0012), male allotype (NTUIO-COPEPOD 0013), and 1♀ and 2 ♂♂ of paratypes (NTUIO-COPEPOD s0003)

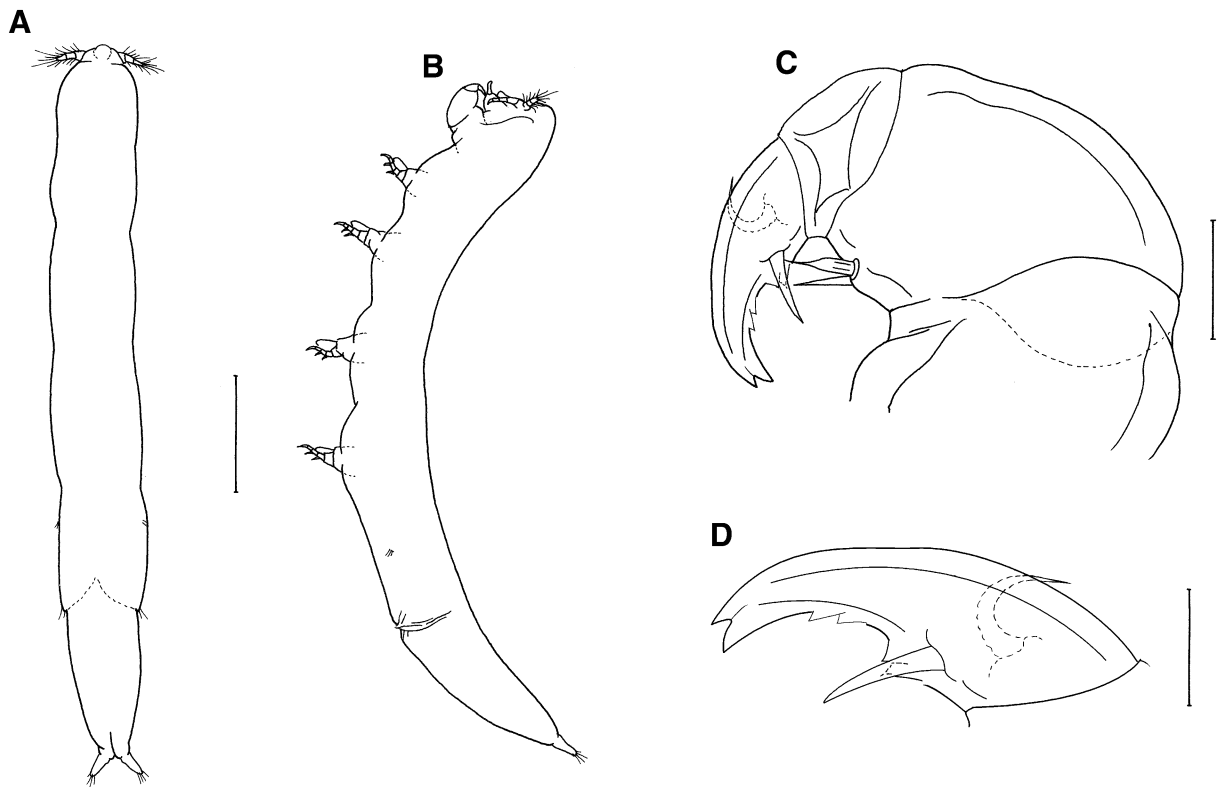


Fig. 6 *Xarifia parva* n. sp., male. A, habitus, dorsal; B, habitus, lateral; C, maxilliped; D, claw of maxilliped. Scale-bars: A,B, 200 μ m; C, 20 μ m; D, 40 μ m

deposited in the Institute of Oceanography, National Taiwan University, Taipei, Taiwan.

Description (Figs. 1–3)

Female

Body (Fig. 1A, B) stout. Length 1.41 (1.40–1.42) mm and greatest width 0.22 (0.21–0.22) mm, based on 3 specimens. Segmentation of somites indistinct. Region dorsal to fifth legs with single central process which is tipped with tuft of setules (Fig. 1A–C). Genital and postgenital somites slightly recurved (Fig. 1B). Areas of attachment of egg-sacs located dorso-laterally. Caudal ramus (Fig. 1D) bears 4 simple, terminal setae. Surface of body with small setules (Fig. 1A, B). Egg-sac not seen.

Antennule (Fig. 1E) 4- or indistinctly 6-segmented; armature: 3, 11, 5, 2 + 1 aesthetasc, 2 + 1 aesthetasc

and 7 + 1 aesthetasc in case with 6 segments and 3, 16, 2 + 1 aesthetasc and 9 + 2 aesthetasc in case with 4 segments; all setae naked. Antenna (Fig. 1F) 4-segmented; formula 1, 1, 2 and 2 + I.

Mandible (Fig. 1G) slender, with smooth, pointed blade. Maxillule (Fig. 1H) tipped with 2 long setae and single small, lateral seta. Maxilla (Fig. 1I) 2-segmented; first segment unarmed; second segment drawn out into pointed process with lamella and 2 small basal setae. Maxilliped (Fig. 1J) 3-segmented; first segment with single large, round distal protuberance; second segment with small, medial protuberance tipped with 2 inner setae; small third segment tipped with 2 small spines.

