



## Five new species of Axiidae (Crustacea: Decapoda: Axiidea) from deep-water off Taiwan, with description of a new genus

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### Abstract

One new genus and five new species of axiid burrowing shrimps are described from deep-waters around Taiwan: *Formosaxius dorsum* n. gen., n. sp.; *Ambiaxius propinquus* n. sp., *Calastacus formosus* n. sp.; *Eiconaxius rubrirostris* n. sp. and *E. kensleyi* n. sp. The new genus, *Formosaxius*, appears closest to *Bouvieraxius* Sakai & de Saint Laurent, 1989 in the arrangement and armature of the gastric carinae on the carapace and the possession of pleurobranchs, but the presence of appendices internae on the third to fifth pleopods readily separates the new genus from *Bouvieraxius*. Affinities of the other four new species are also discussed. This study raises the number of species of Axiidae known from Taiwan to 13.

**Key words:** Crustacea, Decapoda, Axiidea, Axiidae, new genus, new species, Taiwan

### Introduction

Recent phylogenetic studies (Tsang *et al.* 2008; Robles *et al.* 2009) support that the traditional infraorder Thalassinidea is not monophyletic. Four families previously assigned to the superfamily Axioidea, viz., Axiidae, Calocarididae, Eiconaxiidae and Strahlaxiidae, are now placed within a smaller group, infraorder Axiidea de Saint Laurent, 1973, together with the families previously referred to Callianassoidea (Robles *et al.* 2009; De Grave *et al.* 2009). Furthermore, these studies strongly suggest that the two familial taxa, Calocarididae and Eiconaxiidae are subordinated within Axiidae. Finally, Poore & Collins (2009) abandoned the recognition of Calocarididae and Eiconaxiidae as distinct families, placing them in the synonymy of Axiidae. In this study, we follow the classification of Poore & Collins (2009).

The Taiwanese axiid fauna has only been recently known by eight species (Kensley & Chan 1998; Kensley *et al.* 2000; Lin *et al.* 2000; Lin & Komai 2006): *Acanthaxius formosa* Kensley & Chan, 1998, *A. grandis* Kensley & Chan, 1998, *Ambiaxius foveolatus* Kensley, Lin & Yu, 2000, *Calastacus crosnieri* Kensley & Chan, 1998, *Calaxiopsis mclaughlinae* Lin & Komai, 2006, *Calaxius manningi* Kensley, Lin & Yu, 2000, *Calocarides chani* Kensley, Lin & Yu, 2000, and *Oxyrynchaxius japonicus* Parisi, 1917.

Recent deep-sea surveys in Taiwan revealed the presence of five more species of Axiidae. All the five species are new to science and one species even belongs to a new genus. The new axiid genus, *Formosaxius*, which is established to accommodate the new species *F. dorsum* n. sp., shows substantial similarity to *Bouvieraxius* Sakai & de Saint Laurent, 1989, but the presence of appendices internae on the third to fifth pleopods immediately distinguishes the new genus from the latter. Other four new species are: *Ambiaxius propinquus* n. sp., *Calastacus formosus* n. sp., *Eiconaxius rubrirostris* n. sp., and *E. kensleyi* n. sp. All the five species are described and illustrated in detail.

## Material and Methods

Material used in this study is deposited in the National Taiwan Ocean University (NTOU). Following the recommendation by Poore & Collins (2009), the mouthparts were not illustrated, although some necessary observations were made as possible. The carapace length (cl) is measured dorsally from the level of orbital margin to the posterior margin of the carapace. The abbreviations CP, CD and DW before the station numbers are gear types, referring to the beam trawl, the otter trawl Le Drezen type solo hard bottom 12.4 m and the Warén dredge, respectively.

## Taxonomic Accounts

### Family Axiidae Huxley, 1879

**Remarks.** The family Calocarididae was revived and redefined by Kensley (1989), although his hypothetical scheme for derivation of the family suggested that the genera assigned to Calocarididae form a clade but is subordinated within Axiidae. Nevertheless, subsequent authors have continued to recognize Calocarididae as a distinct family (e.g., Poore 1994, 2008; Komai 2000; Sakai & Ohta 2005; De Grave *et al.* 2009), because the morphological evidence strongly suggests that genera assigned to the family clearly form a monophyletic group. Based on molecular data, Tsang *et al.* (2008) analysed relationships between two calocaridid species (*Calastacus crosnieri* and *Paracalocaris sagamiensis*) and three axiids, finding the two calocaridids to sister taxa and the axiids to form a paraphyletic grade. Robles *et al.* (2009) showed that the calocaridid, *Calocaris caribbaeus*, is nested among seven species of Axiidae, also suggesting the paraphyly of Axiidae. Sakai & Ohta (2005) separated *Eiconaxius* in its own family, Eiconaxiidae, because the genus is characterized by rounded dactyli of the third to fifth pereopods, representing a unique feature for the genus. However, Poore & Collins (2009) showed that this characteristic is also seen, in part, in the axiid *Platyaxius* Sakai, 1994. They finally synonymized Calocarididae and Eiconaxiidae with Axiidae.

### *Formosaxius* n. gen.

**Type species:** *Formosaxius dorsum* n. sp. Gender: masculine.

**Diagnosis.** Rostrum triangular, acute, laterally spinose, longer than eyestalks, not much depressed below level of carapace, continuous with distinct lateral carinae on gastric region of carapace. Carapace smooth; dorsal surface strongly convex, anterior part sloping down to rostrum; cervical groove visible laterally over almost half distance to anterolateral margin; supraocular spines barely differentiated from other spines; lateral carina smooth; submedian carina present, consisting of row of spines; median carina with few spines anteriorly; postcervical carina present at least in posterior half. First abdominal pleuron rounded ventrally; second pleuron broad, rounded; third to fifth pleura posteriorly rounded. Telson with 2 minute, marginal spiniform setae at each posterolateral angle; posterior margin rounded, unarmed medially. Eyestalk cylindrical, articulating; cornea pigmented. Antenna with scaphocerite long, acute. Third maxilliped with exopod not clearly bent at base of flagellum. Gill formula summarized in Table 1; pleurobranchs present on fifth to seventh thoracic somites (above bases of second to fourth pereopods); podobranchs and arthrobranchs well developed; epipods present on second maxilliped through fourth pereopod. First pereopod (only one side known at present) with laterally compressed palm; dorsal margin of carpus to dactylus smooth, with subdistal tooth on palm; cutting edges of fingers each with row of corneous spinules. Third to fifth pereopods with propodi lacking transverse rows of spiniform setae; dactyli of third and fourth pereopods subconical, slender, slightly twisted, only that of fourth pereopod with spiniform setae. Fourth pereopod with well-developed grooming apparatus on propodus. Third to fifth pleopods each with well-developed appendix interna. Uropodal exopod with transverse suture.

**TABLE 1.** Gill formula of *Formosaxius dorsum* n. gen., n. sp.

	Thoracic somites							
	1	2	3	4	5	6	7	8
	Maxillipeds			Pereopods				
	1	2	3	1	2	3	4	5
Pleurobranchs	0	0	0	0	1	1	1	0
Arthrobranchs	0	1	2	2	2	2	2	0
Podobranchs	0	0	r	r	r	r	r	0
Epipods	1	1	1	1	1	1	1	0
Exopods	1	1	1	0	0	0	0	0

**Remarks.** At present 23 genera are known in Axiidae (Poore 1994; Sakai 1994; Kensley 1996b; Sakai & Ohta 2005; Komai & Tachikawa 2007, 2008; Clark *et al.* 2007; De Grave *et al.* 2009). Only female specimens of *F. dorsum* are presently known, so no information on male pleopods is available. Nevertheless, the presence of pleurobranchs, the general armature of the rostrum and the arrangement of the carapace gastric carinae, the simple antennal scaphocerite, and the lack of spines on the dorsal margins of the cheliped palms link *Formosaxius* to *Bouvieraxius* Sakai & de Saint Laurent, 1989. In these two genera, the lateral margin of the rostrum is spinose, but the supraocular spine is not differentiated; the submedian gastric carina consists of a row of spines; and the lateral gastric carina is unarmed. However, the possession of appendices internae on the third to fifth pleopods immediately distinguishes the new genus from *Bouvieraxius*. Furthermore, the ventrally rounded first pleuron seems to differentiate the new genus from *Bouvieraxius*. The fingers of the cheliped (only one side is known) are armed with a row of corneous spinules on the cutting edges, a character not known at present for other axiid species. This character may be of generic significance. *Planaxius* Komai & Tachikawa, 2008 is also similar to *Formosaxius* n. gen. in having pleurobranchs and appendices internae on the third to fifth pleopods. However, *Planaxius* differs from the new genus in the lack of gastric submedian carinae on the carapace. The unarmed median gastric carina and the possession of spinules on the lateral faces of the dactyli of the third to fifth pereopods are also major characters separating *Planaxius* from *Formosaxius* n. gen. In the new genus, the median gastric carina is armed with two spines and one obtuse tubercle; the dactyli of the third and fifth pereopods are devoid of spinules on the lateral faces.

**Etymology.** The name is derived from the combination of *Formosa* (old name of Taiwan) and the generic name *Axius*, in reference to the type locality of the new species.

***Formosaxius dorsum* n. sp.**

(Figs. 1–3, 13A, B)

**Type material.** Holotype: female (cl ca. 12.0 mm), TAIWAN 2005, stn CP 290, 8 August 2005, 24°57.301'N, 122°5.030'E, 249–255 m, (NTOU A01087).

Paratype: female (cl 12.6 mm), TAIWAN 2001, stn CP 95, 18 May 2001, 24°55.80'N, 122°5.73'E, 269–360 m (NTOU A00023).

**Description of holotype.** Dorsum of carapace damaged in posterior part, left cheliped, right second, left third, right fourth and both fifth pereopods missing. Rostrum (Fig. 1A, B) 0.3 times of distance between rostral base and cervical groove, triangular with acute tip in dorsal view; lateral margin with 4 small spines anterior to rostral base, continuous with distinct, unarmed lateral gastric carina on carapace; dorsal surface shallowly concave. Carapace (Fig. 1A, B) nearly smooth on surface; dorsal surface weakly convex, gastric region sloping down to rostrum; no clearly differentiated supraocular spine; median gastric carina distinct,

reaching to cervical groove, with 2 small spines anteriorly and 1 obtuse convexity anterior to midway between rostral base and cervical groove; submedian carina consisting of longitudinal row of 6 small spines and 2 minute tubercles (left) or 7 small spines (right); lateral gastric carina extending beyond midway between rostral base and cervical groove; blunt postcervical carina apparent at least in posterior part (Fig. 1C); cervical groove distinct, extending to pterygostomial region; pterygostomial margin rounded.

Seventh thoracic sternite with thoracic shield (Fig. 1D) deeply divided in midline over posterior two-thirds and slightly produced anteriorly in obtuse apex. Eighth sternite (not figured) with setose semicircular flap on anterior face at base of leg.

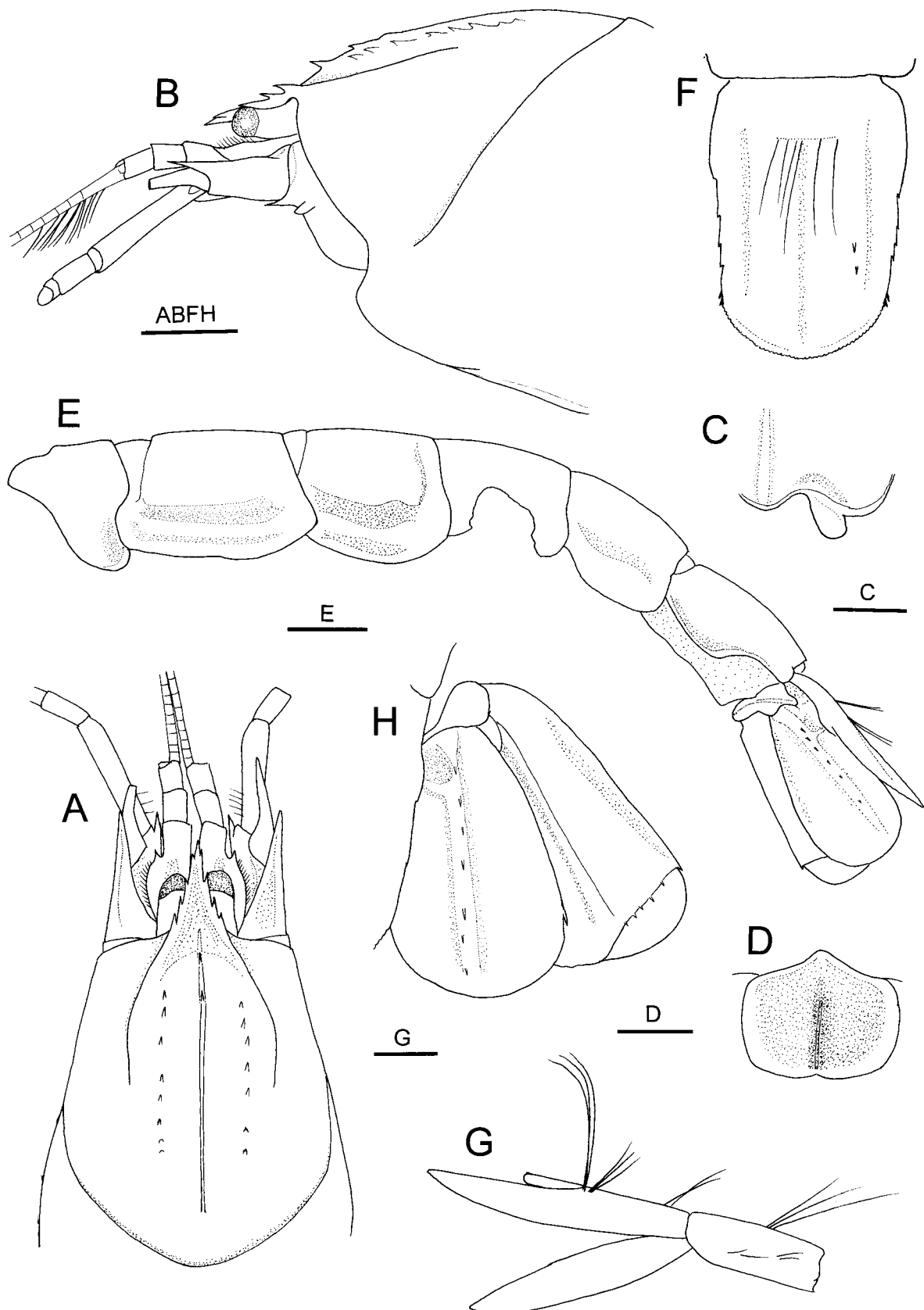
First abdominal pleuron (Fig. 1E) shallowly depressed on lateral surface with slightly upturned posterior margin, ventral margin rounded. Second pleuron asymmetrical (*i.e.*, anterior and posterior parts unequal); lateral surface with fairly deep longitudinal depression accompanied dorsally with blunt ridge; ventral margin unarmed, rounded at either angle. Third and fourth pleura each with shallow depression on lateral surface, ventral margin rounded. Fifth pleuron also with shallow depression on lateral surface, ventral margin rounded. Sixth pleuron broadly rounded ventrally, with rounded posterolateral projection. Telson (Fig. 1F) 1.4 times as long as broad, lateral margin with 4 minute spines, posterior margin convex, without posteromedian spine, posterolateral angle with 2 minute, marginal spiniform setae; dorsal face shallowly sulcate medially, left dorsolateral ridge unarmed, right dorsolateral ridge with 2 spines in posterior one-third.

Eyestalk (Fig. 1A, B) about 0.8 length of rostrum; cornea shorter than eyestalk, darkly pigmented. Antennular peduncle (Fig. 1A, B) reaching midlength of fourth segment of antennal peduncle; statocyst lobe on first segment with distal spine. Antennal peduncle (Fig. 1A, B) with first segment bearing 2 spinules at ventromesial distal angle and 1 slender spine on ventrodistal margin; second segment with straight dorsolateral distal spine reaching nearly midlength of scaphocerite; scaphocerite simple, straight, reaching midlength of fourth segment; third segment with 1 prominent spine at distomesial angle; fourth segment slightly longer than second segment; fifth segment less than half length of fourth segment.

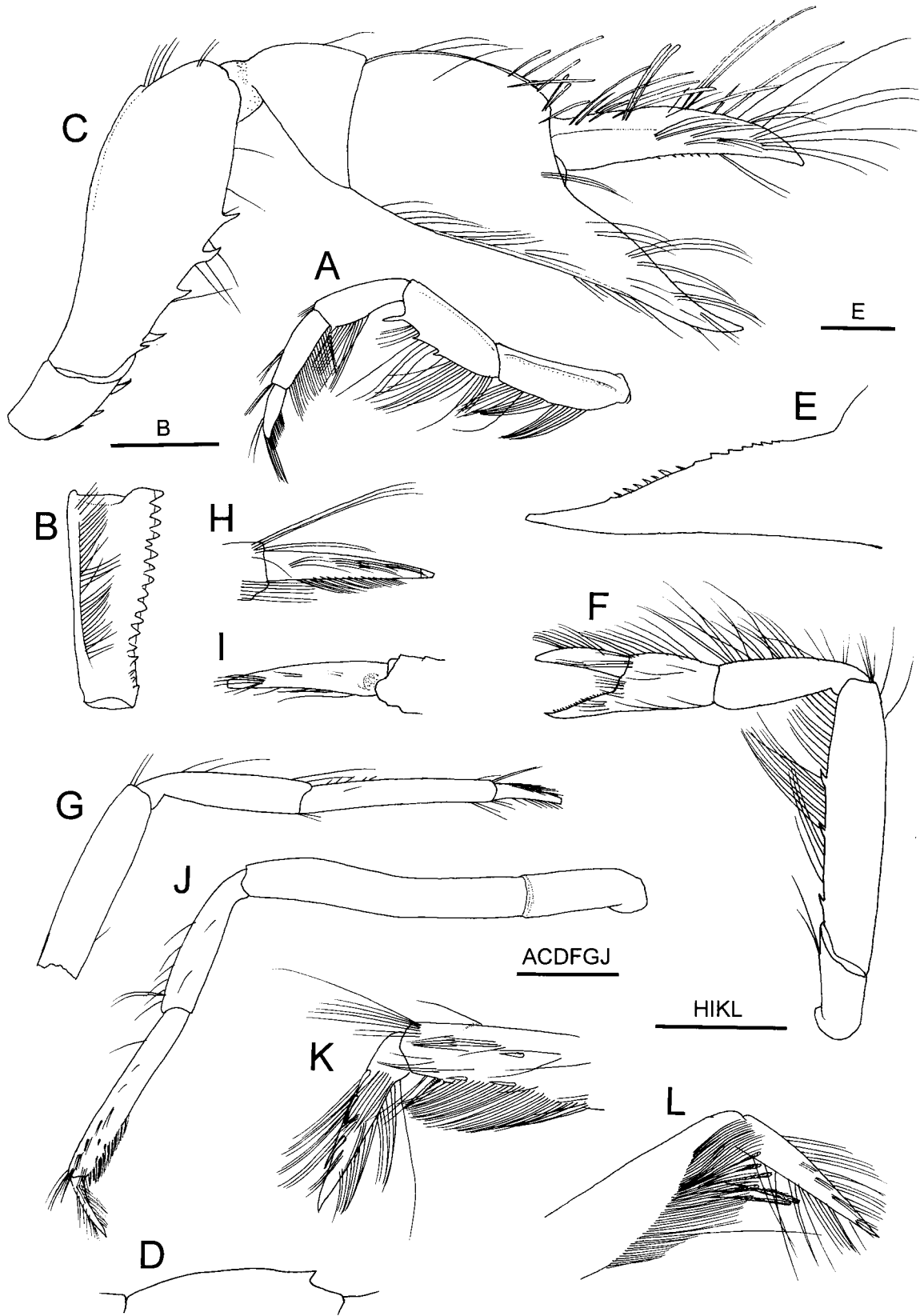
Third maxilliped (Fig. 2A) moderately slender; basis with 1 spine distomesially; crista dentata on ischium with 17 corneous-tipped teeth increasing in size distally; merus with 3 spines on ventral margin (distal spine largest); carpus with 1 small distal spine on ventral margin; propodus slightly tapering distally; exopod slightly overreaching distal margin of first segment of antennal peduncle.

Only right cheliped remaining (Fig. 2C). Coxa with 2 ventromesial spines. Basis unarmed. Ischium with 3 spines on ventral margin (proximal one minute); merus with dorsal margin sinuous, sharply carinate, with 1 small spine subdistally, lower margin with row of 5 spines in proximal 0.7, lateral and mesial faces smooth. Carpus 1.1 times longer than high, dorsal margin smooth, ventral margin also unarmed, lateral and mesial faces smooth. Palm 1.1 times longer than high, dorsal margin slightly concave, sharply carinate, with 1 small subdistal spine (Fig. 2D), ventral margin (including fixed finger) slightly sinuous; lateral face slightly convex, nearly smooth, with tufts of long stiff setae adjacent to dorsal and ventral margins and at base of dactylus, sharply carinate along ventral margin. Fixed finger 1.3 times longer than palm; lateral surface faintly elevated in midline, with row of tufts of long setae adjacent to cutting edge; cutting edge slightly sinuous, with row of minute corneous spinules (Fig. 2E). Dactylus weakly curved, crossing with fixed finger at tip when closed, with numerous tufts of long stiff setae on lateral and mesial faces; both lateral and mesial faces slightly elevated in midline as blunt ridge in proximal half; dorsal margin unarmed; cutting edge without conspicuous teeth, but with row of minute corneous spinules.

Second pereopod (Fig. 2F) moderately slender; ischium unarmed; merus with 3 ventral spine; carpus slightly shorter than chela; fingers subequal in length to palm, each with row of minute corneous spinules on cutting edge. Third pereopod (Fig. 2G) unarmed; propodus with sparse setae; dactylus (Fig. 2H, I; tip broken off) subconical, slightly twisted, lateral surface with row of tufts of setae on midline and ventrally with thick covering of setae, mesial face also with few tufts of setae. Fourth pereopod (Fig. 2J) moderately slender; propodus with grooming apparatus consisting of thick cluster of setae and several stout, setulose setae located subdistally (Fig. 2K, L); dactylus (Fig. 2K, L) about 0.4 times as long as propodus, subconical, slightly twisted, lateral surface with 4 long, slender spiniform setae along extensor margin, obscured by thick long setae.