Legs 1–4 (Figs. 1K, 2A–C) 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 | I-0; I-0; I + 3 | 0-0; 2 |
| Leg 2 | 0-0 | 1-0 | I-0; I-0; I + 2 | 0-0; 2 |
| Legs 3 and 4 | 0-0 | 1-0 | I-0; I-0; I + 2 | 0-0; 0 |

Leg 5 (Fig. 1A–C) elongate, bearing 2 terminal setae and single adjacent dorsal seta.

Male

Body (Fig. 3A, B) more slender than female and slightly arched dorsally. Length 1.39 (1.39–1.40) mm and greatest width 0.18 (0.18–0.18) mm, based on 3 specimens. Caudal ramus as in female.

Antennule, antenna, mandible, maxillule and maxilla like those in female, but antennule with single aesthetasc added on second or third segment (at point indicated by dot in Fig. 1E). Maxilliped (Fig. 3C, D) 4-segmented; first and third segments unarmed; second segment with 2 medial setae; fourth segment claw with bifid tip, bearing 2 proximal setae and 3 basally located teeth on concave surface (Fig. 3D).

Legs 1–4 as in female.

Leg 5 (Fig. 3B) represented by 3 small setae.

Leg 6 (Fig. 3A, B) represented by 2 small setae on posteroventral flap of genital segment.

Remarks

Only four species of *Xarifia* are known to be similar to this new species in possessing a central process above and between the fifth legs of the female. They are: *X. eminula* Humes, 1985; *X. exuta* Humes & Dojiri, 1982; *X. mediolobata* Humes & Dojiri, 1982; and *X. serrata* Humes, 1962. The new species can be readily distinguished from these four congeners by the terminal armature on the endopod of legs 1–4 being 2, 2, 0, 0.

Xarifia parva n. sp.

Type-host: *Pavona explanulata* (Lamarck) (family Agariciidae).

Site: Inside polyps.

Type-locality: Off Yenliao, Taiwan.

Etymology: The specific name *parva* is Latin, meaning small. It refers to the three small processes in the dorsal region of the fifth pediger in the female.

Type-material: Nineteen ♀♀ and 14 ♂♂ obtained from the same washing from which *X. capillata* n. sp. was obtained. Female holotype (NTUIO-COPEPOD 0014), male allotype (NTUIO-COPEPOD 0015), and 15 ♀♀ and 10 ♂♂ of paratypes (NTUIO-COPEPOD s0004) deposited in the Institute of Oceanography, National Taiwan University, Taipei, Taiwan.

Description (Figs. 4–6)

Female

Body (Fig. 4A, B) moderately slender. Length 1.31 (1.26–1.38) mm and greatest width 0.18 (0.16–0.20) mm, based on 5 specimens. Segmentation of somites indistinct. Region dorsal to fifth legs with 3 posteriorly directed small processes (Fig. 4A–C). Genital and postgenital somites slightly curved ventrally (Fig. 4B). Areas of attachment of egg-sacs located on dorso-lateral part of genital somite. Caudal ramus (Fig. 4D) bears setules in addition to 4 simple, terminal setae. Surface of body with setules (Fig. 4A–C). Egg-sac not seen.

Antennule (Fig. 4E) 5-segmented; armature: 3, 16, 2 + 1 aesthetasc, 1 + 1 aesthetasc and 5 + 1 aesthetasc; all setae naked. Antenna (Fig. 4F) 4-segmented; formula 1, 1, 2 and 2 + I (medial seta much smaller than outer seta).

Mandible (Fig. 4G) slender, with smooth, pointed blade. Maxillule (Fig. 4H) tipped with 2 large setae. Maxilla (Fig. 4I) 2-segmented; first segment unarmed; second segment drawn out into pointed process bearing lamella and with single basal seta. Maxilliped (Fig. 4J, K) 3-segmented; first segment with single large, lateral protuberance; second segment with small, medial protuberance and 2 inner setae; small third segment tipped with single claw and 2 minute spines.

Legs 1–4 (Fig. 5A–D) with 3-segmented exopod and 1-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 | I-0; I-0; I + 3 | 2 |
| Leg 2 | 0-0 | 1-0 | I-0; I-0; I + 2 | 2 |
| Legs 3 and 4 | 0-0 | 1-0 | I-0; I-0; I + 2 | 0 |