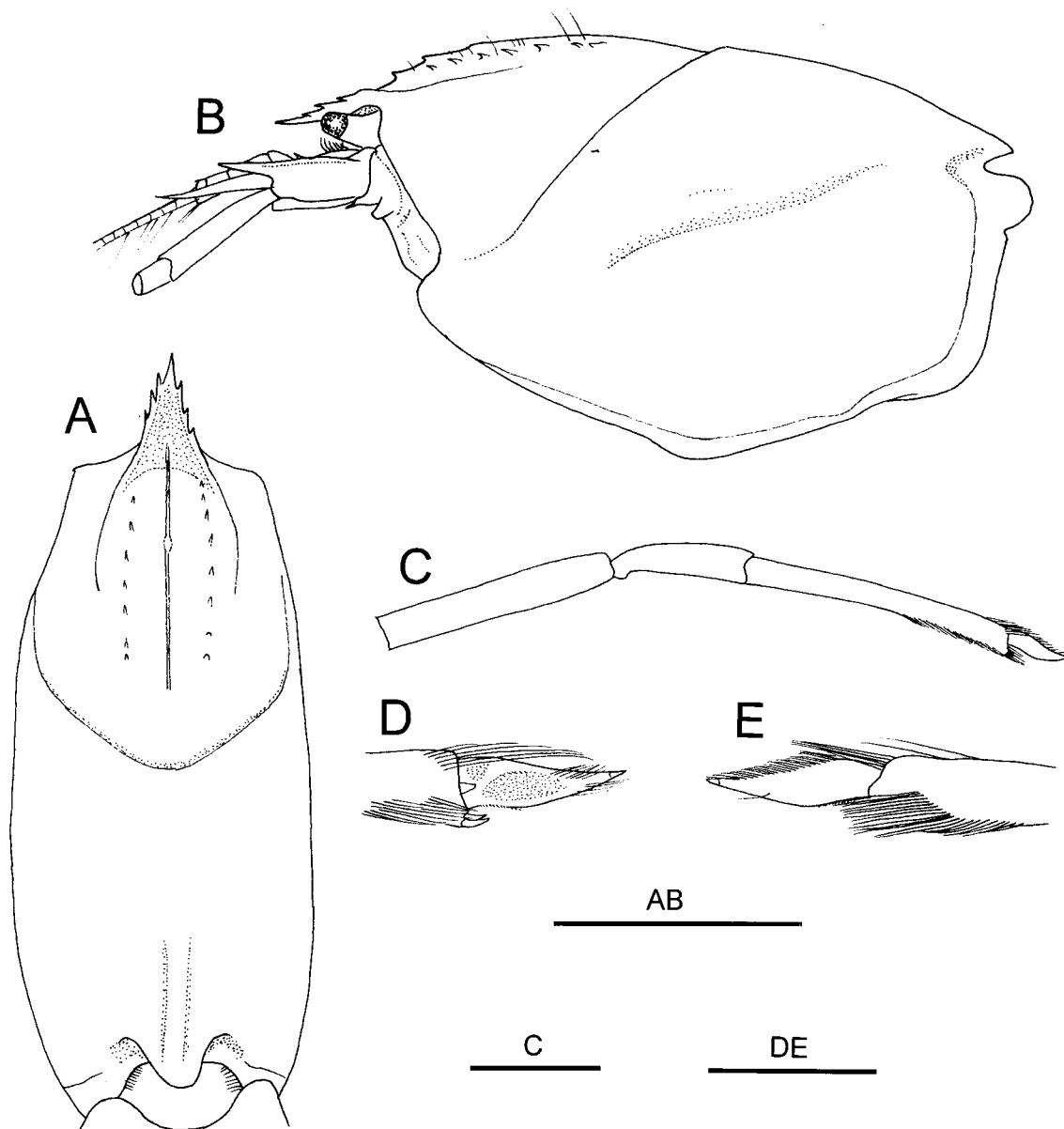
**FIGURE 1.** *Formosaxius dorsum* n. gen., n. sp., holotype, female (cl about 12.0 mm), NTOU A01087. A, anterior part of carapace and cephalic appendages, dorsal (outer antennular and antennal flagella missing); B, same, lateral view; C, fragment of right posterodorsal part of carapace, dorsal, showing presence of mid-dorsal carina in posterior part; D, thoracic shield on seventh somite, ventral view; E, abdomen, telson and left uropod, lateral view (setae partially omitted; fourth pleuron damaged); F, telson, dorsal view; G, left third pleopod, ventral view; H, right uropod, dorsal view (perpendicular to horizontal plane of uropod). Scale bars A–C, E, F, H = 2 mm; D, G = 1 mm.



**FIGURE 2.** *Formosaxius dorsum* n. gen., n. sp., holotype, female (cl about 12.0 mm), NTOU A01087. A, left third maxilliped (detached at articulation between ischium and basis); B, same, ischium, dorsal view, showing crista dentata; C, right cheliped, lateral view; D, same, dorsal margin of palm, showing subdistal spine; E, same, fixed finger, mesial view (setae omitted); F, left second pereopod, lateral view; G, right third pereopod, lateral view (merus damaged, tip of dactylus broken off); H, same, dactylus, lateral view; I, same, mesial view; J, left fourth pereopod, lateral view; K, same, distal part of propodus and dactylus, lateral view; L, same, mesial view. Scale bars: A, C, D, F, G, I = 2 mm; B, E, H, I, K, L = 1 mm.

First pleopod uniramous, two-segmented, ramus flexible, longer than protopod. Second to fifth pleopods moderately narrow, each with well-developed appendix interna (Fig. 1G).

Uropodal endopod (Fig. 1H) 1.5 times as long as wide, with 1 lateral spine at posterolateral position; longitudinal ridge on dorsal surface with row of 8 (left) or 7 (right) spines. Uropodal exopod (Fig. 1H) with straight, unarmed lateral margin, posterolateral angle with 1 tiny spine; dorsal ridge unarmed; transverse suture with row of minute spinules.



**FIGURE 3.** *Formosaxius dorsum* n. gen., n. sp., paratype, female (cl 12.6 mm), NTOU A00023. A, carapace, dorsal view; B, carapace and cephalic appendages, lateral view (left); C, right fifth pereopod, lateral view (proximal part of merus broken off); D, same, dactylus, lateral view; E, same, mesial view. Scale bars: A, B = 5 mm; C = 2 mm; D, E = 1 mm.

**Note on paratype.** Both chelipeds, left third to fifth pereopods missing. Rostrum (Fig. 3A, B) 0.17 times as long as carapace and 0.3 times of distance between rostral base and cervical groove, with 3 lateral spines. Carapace (Fig. 3A, B) with median gastric carina with 2 small spines anteriorly and 1 very low convexity anterior to midway between rostral base and cervical groove; submedian carina consisting of longitudinal row of 5 small spines and 3 tiny tubercles (left) or 7 small spines (right). Telson with lateral margin unarmed,

posterolateral angle with 2 subequal, minute spiniform setae; dorsal face with 2 pairs of small spines medially, anterior pair on submedian ridges and posterior pair on dorsolateral ridges. Eyestalk about half length of rostrum; cornea shorter than eyestalk, darkly pigmented. Antennal peduncle (Fig. 3B) with scaphocerite far overreaching midlength of fourth segment. Third maxilliped moderately slender; basis with 1 spine distomesially; ischium with 2 minute denticles on ventral margin; merus with 3 spines on ventral margin increasing in size distally; carpus unarmed on ventral margin. Second pereopod with merus unarmed (left) or armed with 1 ventral spine arising slightly distal to midlength. Fifth pereopod (Fig. 3C) more slender than third and fourth pereopods; propodus with grooming apparatus consisting of short transverse rows of stiff setae, ventrodiscal projection bearing terminal cluster of 4 spiniform setae; dactylus lanceolate, outer surface slightly excavate. Uropodal endopod unarmed on lateral margin, middorsal ridge with row of 6 spinules (left) or unarmed (right).

**Coloration.** Body (Fig. 13A, B) generally pinkish brown (holotype) to pale brown (paratype), ventral parts and appendages lighter in color; corneas dark brown.

**Distribution.** Known only from northeastern Taiwan, 249–360 m deep.

**Remarks.** As is apparent from the above description, variations are observed in the armament of various body structures, including the rostrum, gastric submedian carinae, telson, third maxilliped, chelipeds, second pereopods, and uropods, and the length of the scaphocerite.

**Etymology.** The name “*dorsum*” alludes to the distinct middorsal carina on the posterior 0.2 of the carapace in the new species. Used as a noun in apposition.

### Genus *Ambiaxius* Sakai & de Saint Laurent, 1989

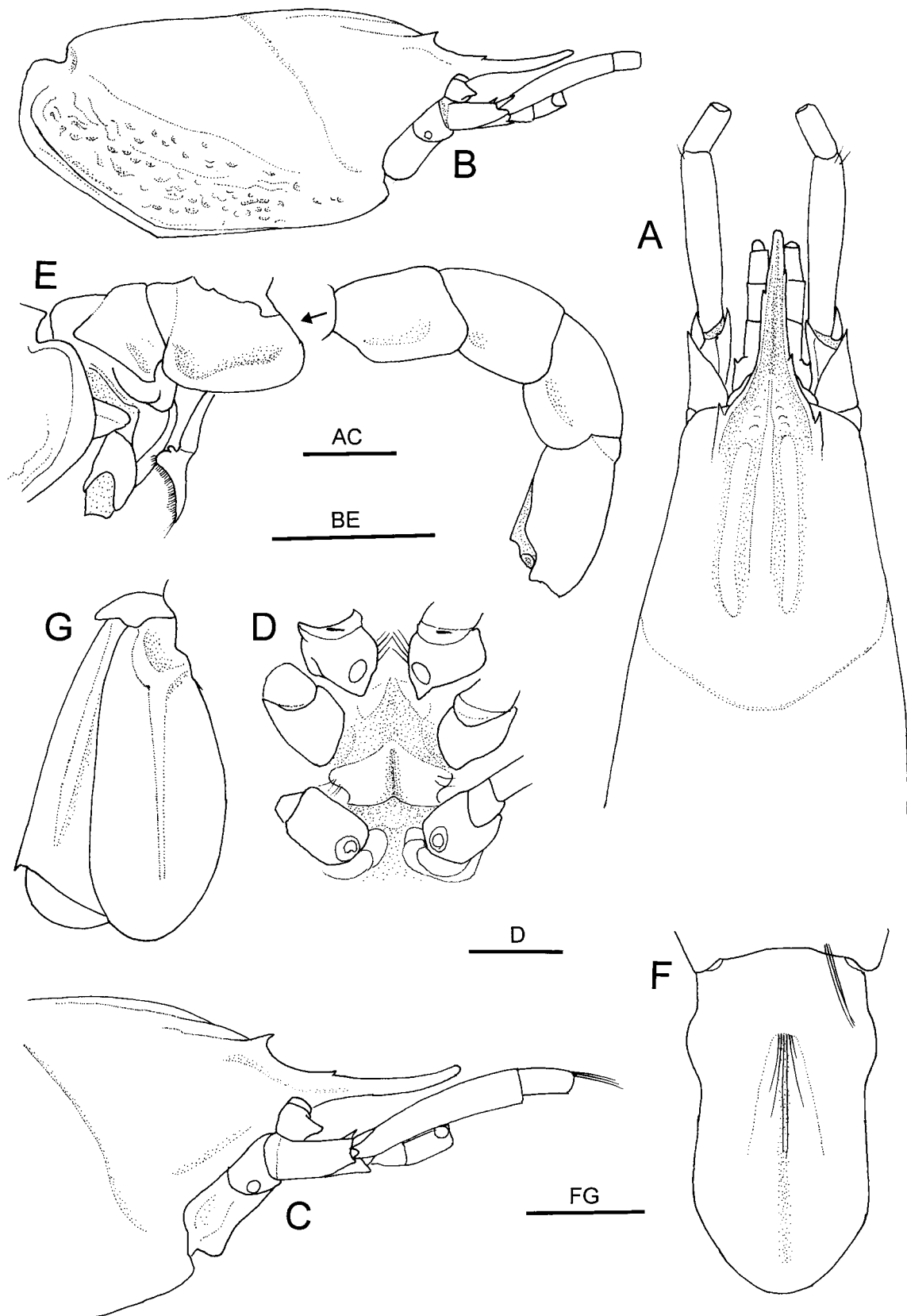
**Remarks.** *Ambiaxius* was originally established by Sakai & de Saint Laurent (1989) to accommodate two species, *Calocaris alcocki* McArdle, 1900 and *Calocaris aberrans* Bouvier, 1905. Kensley (1989) also described a new genus *Callistocaris* for *Calocaris alcocki*, but his paper was published two months later than Sakai & de Saint Laurent’s work. Thus *Callistocaris* is a junior objective synonym of *Ambiaxius*. Since then, four new species have been described in this genus, *A. franklinae* Sakai, 1994 from Australia, *A. japonicus* Kensley, 1996 from Japan, *A. foveolatus* Kensley, Lin & Yu, 2000 from Taiwan, and *A. surugaensis* Sakai & Ohta, 2005 from Japan. Sakai & Ohta (2005) proposed a new genus, *Briancaris*, for *A. aberrans*, *A. japonicus* (type species) and *A. foveolatus*. Sakai & Ohta (2005) argued that *Briancaris* differs from *Ambiaxius* in the short, triangular rostrum with denticulate lateral margins and the structure of the second pleopod. In *Ambiaxius*, the rostrum is slender and upturned, bearing one or two tiny lateral spines. With regard to the second pleopod, they noted that “distal segment of endopod enlarged with a boot-shaped appendix masculina with a small protrusion, on which is a small appendix interna, that is slightly distant from basal segment” for *Ambiaxius*, while that “distal segment of the endopod enlarged with a small appendix interna, which is attached close to the proximal segment basally” for *Briancaris*. However, these conditions are barely distinguishable. Except for the shape of the rostrum, the diagnostic features of *Ambiaxius* and *Briancaris* are virtually identical, and thus the status of *Briancaris* is questionable. Sakai & Ohta (2005) gave the confusing comment that “Kensley’s *Callistocaris* is obviously different from Sakai & de Saint Laurent’s (1989) *Ambiaxius*”, even though these two genera were based on the same type species (*i.e.*, *Calocaris alcocki*). We prefer to synonymize *Briancaris* with *Ambiaxius*.