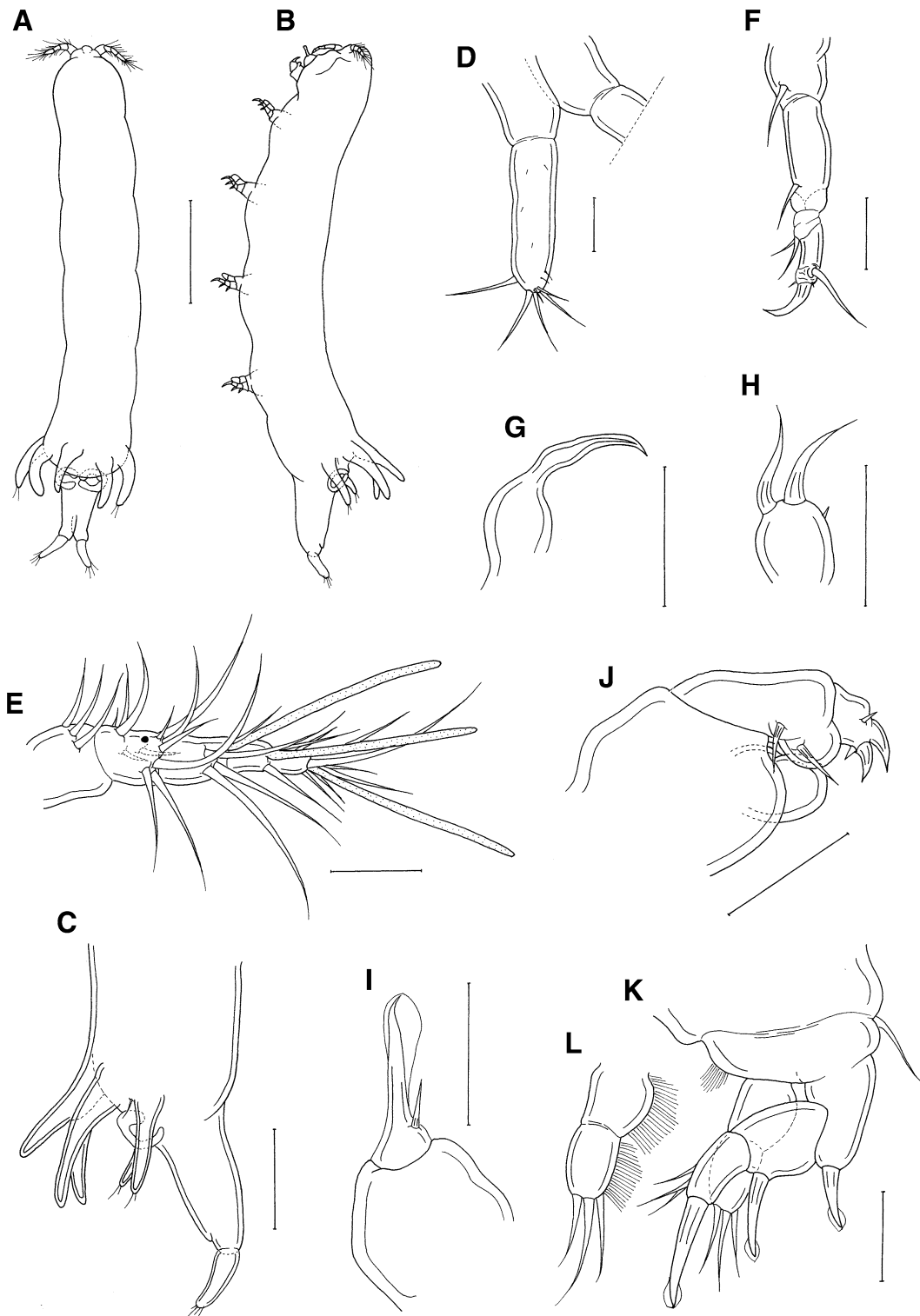


Fig. 7 *Xarifia pavonae* n. sp., female. A, habitus, dorsal; B, habitus, lateral; C, urosome; D, caudal ramus; E, antennule; F, antenna; G, mandible; H, maxillule; I, maxilla; J, maxilliped; K, leg I; L, endopod of leg I. Scale-bars: A,B, 200 μ m; C, 100 μ m; D–K, 20 μ m

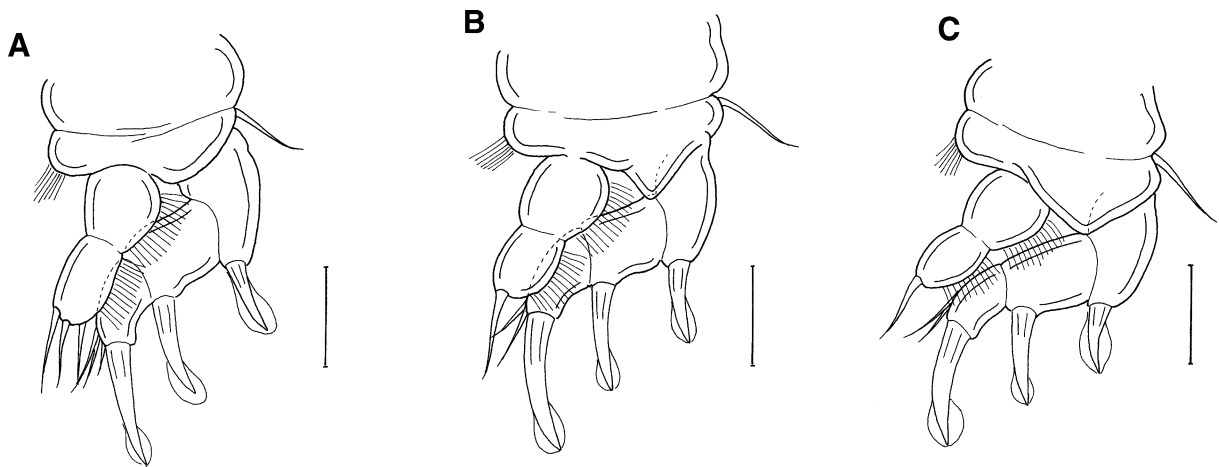


Fig. 8 *Xarifia pavonae* n. sp., female. A, leg 2; B, leg 3; C, leg 4. Scale-bars: 20 μ m