### *Ambiaxius propinquus* n. sp.

(Figs. 4, 5, 13C)

**Type material.** Holotype: hermaphrodite (cl 11.8 mm), TAIWAN 2001, stn CD 129, 6 May 2001, 22°56.13’N, 122°3.69’E, 1271–1275 m, (NTOU A00044).





**FIGURE 4.** *Ambiaxius propinquus* n. sp., holotype, hermaphrodite (cl 11.8 mm), NTOU A00044. A, anterior part of carapace and cephalic appendages, dorsal view; B, carapace and cephalic appendages, lateral view; C, anterior part of carapace and cephalic appendages, lateral view; D, sixth to eighth thoracic sternites and coxae of third to fifth pereopods, ventral view (setae omitted); E, posterior part of thorax and abdomen, lateral view (damaged at second abdominal somite; setae omitted); F, telson, dorsal view (setae partially omitted); G, left uropod (setae omitted). Scale bars: B, E = 5 mm; A, C, F, G = 2 mm; D = 1 mm.

**Description of holotype.** Rostrum (Fig. 4A–C) 0.35 as long as carapace, slender, upturned, extending to midlength of fourth segment of antennal peduncle, armed with 1 (left) or 2 (right) tiny lateral spines, continuous with base of supraocular spine; dorsal surface channeled medially. Carapace (Fig. 4A–C) smooth except for slight rugosity on branchiostegite; supraocular spines prominent; gastric region convex, sloping to rostral base; lateral gastric carina very short, limited to base of supraocular spine; submedian gastric carina blunt, slightly rugose anteriorly, gradually becoming obsolete posteriorly; median gastric carina also blunt, unarmed, becoming obsolete gradually, not reaching cervical groove; cervical groove very shallow, but extending to pterygostomial region; very shallow branchial groove also present; no postcervical groove on dorsal midline; pterygostomial margin rounded.

Thoracic sternum (Fig. 4D) with shield on seventh somite weakly delimited, medially divided by deep groove.

First abdominal pleuron (Fig. 4E) short, produced ventrally as projection with narrowly rounded ventral margin; second pleuron broad, anteroventrally rounded, lateral surface shallowly depressed; third to fifth pleura rounded; sixth pleura also rounded. Telson (Fig. 4F) 1.8 times longer than wide, widest proximally, then approximately parallel-sided, lateral margin unarmed, posterior margin strongly convex without posteromedian spine, posterolateral region unarmed; dorsal face without spines on obsolete oblique ridges.

Eyestalks (Fig. 4A, C) very short, immovably attached to cephalothorax, contiguous, hardly visible in dorsal view; cornea depressed dorsoventrally, unpigmented, unfaceted, division between cornea and eyestalk unclear. Antennular peduncle (Fig. 4A, C) slightly falling short of midlength of fourth segment of antennal peduncle; first segment with small spine on statocyst lobe distolaterally; flagella missing. Antennal peduncle (Fig. 4A, C) with first segment unarmed; second segment with very small dorsolateral distal spine; scaphocerite small, directed slightly upwards, less than half length of second segment; third segment with sharp spine on distomesial angle; fourth segment about 1.8 times longer than second segment; fifth segment about 0.3 length of fourth segment; flagellum missing.

Third maxilliped (Fig. 5A) moderately slender; coxa with 1 ventromesial spinule; basis also with very small ventromesial spinule; ischium unarmed on ventral margin; crista dentata with about 30 small, corneous-tipped teeth; merus with 1 small subdistal spine on ventral margin; carpus unarmed; exopod with multiarticulate flagellum.

Only left cheliped preserved. Cheliped (Fig. 5B, C) elongate. Coxa bearing minute denticle on ventrodistal margin. Basis unarmed. Ischium with 2 minute denticles on ventral margin medially. Merus 4.9 times longer than high, with 1 subdistal spine (but fairly close to distal margin) on dorsal margin, unarmed on ventral margin. Carpus about 2.3 times longer than high, unarmed. Chela subequal in length to carapace and about 4.0 times longer than high (dorsal spine excluded), ventral margin faintly sinuous. Palm slightly becoming higher distally, 2.1 times longer than high, with 1 subdistal spine; lateral surface slightly convex, smooth, with few tufts of stiff setae, no carina along ventral margin; mesial face also smooth, with row of long stiff setae along ventral margin extending onto fixed finger. Fixed finger (Fig. 5D) smooth on lateral surface, with row of tufts of setae medially; mesial face faintly elevated along midline; cutting edge with row of very small triangular teeth interspersing 1 to 4 minute denticles in proximal 0.7 and row of tiny denticles in distal 0.3. Dactylus subequal in length to palm, with rows of tufts of long stiff setae on lateral and mesial faces; mesial face slightly elevated along midline; cutting edge thin, sharply edge, with row of minute denticles, tip crossing with that of fixed finger when closed; small hiatus formed proximally between fingers when dactylus closed.

Second pereopod (Fig. 5E) slender, unarmed on ischium to carpus; carpus about 0.6 length of chela; chela wider than carpus, with tufts of long setae on margins, fingers slightly longer than palm, each with row of minute corneous spinules on cutting edge. Third pereopod missing. Fourth pereopod (Fig. 5F) somewhat elongate, unarmed on ischium to carpus; propodus distally with cluster consisting of stiff setae and few stout setulose setae located distally (Fig. 5G, H), possibly representing grooming apparatus, but otherwise nearly smooth on lateral surface; dactylus (Fig. 5G, H) slender, about 0.3 times as long as propodus, slightly twisted, bearing numerous tufts of stiff setae along extensor and flexor margins. Fifth pereopod (Fig. 5I) not subchelate, unarmed on ischium to carpus; propodus distally with grooming apparatus consisting of cluster of

short to long setae, extending onto lateral and mesial faces, and transverse row of short, setulose, stout setae on ventrodistal margin (Fig. 5J, K); dactylus (Fig. 5J, K) very slender, elongate, about 0.4 times as long as propodus, flexor surface excavated near base, proximomesial margin slightly expanded, dorsal surface with numerous stiff setae.

Gonopores present on coxae of third and fifth pereopods (Fig. 4D).

Pleurobranchs absent. Two arthrobranchs above bases of third maxilliped to fourth pereopod. Podobranchs on third maxilliped to third pereopod slender, simple, without trace of gill elements.

First pleopod (Fig. 5L) with first segment (protopod) strongly flattened, slightly twisted; second segment (ramus) about 0.3 length of first segment, rounded triangular, leaf-like, small proximomesial protrusion representing appendix interna, terminally divided into two lobes by deep V-shaped incision. Second pleopod (Fig. 5M) with inner ramus consisting of elongate, somewhat twisted first segment of endopod while distal segment of endopod fused with appendix masculina (= distal fused segment); thumb-like appendix interna located at proximomesial margin of distal fused segment; distal fused segment tapering distally, boot-like in shape, distinctly shorter than first segment of endopod, with double row of spiniform setae on strongly sinuous mesial margin and with several terminal setae. Third to fifth pleopods very slender, without appendices internae.

Uropodal endopod (Fig. 4G) 2.4 times as long as wide, without lateral spines, dorsal ridge unarmed. Uropodal exopod (Fig. 4G) without lateral spines, posterolateral angle with 1 spine, but no spiniform setae apparent; transverse suture unarmed.

**Coloration.** Body generally ivory-whitish, with anterior part of carapace including eyes somewhat dark greenish (Fig. 13C).

**Distribution.** Known only from southeastern Taiwan at depths of 1271–1275 m.

**Remarks.** The present specimen from Taiwan is very similar to the respective holotypes of *A. alcocki* and *A. franklinae*. However, it differs from the descriptions of the holotype of *Ambiaxius alcocki* from the Bay of Bengal in two points (McArdle 1900; Alcock 1901). In the Taiwanese specimen, the postcervical carapace is rounded in the dorsal surface, whereas it was mentioned that the carapace was bluntly carinate along the midline in the holotype, clearly suggesting the presence of a postcervical carina on the carapace. In fact, Sakai (1995) identified a Japanese specimen, which has a clearly delimited postcervical carina on the carapace, as *A. alcocki*, although he later referred it to a new species, *A. surugaensis* (cf. Sakai & Ohta 2005). The second point is the absence of an enlarged tooth on the cutting edge of the dactylus of the cheliped in the present specimen, which was said to be present in the holotype. The significance of the second point is rather questionable, because only the left cheliped is preserved in the present specimen. However, the development of the postcervical carina on the carapace is considered to be species specific in Axiidae and Calocarididae, and its absence alone seems to justify the separation of the Taiwanese specimen from *A. alcocki*. Direct comparison with the holotype likely will reveal further morphological differences. Moreover, the identities of *A. alcocki* reported from discrete localities such as South Africa and New Caledonia (cf. Stebbing 1915, 1917; Barnard 1950; Sakai & de Saint Laurent 1989; Sakai & Ohta 1995) will need to be verified (e.g., Kensley 1996a). The lack of the postcervical carina on the carapace aligns the Taiwanese specimen with *A. franklinae*. However, it differs from the latter by the shorter and less curved rostrum. In the Taiwanese specimen, the rostrum does not reach the distal end of the fourth segment of the antennal peduncle, whereas in the holotype of *A. franklinae* it is longer, nearly reaching the distal end of the fifth segment of the antennal peduncle. Furthermore, the spiniform setae on the concave anterior margin of the boot-shaped appendix masculina of the second pleopod seem to be more numerous in the Taiwanese specimen than in *A. franklinae*. Therefore, it is concluded that the Taiwanese form is a separate species.

Another species of the genus, *Ambiaxius surugaensis*, can be immediately distinguished from the present new species and the other two species by the arthrobranchs bearing rudimentary gill elements. In the other three species, the arthrobranchs are distinctly lamellate. The presence of the postcervical carina also distinguishes *A. surugaensis* from *A. propinquus* n. sp. and *A. franklinae*. The much broader distal segment of the first pleopod is also characteristic to *A. surugaensis*, although the detailed structure of the appendage remains unknown for the holotype of *A. alcocki*.