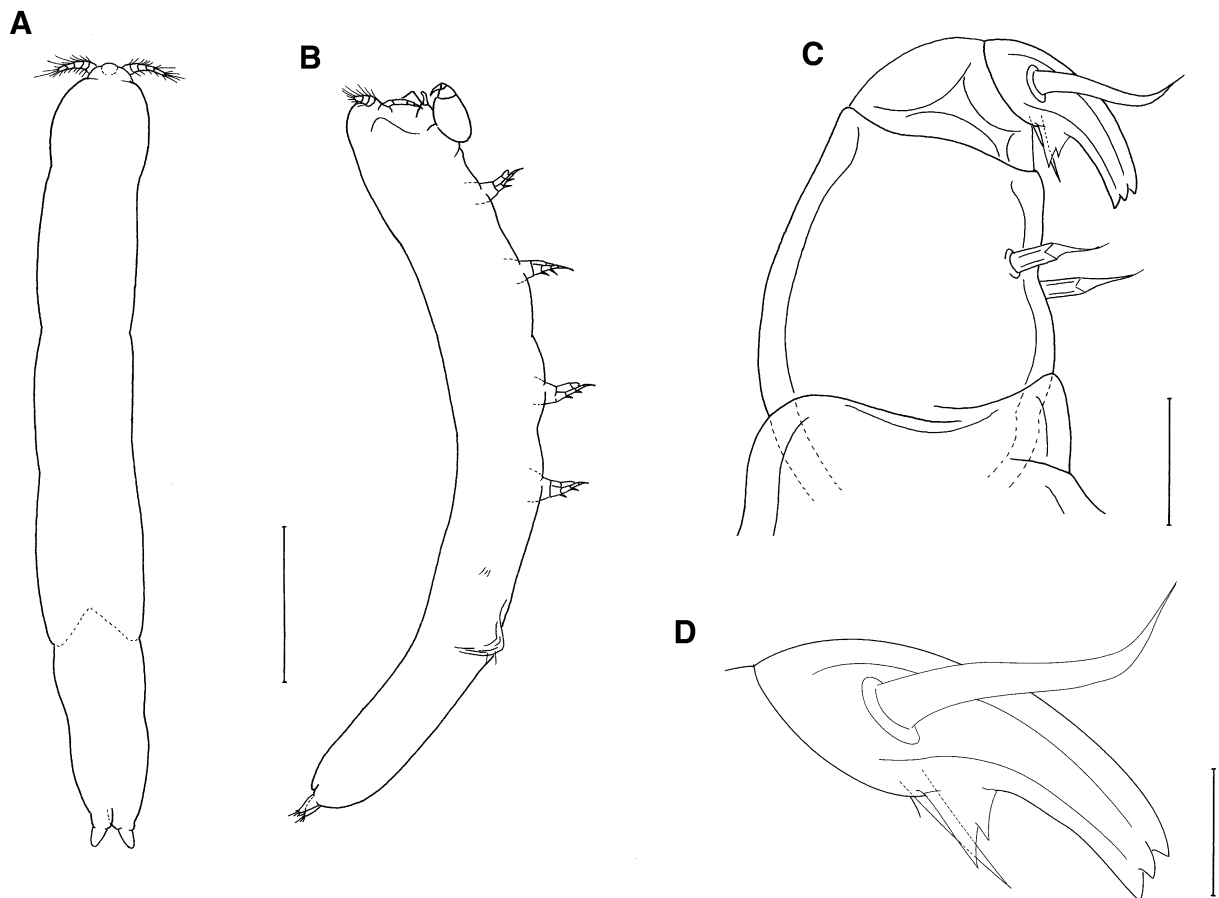


Fig. 9 *Xarifia pavonae* n. sp., male. A, habitus, dorsal; B, habitus, lateral; C, maxilliped; D, claw of maxilliped. Scale-bars: A,B, 200 μ m; C, 20 μ m; D, 40 μ m

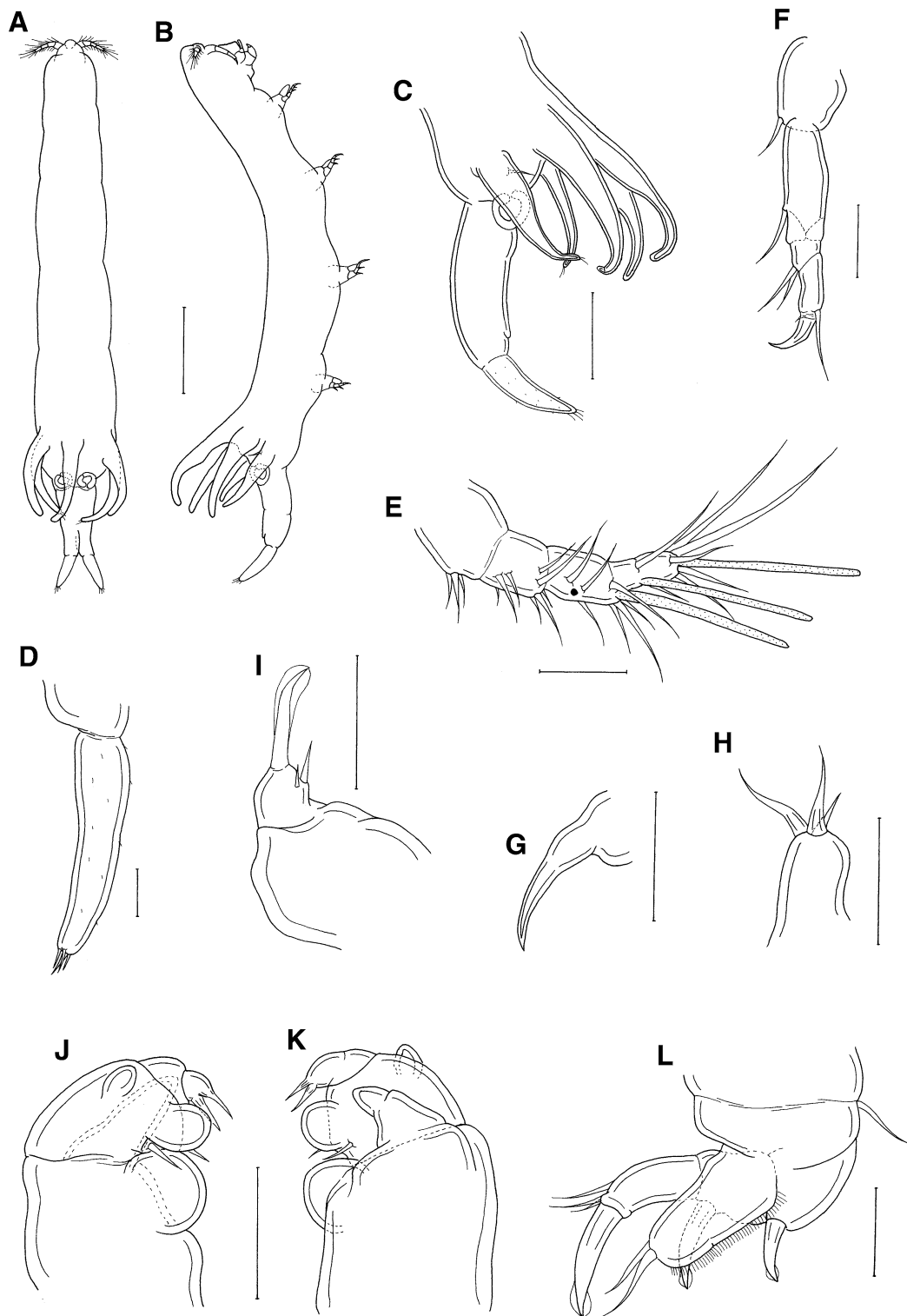


Fig. 10 *Xarifia taiwanensis* n. sp., female. A, habitus, dorsal; B, habitus, lateral; C, urosome; D, caudal ramus; E, antennule; F, antenna; G, mandible; H, maxillule; I, maxilla; J, maxilliped, lateral view; K, maxilliped, medial view; L, leg 1. Scale-bars: A,B, 200 μ m; C, 100 μ m; D–L, 20 μ m