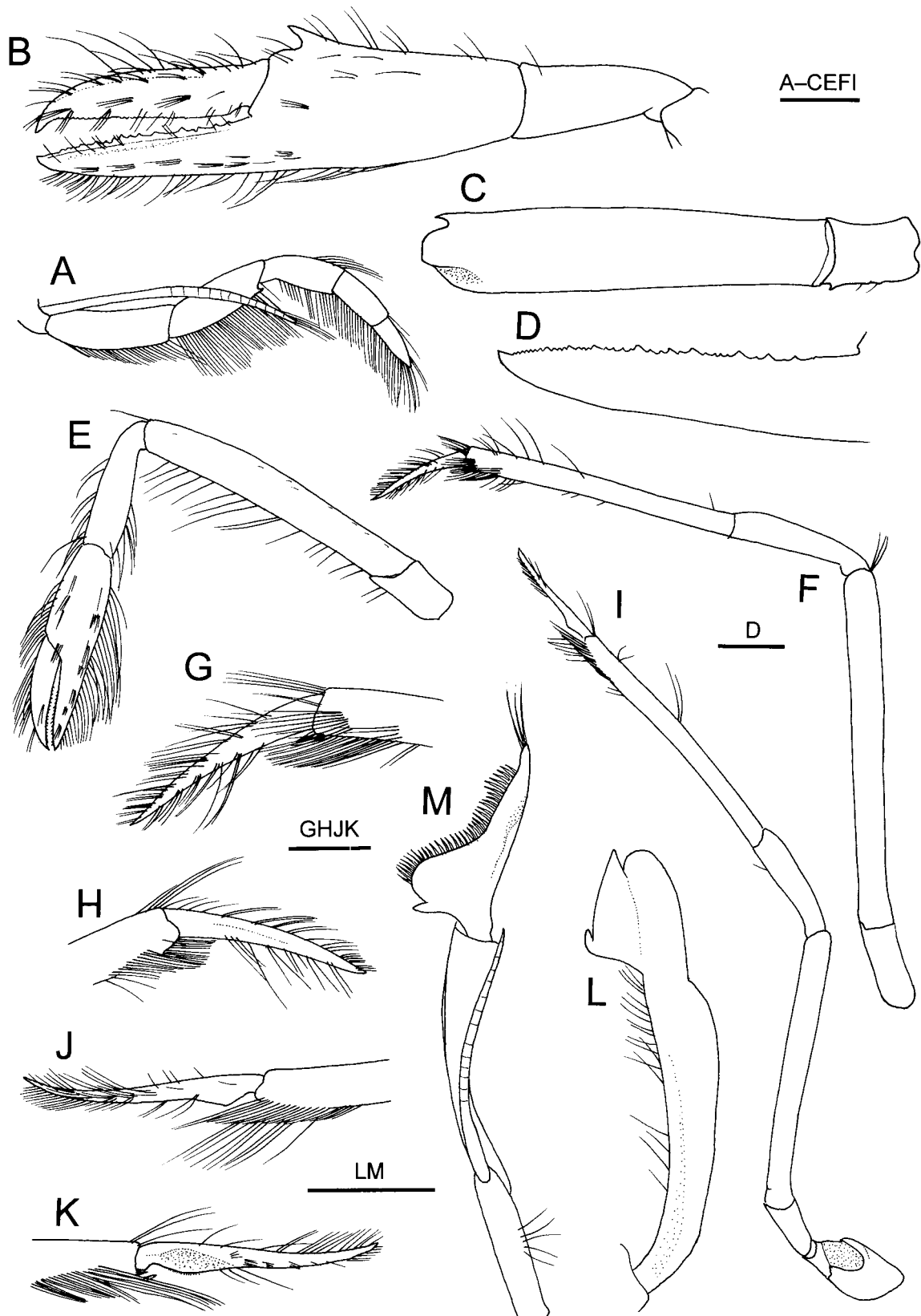


FIGURE 5. *Ambiaxius propinquus* n. sp., holotype hermaphrodite (cl 11.8 mm), NTOU A00044. A, right third maxilliped, lateral view; B, chela and carpus of left cheliped, lateral view; C, merus of left cheliped, lateral view; D, fixed finger of left chela, lateral view; E, left second pereopod, lateral view; F, left fourth pereopod; G, same, distal part of propodus and dactylus, lateral view; H, same, mesial view; I, left fifth pereopod, lateral view; J, same, distal part of propodus and dactylus, lateral view; K, same, mesial view. Scale bars: A–C, E, F, I = 2 mm; D, G, H, J, K–M = 1 mm.

**Etymology.** From the Latin, *propinquus*, meaning similar or related, in reference to the close similarity of the new species to *A. alcocki* and *A. franklinae*.

**Genus *Calastacus* Faxon, 1893**

***Calastacus formosus* n. sp.**

(Figs. 6–8, 13D)

**Type material.** Holotype: hermaphrodite (cl 7.1 mm), TAIWAN 2001, stn CP 104, 24°48.86'N, 122°05.31'E, 365–447 m, 19 May 2001 (NTOU A00083).

Paratypes: 2 hermaphrodites (cl 6.0, 6.5 mm), 1 ovigerous hermaphrodite (cl 9.0 mm), TAIWAN 2001, stn CP 102, 24°48.38'N, 122°07.97'E, 326–331 m, 19 May 2001 (NTOU A00110).

**Description of holotype.** Rostrum (Fig. 6A–D) 0.2 times as long as carapace and about 0.4 times of distance between rostral base and cervical groove, spike-like with acute tip, unarmed anterior to supraocular spine, not continuous with lateral gastric carinae on carapace. Carapace (Fig. 6A–D) smooth; gastric region convex, higher than rostral base; supraocular spines prominent; lateral and submedian gastric carinae absent; median gastric carina unarmed, extending over midway between rostral base and cervical groove; cervical groove distinct, extending nearly to pterygostomial part of carapace; no postcervical carina; pterygostomial margin with small spine.

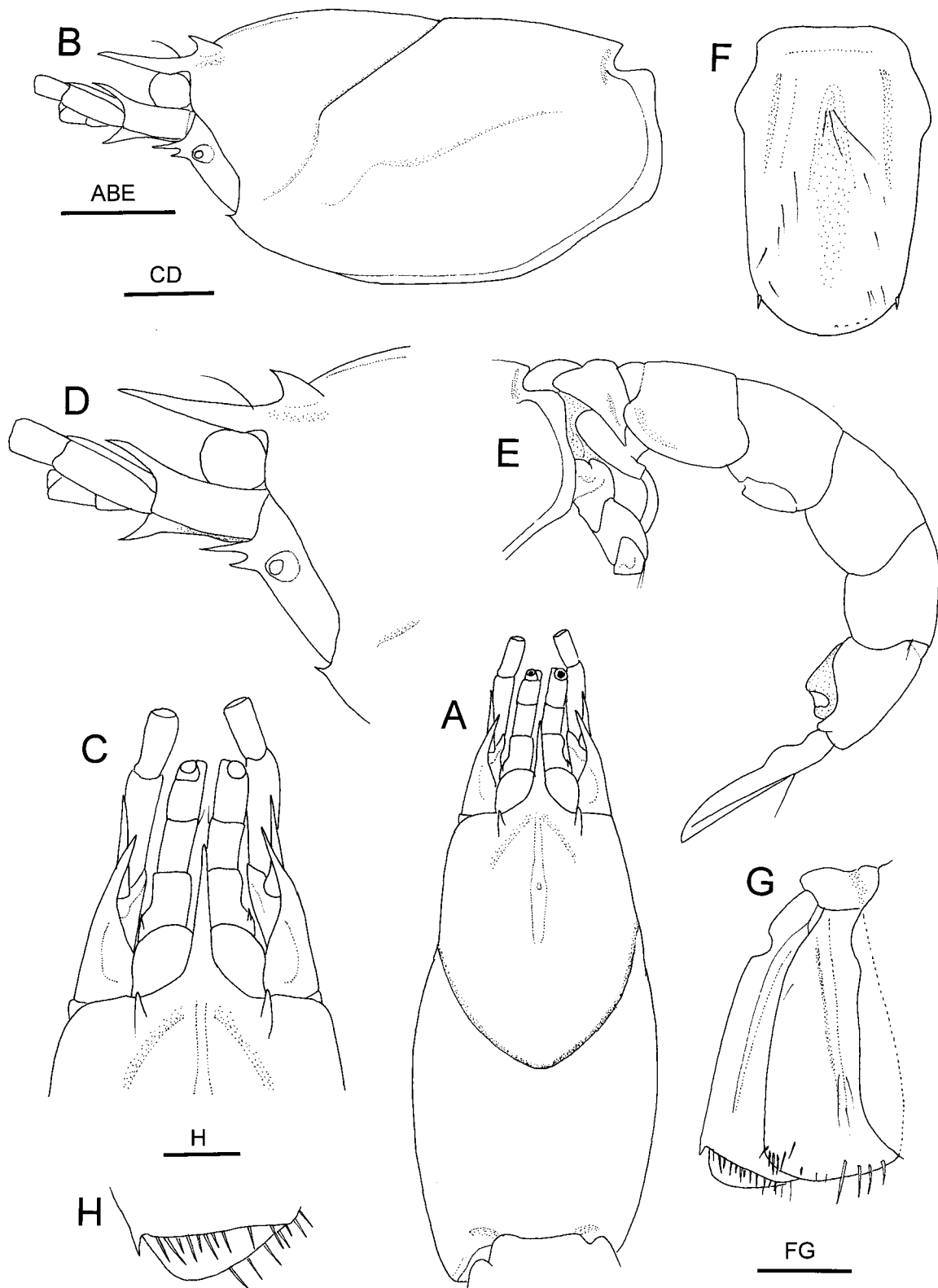
Thoracic sternum (Fig. 7A) with poorly delimited shield on seventh somite, medially separated by deep groove; sixth somite with spade-shaped prominence.

First abdominal pleuron (Fig. 6E) short, produced ventrally as acute projection; second pleuron broad, anteroventrally rounded; third to fifth pleura rounded; sixth pleura also rounded. Telson (Fig. 6F) 1.6 times longer than wide, widest proximally, then approximately parallel-sided, lateral margin unarmed, posterior margin strongly convex without posteromedian spine, posterolateral region with 1 minute spiniform seta; dorsal face without spines on obsolete oblique ridges.

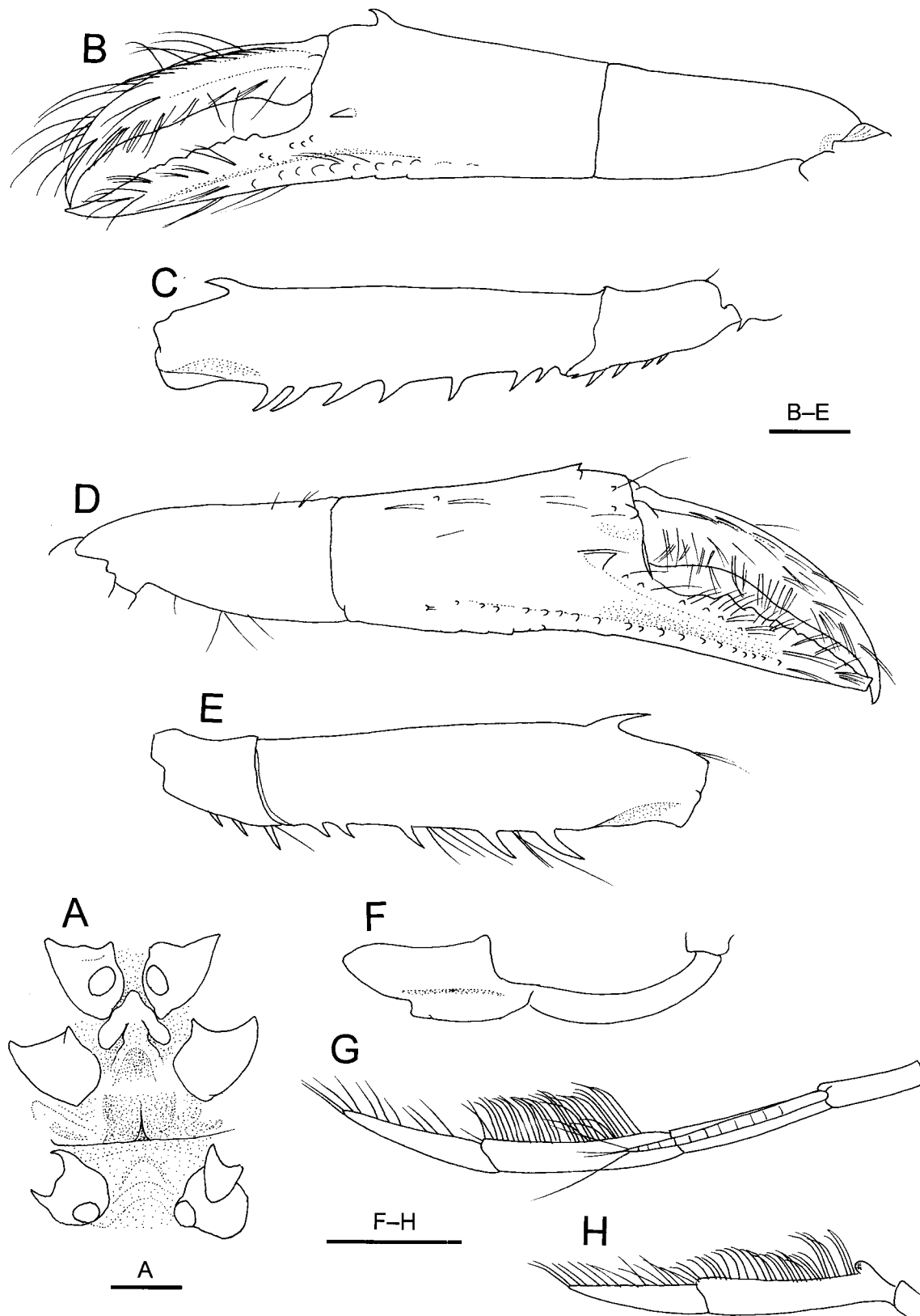
Eyestalks (Fig. 6C, D) subglobose, 0.4 length of rostrum, immovably attached to cephalothorax, not contiguous; cornea unpigmented, unafaceted, division between cornea and eyestalk unclear. Antennular peduncle (Fig. 6C) reaching distal margin of fourth segment of antennal peduncle; first segment with small submarginal spine on statocyst lobe dorsodistally; flagella missing. Antennal peduncle (Fig. 6C, D) with first segment bearing 2 spines on ventrodorsal margin (lateral spine longer than mesial spine); second segment with dorsolateral distal spine slender, slightly curved inward in dorsal view, slightly directed dorsally in lateral view, reaching to midlength of fourth segment; scaphocerite slender, directed slightly upwards, slightly falling short of distal margin of fourth segment; third segment with sharp spine on distomesial angle; fourth segment slightly longer than second segment (excluding dorsolateral distal spine); fifth segment about half length of fourth segment; flagellum missing.