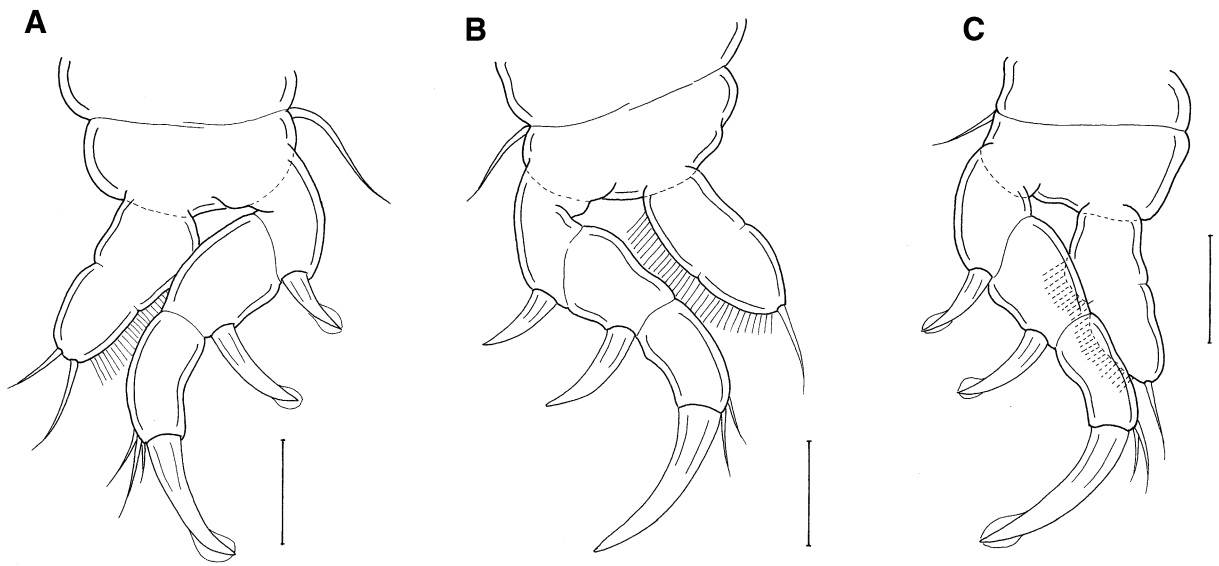


Fig. 11 *Xarifia taiwanensis* n. sp., female. A, leg 2; B, leg 3; C, leg 4. Scale-bars: 20 μ m

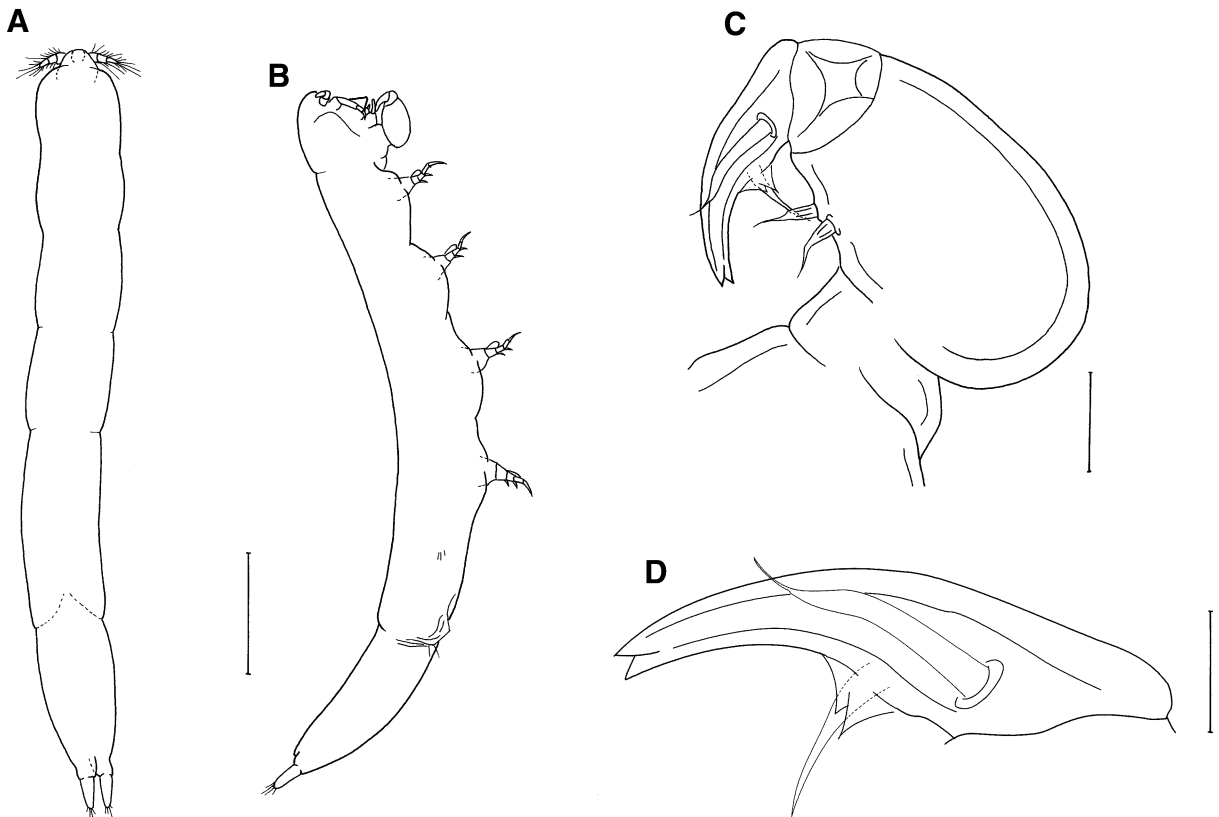


Fig. 12 *Xarifia taiwanensis* n. sp., male. A, habitus, dorsal; B, habitus, lateral; C, maxilliped; D, claw of maxilliped. Scale-bars: A,B, 200 μ m; C, 20 μ m; D, 40 μ m

Leg 5 (Figs. 4A–C, 5E) subtriangular, bearing 2 terminal setae and single adjacent dorsal seta.

Male

Body (Fig. 6A, B) more slender than female and slightly arched dorsally. Length 1.24 (1.22–1.26) mm and greatest width 0.12 (0.11–0.12) mm, based on 5 specimens. Caudal ramus as in female.