Third maxilliped (Fig. 8A) moderately slender; coxa with 1 small ventromesial spine; basis also with small ventromesial spine; ischium unarmed on ventral margin; crista dentata with about 20 corneous-tipped teeth; merus with 2 long subdistal spines on ventral margin; carpus unarmed.

Chelipeds (Fig. 7B–E) subequal, similar, fairly elongate. Right cheliped (Fig. 7D, E) with coxa bearing spine on ventrodorsal margin. Basis also with small spine ventrodorsally. Ischium with row of 3 slender spines on ventral margin. Merus with 1 subdistal spine (slightly hooked) and row of 5 slender spines increasing in size distally on ventral margin. Carpus unarmed. Chela 0.9 times as long as carapace and 3.6 times longer than high, ventral margin slightly curving. Palm slightly becoming higher distally, 1.8 times longer than high, with 1 subdistal spine on faintly carinate dorsal margin and 1 spine on lateral surface adjacent to base of fixed finger; lateral surface slightly convex, with few tufts of long setae and row of low tubercles bearing tufts of setae adjacent to ventral margin, extending onto fixed finger; mesial face also with spine adjacent to base of fixed finger. Fixed finger with row of small tubercles and tufts of long setae on mesial face along ventral margin, latter extending onto palm; cutting edge with row of rounded teeth. Dactylus with 3 longitudinal rows of long stiff setae on lateral surface; mesial face medially carinate, also with rows of long stiff setae; cutting edge with broad concavity proximally, forming narrow hiatus when closed, tip closing with tip of fixed finger.



**FIGURE 6.** *Calastacus formosus* n. sp., holotype, hermaphrodite (cl 7.6 mm), NTOU A00083. A, carapace and cephalic appendages, dorsal view; B, same, lateral view; C, anterior part of carapace and cephalic appendages, dorsal view; D, same, lateral view; E, posterior part of thorax, abdomen and telson, lateral view; F, telson, dorsal view (setae partially omitted); G, left uropod, dorsal view (perpendicular to horizontal plane of uropod; setae partially omitted; lateral margin of exopod damaged proximally); H, close up of distal part of uropodal exopod (setae partially omitted). Scale bars: A, B, E = 2 mm; C, D, F, G = 1 mm; H = 0.5 mm.



**FIGURE 7.** *Calastacus formosus* n. sp., holotype, hermaphrodite (cl 7.6 mm), NTOU A00083. A, sixth to eighth thoracic sternites and coxae of third to fifth pereopods, ventral view (setae omitted); B, chela and carpus of left cheliped, lateral view; C, merus and ischium of left cheliped, lateral view; D, chela and carpus of right cheliped, lateral view; E, merus and ischium of right cheliped, lateral view; F, left first pleopod, lateral view; G, left second pleopod, lateral view; H, distal segments of right second pleopod, mesial view. Scale bars: 1 mm.

Left cheliped (Fig. 7A, B) only slightly shorter than major cheliped, otherwise generally similar. Ischium with 4 spines on ventral margin. Merus with 1 subdistal spine on dorsal margin and 7 spines on ventral margin. Armament and setation of other segments identical with those on major cheliped.

Second pereopod (Fig. 8B) slender, unarmed on ischium to carpus; carpus about 0.6 length of chela; chela with tufts of long setae on margins, fingers slightly shorter than palm, each with row of minute corneous spinules on cutting edge. Ambulatory legs (third to fifth pereopods) somewhat elongate. Third pereopod (Fig. 8C) unarmed on ischium to carpus; propodus with row of spiniform setae on lateral surface distally (Fig. 8D); dactylus (Fig. 8D, E) subconical, slender, about 0.3 times as long as propodus, slightly twisted, setose. Fourth pereopod (Fig. 8F) unarmed on ischium to carpus; propodus distally with cluster consisting of stiff setae and longer, stout setulose setae, possibly representing grooming apparatus, and with sets of 1 or 2 spiniform setae and longer stiff setae on lateral surface distally (Fig. 8G); dactylus (Fig. 8G, H) subconical, setose, slightly twisted (tip broken, thus proportion against propodus unknown). Fifth pereopod (Fig. 8I) not subchelate, unarmed on ischium to carpus; propodus distally with grooming apparatus consisting of cluster of short to long setae, extending onto lateral and mesial faces (Fig. 8J, K); dactylus (Fig. 8J, K) very slender, elongate, about 0.4 times as long as propodus, flexor surface excavated near base, proximomesial margin expanded, dorsal surface with row of tufts of stiff setae.

Gonopores present on coxae of third and fifth pereopods (Fig. 7A).

Pleurobranchs absent; podobranchs and arthrobranchs present on second maxilliped through fourth pereopods, podobranchs bearing papillae representing rudimentary gill filaments; epipods present on first maxilliped through fourth pereopod.

First pleopod (Fig. 7F) with first segment (protopod) strongly flattened; second segment (ramus) 0.7 length of first segment, leaf-like, deeply concave on mesial margin proximally, proximomesial protrusion representing appendix interna conspicuous on broad triangular anterior fold, lateral fold forming definite shoulder on lateral margin. Second pleopod (Fig. 7G, H) with inner ramus consisting of 2-segmented endopod plus distally articulated appendix masculina, all components more or less in line with peduncle, with thumb-like appendix interna at base of second segment of endopod; second segment of endopod with slightly concave dorsal (or anterior) margin bearing numerous stiff, curving setae; appendix masculina tapering distally with row of sparse stiff setae laterally and mesially, and with terminal tuft of stiff setae; exopod very slender, half length of endopod. Third to fifth pleopods very slender, without appendices internae.

Uropodal endopod (Fig. 6G) about 2.0 times as long as wide, without lateral spines, dorsal ridge unarmed, distal margin subtruncate; exopod (Fig. 6G) without lateral serration, posterolateral angle with 1 spine, but no spiniform setae apparent; transverse suture with about 10 slender spiniform setae (Fig. 6H).

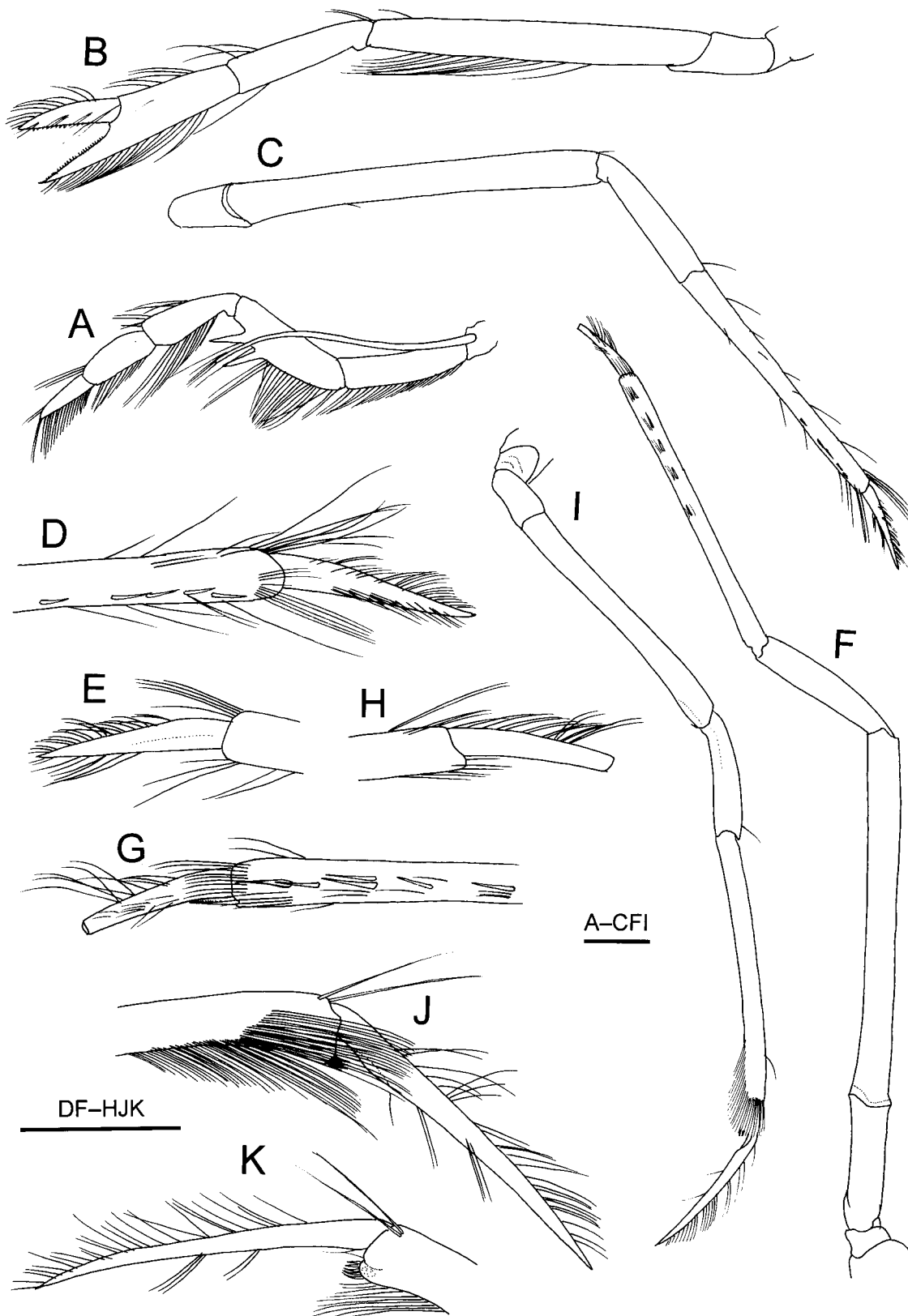
**Note on paratypes.** One paratype lacks right first and fifth pereopods; other two missing first chelipeds and several pereopods. Antennal peduncle with first segment bearing 2 spines on ventrodorsal margin (lateral spine longer than mesial spine, and mesial spine small to distinct). First chela 0.7 times as long as carapace and 3.3 times longer than high, ventral margin slightly curving; palm slightly becoming higher distally, 1.8 times longer than high, with 1 subdistal spine on dorsal margin and 1 spine on lateral surface near base of fixed finger; carpus unarmed; merus with 1 subdistal spine on dorsal margin and 7 spines on ventral margin; ischium with 3 spines on ventral margin. Uropodal endopod about 2.0 times as long as wide, without lateral spines, dorsal ridge unarmed, distal margin subtruncate; exopod without lateral serration, posterolateral angle with 1 spine and 1 small spiniform seta; transverse suture with 10 or more slender spiniform setae.

**Coloration.** Body and appendages entirely pale yellowish to pale yellowish pink; cornea of eye opaque. Inner margins of fingers of second chelae dark purplish.

**Distribution.** Known only from northeastern Taiwan; at depths of 326–447 m.

**Remarks.** The present new species agrees well with the diagnosis of *Calastacus*, provided by de Saint Laurent (1972), Kensley (1989), Poore (1994) and Poore & Collins (2009). The genus is currently represented by seven species worldwide, *C. stilirostris* Faxon, 1893 (type species) from the eastern Pacific off Mexico to Peru, *C. laevis* de Saint Laurent, 1972 from the eastern Atlantic and Mediterranean, *C. colpos* Kensley, 1996 from the northwestern Gulf of Mexico, *C. mexicanus* Kensley, 1996 from the Gulf of Mexico, *C. crosnieri* Kensley & Chan, 1998 from Taiwan, *C. inflatus* Komai, Lin & Chan, 2009 from the South China Sea off the





**FIGURE 8.** *Calastacus formosus* n. sp., holotype, hermaphrodite (cl 7.6 mm), NTOU A00083. A, left third maxilliped, lateral view; B, left second pereopod, lateral view; C, right third pereopod, lateral view; D, same, distal part of propodus and dactylus, lateral view; E, same, mesial view; F, left fourth pereopod, lateral view (distal part of dactylus damaged); G, same, distal part of propodus and dactylus, lateral view; H, same, mesial view; I, right fifth pereopod, lateral view; J, same, distal part of propodus and dactylus, lateral view; K, same, mesial view. Scale bars: 1 mm.

Pratas Islands, and *C. myalup* Poore & Collins, 2009 from south Western Australia (Kensley 1996a; Kensley & Chan 1998; Ngoc-Ho 2003; Komai *et al.* 2009; Poore & Collins 2009). The new species appears closest to *C. myalup* in the presence of a pterygostomial spine on the carapace and the suture of the uropodal exopod, which bears 10 or more slender spiniform setae. Nevertheless, *C. formosus* n. sp. differs from *C. myalup* in the shape of the uropodal endopod. In *C. formosus*, the posterior margin of the uropodal endopod is subtruncate, but it is rounded in *C. myalup*. Furthermore, the supraorbital spine on the carapace only just exceeds the orbital margin of the carapace in *C. formosus* n. sp., rather than overreaching the middle of the eye in *C. myalup*. The ornamentation of the appendix masculina of the second pleopod consists only of stiff setae in *C. formosus*, but it includes spiniform setae in *C. myalup*.

This is the second species of *Calastacus* known from Taiwan. The other species is *C. crosnieri*, which is golden yellow in color and very different from the pale yellowish body of *C. formosus*. Considering the general scarcity of species of the genus around the world, the presence of two species from the same region is rather remarkable.

**Etymology.** The species is named after its type locality Taiwan derived from a former name, “Formosa”.

## Family Eiconaxiidae

### Genus *Eiconaxius* Bate, 1888

**Remarks.** Kensley (1996b) briefly summarized the taxonomy of the genus, and listed 23 species. Since then, Sakai & Ohta (2005) added a further new species, *Eiconaxius hakuhou*, from the Sulu Sea, the Philippines. As indicated by Kensley (1996b), dentition of the median carina and rostral margins, development of the submedian and lateral carinae, shape of the abdominal pleura seem to be particularly useful in species discrimination. Two specimens of this genus are now known from Taiwanese waters. In spite of the paucity of the material, comparison with literature and specimens from other localities led to the conclusion that the Taiwanese material represents two separate new species.

### *Eiconaxius rubrirostris* n. sp.

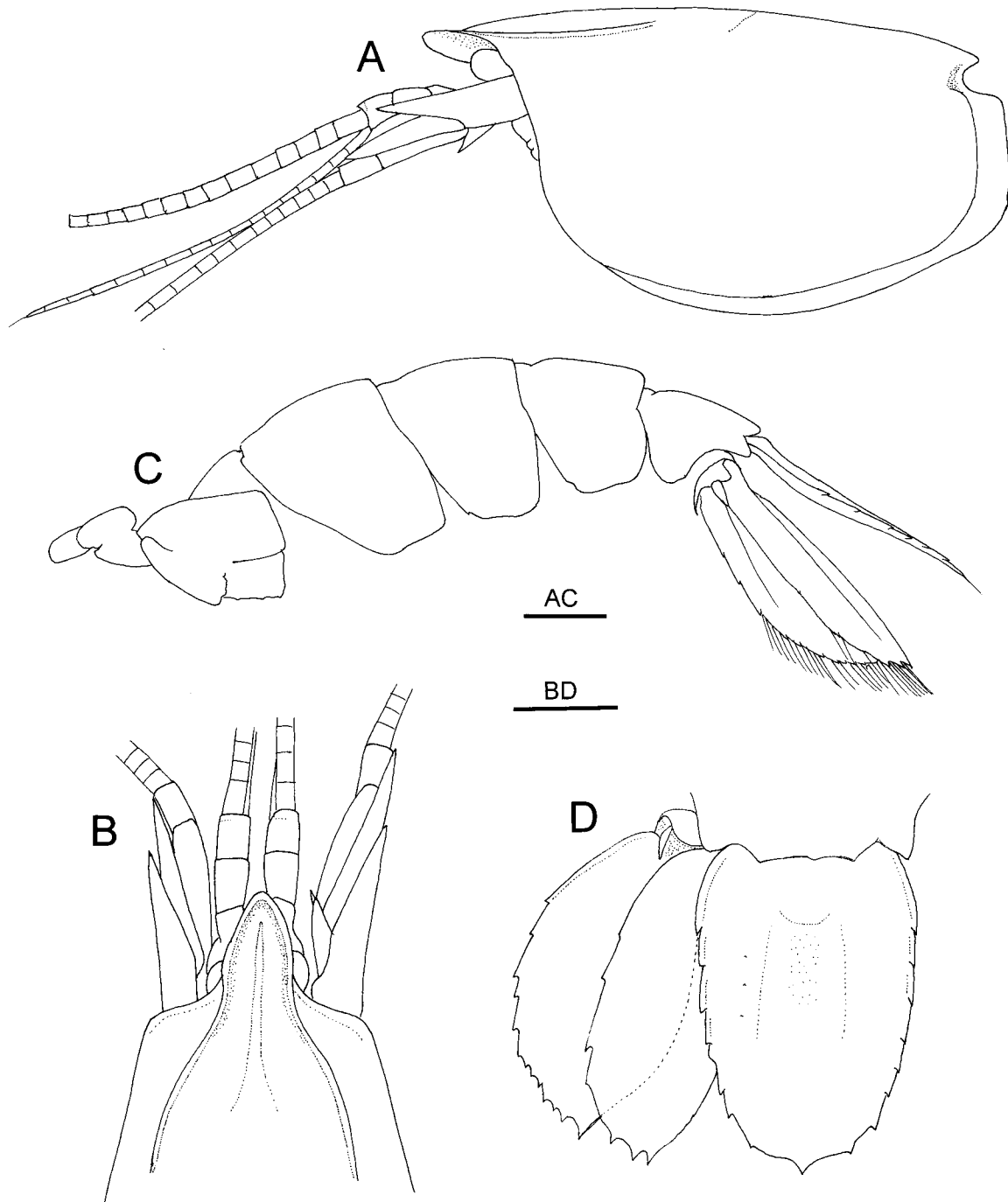
(Figs. 9, 10, 13E)

**Type material.** Holotype: male (cl 5.4 mm), TAIWAN 2000, stn CP 55, 24°24.40'N, 122°18.0'E, 638–824 m, 4 August 2000 (NTOU A00114).

**Description.** Rostrum (Fig. 9A, B) lanceolate, apically narrowly rounded, straight, reaching slightly beyond distal margin of first segment of antennular peduncle; lateral margins nearly smooth, slightly upturned. Carapace (Fig. 9A, B) with gastric region very slightly convex; cervical groove faint; median carina entire, broadened posteriorly, but not distinctly bifurcate; submedian carina absent; lateral carinae reaching posteriorly to about anterior one-third of carapace length, slightly constricted posterior to orbit; submarginal carina distinct.

First and second abdominal somites damaged. Second to fourth pleura (Fig. 9C) angular (second and third) or rounded posteroventrally (fourth), none forming acute ventral or posteroventral tooth, fifth pleura generally rounded ventrally; anterolateral margin of fourth and fifth pleura each with minute tooth ventrally; sixth abdominal somite short, with 3 obtuse small protuberances on posterodorsal margin, unarmed on pleural ventral margin. Telson (Fig. 9D) with greatest width at anterior 0.25 length, with 8 serrations, including 1 tiny posterolateral one, on lateral margin; moderately small posteromedian tooth present.

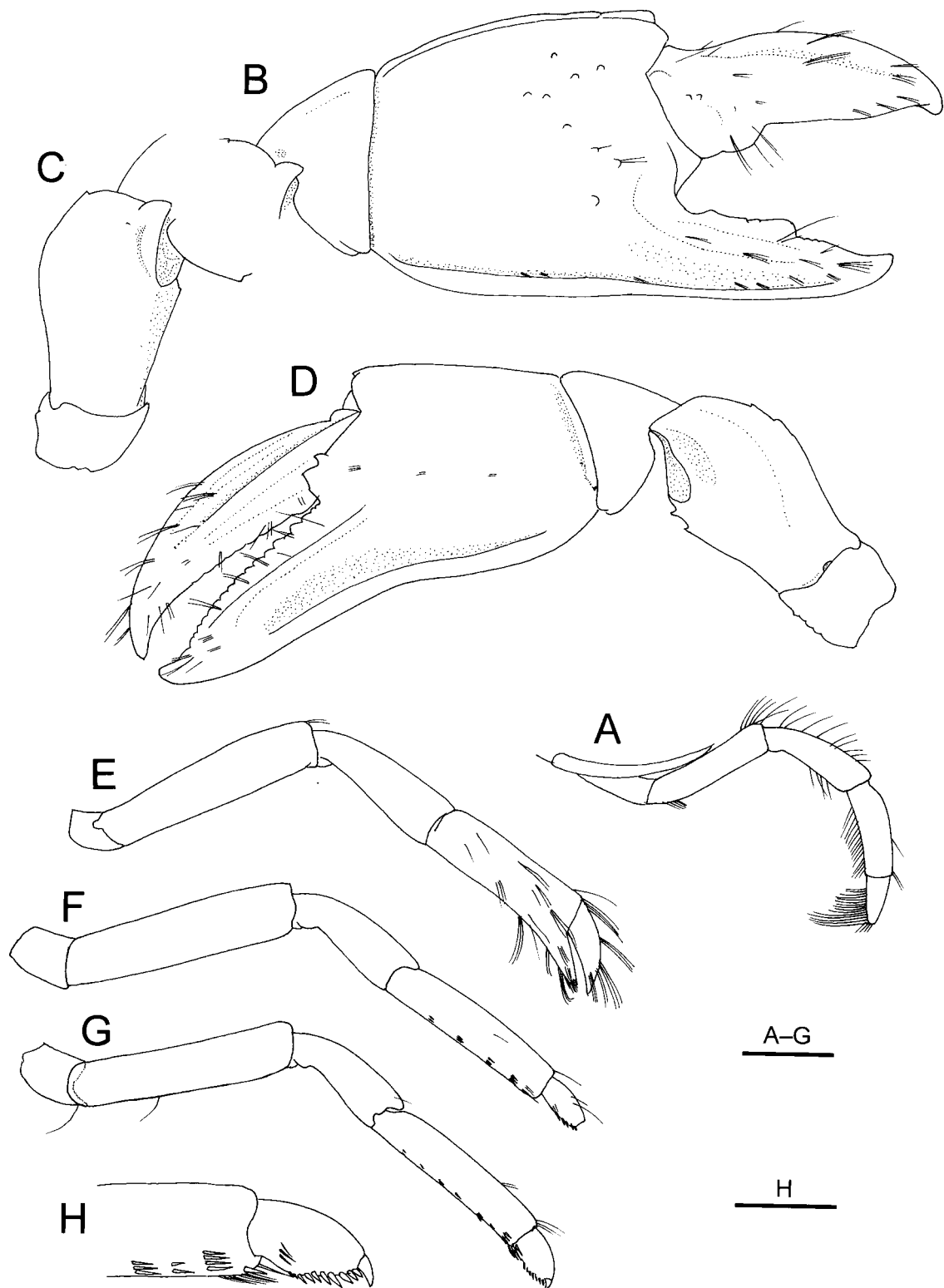
Eye (Fig. 9A) reaching midlength of rostrum; cornea subglobose, not faceted, lacking pigment. Antennular peduncle (Fig. 9A, B) with distal two segments subequal in length to first segment; flagella nearly as long as carapace. Antennal peduncle (Fig. 9A, B) moderately stout; distolateral prolongation of second segment acute, overreaching distal margin of second segment of antennular peduncle; third segment with small spine at ventromesial distal angle; antennal acicle large, acuminate, reaching nearly to distal margin of fifth segment of antennal peduncle or far overreaching distal margin of antennular peduncle; flagellum moderately slender (distal half missing).