Antennule, antenna, mandible, maxillule and maxilla as for female, but antennule with single aesthetasc added on second segment (at point indicated by dot in Fig. 4E). Maxilliped (Fig. 6C, D) 4-segmented; first and third segments unarmed; second segment robust, with 2 inner setae; fourth segment a claw with bifid tip, bearing 2 proximal setae and serrated concave surface, as shown in Fig. 6D.

Legs 1–4 as in female.

Leg 5 (Fig. 6B) represented by 3 small setae.

Leg 6 (Fig. 6A, B) represented by 2 small setae on posteroventral flap of genital somite.

Remarks

This new species can be readily distinguished from its congeners by the armature on the endopod of legs 1–4 being 3, 2, 2, 2. This pattern of armature is unique among the species of *Xarifia*. Furthermore, the possession of a short urosome together with a large leg 5 can also be used to discriminate between *X. parva* n. sp. and other xarifiid copepods.

Xarifia pavonae n. sp.

Type-host: *Pavona explanulata* (Lamarck) (family Agariciidae).

Site: Inside polyps.

Type-locality: Off Yenliao, Taiwan.

Etymology: The specific name *pavonae* is derived from the generic name of the host.

Type-material: Twenty-four ♀♀ and 18 ♂♂ collected in the same washing from which *X. capillata* n. sp. and *X. parva* n. sp. were found. Female holotype (NTUIO-COPEPOD 0016), male allotype (NTUIO-COPEPOD 0017), and 14 ♀♀ and 10 ♂♂ paratypes (NTUIO-COPEPOD s0005) deposited in the Institute of Oceanography, National Taiwan University, Taipei, Taiwan.

Description (Figs. 7–9)

Female

Body (Fig. 7A, B) elongate. Length 1.03 (1.01–1.04) mm and greatest width 0.17 (0.16–0.18) mm, based on 5 specimens. Segmentation of somites indistinct. Region dorsal to fifth legs with 3 posteriorly directed processes which are nearly equal in length (Fig. 7A–C). Genital and postgenital somites slightly recurved (Fig. 7B). Areas of attachment of egg-sacs located dorso-laterally. Caudal ramus (Fig. 7D) bears single outer lateral seta and 5 terminal setae. Surface of body smooth (Fig. 7A–C). Egg-sac not seen.

Antennule (Fig. 7E) 5-segmented; armature: 3, 12, 4 + 1 aesthetasc, 2 + 1 aesthetasc and 7 + 1 aesthetasc; all setae naked. Antenna (Fig. 7F) 4-segmented; formula 1, 1, 2 and 2 + 1.

Mandibular blade (Fig. 7G) smooth. Maxillule (Fig. 7H) tipped with 2 long setae and single small, lateral seta. Maxilla (Fig. 7I) 2-segmented; first segment unarmed; second segment drawn out into pointed process with single basal seta and lamellate tip. Maxilliped (Fig. 7J) 3-segmented; first segment with single large, distal protuberance; second segment with medial protuberance and 2 inner setae; small third segment tipped with 2 claws and 2 minute spines.

Legs 1–4 (Figs. 7L, K, 8A–C) with 3-segmented exopods and 2-segmented endopods. Formula of spines (in Roman numerals) and setae (in Arabic numerals) as follows:

| | Coxa | Basis | Exopod | Endopod |
|--------------|------|-------|-----------------|---------|
| Legs 1 and 2 | 0-0 | 1-0 | I-0; I-0; I + 3 | 0-0; 3 |
| Legs 3 and 4 | 0-0 | 1-0 | I-0; I-0; I + 2 | 0-0; 1 |

Leg 5 (Fig. 7A–C) elongate, bearing 2 terminal setae and single small, adjacent dorsal seta.

Male

Body (Fig. 9A, B) slender and slightly arched. Length 1.01 (0.99–1.03) mm and greatest width 0.11 (0.10–0.12) mm, based on 5 specimens. Caudal ramus as in female.

Antennule, antenna, mandible, maxillule and maxilla like those in female, but antennule with single aesthetasc added on second segment (at point indicated by dot in Fig. 7E). Maxilliped (Fig. 9C, D) 4-segmented; first and third segment unarmed; second

segment with 2 inner setae; fourth segment a claw with trifid tip, bearing 2 proximal setae and bifid sharp process on concave surface.

Legs 1–4 as in female.

Leg 5 (Fig. 9B) represented by 3 small setae.

Leg 6 (Fig. 9B) represented by 2 small setae on posteroventral flap of genital segment.

Remarks

There are eight species of *Xarifia* that resemble the present new species in having the following combination of characters: (1) an armature of 3, 3, 1, 1 on the distal endopodal segment of legs 1–4; (2) an armature of I + 3, I + 3, I + 1, I + 1 on the distal exopodal segment of legs 1–4; (3) a 4-segmented antenna; and (4) bearing three processes above the fifth legs. They are: *X. bullifera* Humes, 1985; *X. comptula* Humes & Dojiri, 1983; *X. echinopora* Humes & Dojiri, 1982; *X. fastigiata* Humes & Dojiri, 1982; *X. pectinea* Humes, 1985; *X. radians* Humes & Dojiri, 1982; *X. tumorisa* Misaki, 1978; and *X. villosa* Humes & Dojiri, 1982. Four of them (*X. comptula*, *X. echinopora*, *X. tumorisa* and *X. villosa*) are also similar to the new species in having a relatively short urosome. Nevertheless, *X. pavonae* n. sp. can be differentiated from these four congeners by the combination of the following five character states: (1) body surface without setules; (2) armature on the antennule being 3, 12, 4 + 1 aesthetasc, 2 + 1 aesthetasc and 7 + 1 aesthetasc; (3) mandibular blade smooth; (4) armature on the exopodal segments of legs 1–4 nearly identical; and (5) leg 5 elongate and lacking a swelling.

Xarifia taiwanensis n. sp.

Type-host: *Pavona explanulata* (Lamarck) (family Agariciidae).

Site: Inside polyps.

Type-locality: Off Yenliao, Taiwan.

Etymology: The specific name reflects the location of the type-locality.

Type-material: Four ♀♀ and 1 ♂♂ in the same washings from which the previous three species were found. Female holotype (NTUIO-COPEPOD 0018), male allotype (NTUIO-COPEPOD 0019) and 1 female paratype (NTUIO-COPEPOD s0006) deposited in

the Institute of Oceanography, National Taiwan University, Taipei, Taiwan.

Description (Figs. 10–12)

Female

Body (Fig. 10A, B) moderately slender. Length 1.25 (1.24–1.26) mm and greatest width 0.19 (0.18–0.19) mm, based on 3 specimens. Segmentation of somites indistinct. Region dorsal to fifth legs with 3 posteriorly directed processes nearly equal in length (Fig. 10A–C). Genital and postgenital somites recurved (Fig. 10B). Areas of attachment of egg-sacs located dorso-laterally on genital somite. Caudal ramus (Fig. 10D) bears 4 simple, terminal setae. Surface of body smooth, except for caudal ramus where there are setules (Fig. 10A–D). Egg-sac not seen.

Antennule (Fig. 10E) 5-segmented; armature: 3, 8, 7 + 1 aesthetasc, 2 + 1 aesthetasc and 5 + 1 aesthetasc; all setae naked. Antenna (Fig. 10F) 4-segmented; formula 1, 1, 2 and 2 + I.

Mandibular blade (Fig. 10G) smooth. Maxillule (Fig. 10H) tipped with 3 setae. Maxilla (Fig. 10I) 2-segmented; first segment unarmed; second segment drawn out into pointed process bearing lamella and 2 basal setae. Maxilliped (Fig. 10J, K) 3-segmented; first segment with single distal protuberance and single lateral protuberance; second segment with single medial protuberance bearing 2 inner setae and single small protuberance; small third segment tipped with 2 elements.

Legs 1–4 (Figs. 10L, 11A–C) with 3-segmented exopod and 1-segmented endopod exhibiting vestiges of 2-segmented origin. Formula of spines (in Roman numerals) and setae (in Arabic numerals) as follows:

| | Coxa | Basis | Exopod | Endopod |
|--------------|------|-------|-----------------|---------|
| Legs 1 and 2 | 0-0 | 1-0 | I-0; I-0; I + 3 | 2 |
| Legs 3 and 4 | 0-0 | 1-0 | I-0; I-0; I + 2 | 1 |

Leg 5 (Fig. 10A, B) elongate, bearing 2 terminal setae and single small, adjacent dorsal seta.

Male

Body (Fig. 12A–B) slender and slightly arched. Length 1.25 mm and greatest width 0.12 mm. Caudal ramus as in female.

Antennule, antenna, mandible, maxillule and maxilla like those in female, but antennule with single aesthetasc added on third segment (at point indicated by a dot in Fig. 10E). Maxilliped (Fig. 12C, D) 4-segmented; first and third segments unarmed; second segment with 2 inner setae; fourth segment a claw with bifid tip, bearing 2 proximal setae and bifid, sharp process on concave surface.

Legs 1–4 as in female.

Leg 5 (Fig. 12B) represented by 3 small setae.

Leg 6 (Fig. 12B) represented by 2 small setae on posteroventral flap of genital segment.

Remarks

Xarifia exigua Humes & Ho, 1968 and *X. gerlachi* Humes, 1962 are the only two known species of xarifiids similar to this new species in possessing, in legs 1–4, 1-segmented endopods with a terminal armature of 2, 2, 1, 1 and 3-segmented exopods with outer armature of I, I, I. However, *X. gerlachi* can readily be distinguished from *X. taiwanensis* n. sp. by its possession of three relatively short processes above the fifth legs in the female. The new species can be distinguished from *X. exigua* by: (1) the maxillule being tipped with three (instead of two) setae; (2) the first segment of maxilliped bearing two protuberances (instead of none); (3) the second segment of the maxilliped bearing one medial protuberance and another small lateral protuberance (instead of just a lobate expansion); and (4) the third exopodal segment of legs 1 and 2 bearing two (rather than three) setae.

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