**FIGURE 9.** *Eiconaxius rubrirostris* n. sp., holotype, male (cl 5.4 mm), NTOU A00114. A, carapace and cephalic appendages, lateral view (antennular and antennal flagellum partially broken off); B, anterior part of carapace and cephalic appendages, dorsal view (antennular and antennal flagellum partially omitted); C, abdomen, telson and uropod, lateral view (first and second somites damaged); D, telson and left uropod, dorsal view (setae omitted). Scale bars: 1 mm.

Third maxilliped (Fig. 10A) moderately slender for genus; ischium with crista dentata consisting of row of tiny denticles

Major (right) cheliped (Fig. 10B, C) massive. Ischium unarmed on ventral margin. Merus strongly compressed laterally; dorsal margin strongly convex, bearing minute denticle distal to midlength, but otherwise smooth, terminating distally in minute tooth; ventromesial margin sharply carinate, with 1 minute subterminal denticle; laterodistal projection subacute. Carpus cup shaped, much wider than long, ventral angle



**FIGURE 10.** *Eiconaxius rubrirostris* n. sp., holotype, male (cl 5.4 mm), NTOU A00114. A, right third maxilliped, lateral view; B, chela and carpus of right cheliped, lateral view; C, merus and ischium of right cheliped, lateral view; D, left cheliped, lateral view; E, right second pereopod, lateral view; F, right third pereopod, lateral view; G, right fourth pereopod, lateral view; H, same, dactylus and distal part of propodus, lateral view. Scale bars: A–G = 1 mm; H = 0.5 mm.

faintly dentate. Chela slightly longer than carapace (including rostrum). Palm 1.05 times longer than high, dorsal margin sharply carinate, terminating distally in small subacute tooth, with tiny denticle somewhat proximal to dorsodistal tooth, lateral surface convex with several scattered tubercles in distal half; ventrolateral carina sharp, extending to distal 0.20 of fixed finger, accompanied with deep groove; mesial surface also with scattered tubercles in distal half. Fixed finger nearly straight but distally slightly upturned, with 1 blunt, small but distinct tooth arising at about mid-length, otherwise minutely dentate; finger cleft shallowly excavate; lateral face flanked by blunt upper ridge along cutting edge and ventrolateral ridge concave. Dactylus nearly as long as palm, terminating in slightly curved calcareous claw, dorsal margin sharply carinate; lateral surface shallowly sulcate along dorsal carina; cutting edge with 1 obtuse tooth proximally, otherwise unarmed.

Minor (left) cheliped (Fig. 10D) slightly shorter and less stout than major cheliped. Ischium with 1 minute denticle slightly distal to midlength. Merus strongly compressed laterally; dorsal margin sinuous, sharply carinate, bearing 3 minute denticles distal to midlength, terminating distally in minute denticle; ventromesial margin sharply carinate, with 2 tiny subdistal spinules; laterodistal projection subacute. Carpus cup shaped, much wider than long, ventral angle faintly dentate. Chela subequal in length to carapace (including rostrum). Palm slightly becoming wider distally, 1.1 times higher than long; dorsal margin sharply carinate, smooth, terminating distally in minute denticle; lateral surface generally convex, smooth; ventrolateral carina sharp, extending to midlength of fixed finger; mesial surface smooth. Fixed finger slightly deflexed, almost straight but distally slightly upturned, with row of small, triangular or rounded teeth over entire length; finger cleft with 3-spined cusp laterally; lateral face flanked by sharp upper ridge along cutting edge and ventrolateral ridge shallowly concave. Dactylus about 1.4 times as long as palm, terminating in slightly curved calcareous claw, dorsal margin sharply carinate; lateral surface with distinct longitudinal carina on midline; cutting edge faintly dentate.

Second to fourth pereopods of similar length, moderately stout. Second pereopod (Fig. 10E) unarmed on ischium to carpus; chela about 1.5 times longer than carpus, with scattered tufts of setae; fixed finger slightly deflexed, with row of minute corneous spinules on cutting edge; dactylus about 0.6 times as long as palm, setose, also with row of minute corneous spinules on cutting edge. Third pereopod (Fig. 10F) unarmed on ischium to carpus; propodus about 1.5 times longer than carpus, with 5 sets of slender spiniform setae on lateral surface ventrally and 1 spiniform seta at ventrodistal margin; dactylus (Fig. 10H) strongly compressed laterally, suboval, terminating in clearly demarcated claw, with about 8 spiniform setae on flexor margin and 1 set of 2 slender spiniform setae on lateral surface. Fourth pereopod (Fig. 10G) similar to third pereopod; propodus with 7 sets of spiniform setae and 1 ventrodistal spiniform seta; dactylus with 9 spiniform setae on flexor margin and 1 set of 3 spiniform setae on lateral surface. Fifth pereopods missing.

First pleopod absent. Second to fifth pleopods slender, biramous, each with appendix interna; appendix masculina on second pleopod subequal to appendix interna, bearing about 10 stiff setae. Uropodal exopod (Fig. 9D) with about 13 serrations on lateral and posterior margins, posteriormost one larger than others, mesial margin nearly regularly convex; endopod (Fig. 9D) with about 7 serrations increasing in size posteriorly.

**Coloration.** Body generally whitish, but rostrum distinctly reddish; cornea of eye opaque.

**Distribution.** Known only from northeastern Taiwan; at depths of 638–824 m.

**Remarks.** Affinities of this new species are given under *Eiconaxius kensleyi* n. sp.

**Etymology.** The Latin “*rubrirostris*” refers to the distinctly red rostrum in this new species.

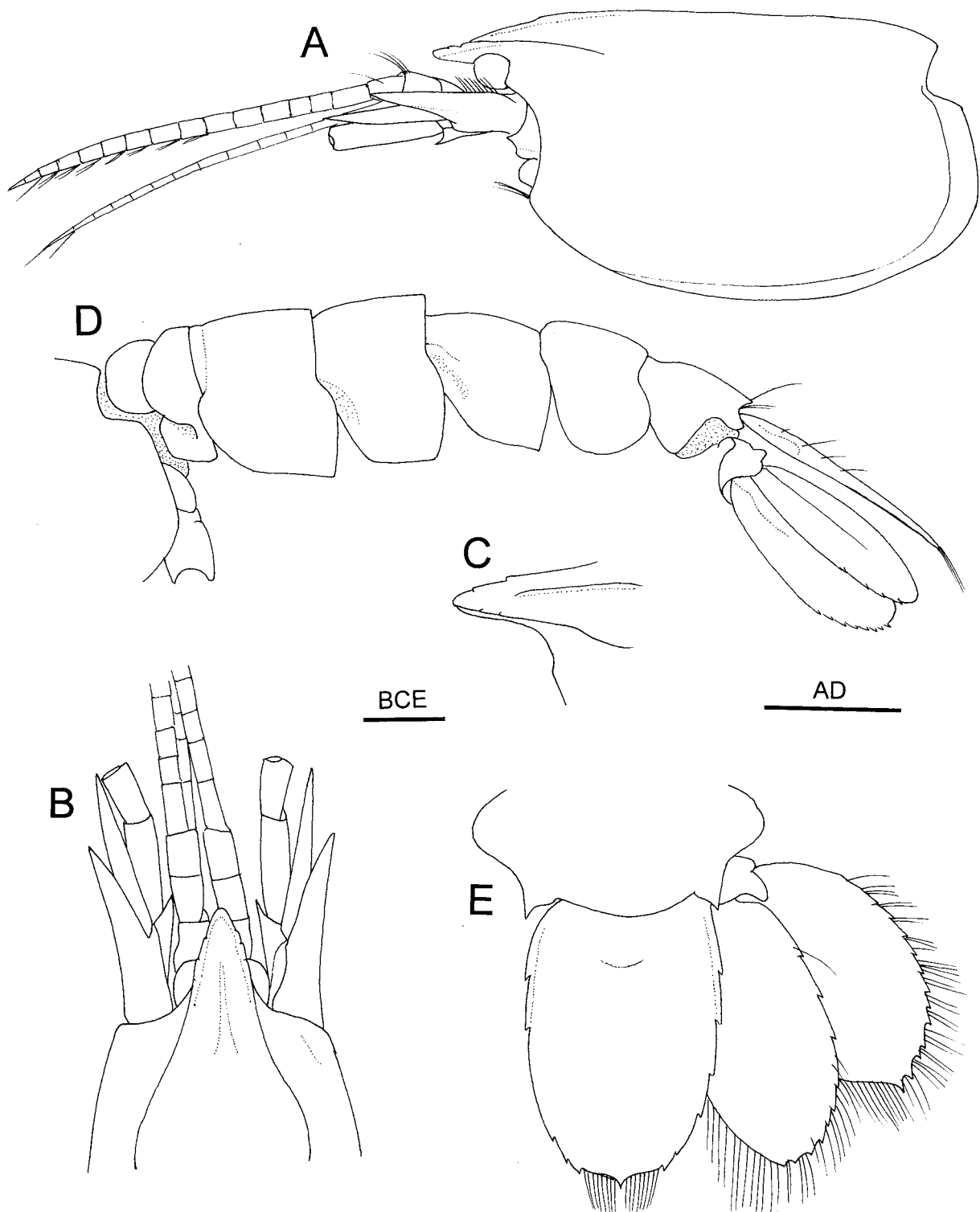
### ***Eiconaxius kensleyi* n. sp.**

(Figs. 11, 12, 13F)

**Type material.** Holotype: male (cl 3.1 mm), TAIWAN 2000, stn DW 45, 22°47.10'N, 121°27.30'E, 439 m, 2 August 2000 (NTOU A00111).

**Description.** Rostrum (Fig. 11A–C) lanceolate, apically narrowly rounded, straight, slightly overreaching distal margin of first segment of antennular peduncle; lateral margins faintly serrulate, slightly upturned.

Carapace (Fig. 11A, B) with gastric region slightly convex; cervical groove absent; median carina entire, slightly broadened posteriorly, but not distinctly bifurcate; submedian carina absent; lateral carinae reaching posteriorly to about anterior one-fourth of carapace length, not constricted posterior to orbit; submarginal carina less distinct.



**FIGURE 11.** *Eiconaxius kensleyi* n. sp., holotype, male (cl 3.1 mm), NTOU A00111. A, carapace and cephalic appendages, lateral view (antennal flagellum missing); B, anterior part of carapace and cephalic appendages, dorsal view (antennular flagellum partially omitted); C, rostrum, dorsolateral view; D, abdomen, telson and uropod, lateral view (setae partially omitted); E, telson and right uropod, dorsal view. Scale bars: A, D = 1 mm; B, C, E = 0.5 mm.

First abdominal pleuron (Fig. 11D) with strongly convex anterior margin; second to fourth pleura with angular posterolateral margins none forming acute ventral or posteroventral tooth; fifth pleura broadly rounded; anterolateral margins of second to fifth pleura unarmed; sixth abdominal somite short, unarmed on posterodorsal margin or ventral margin. Telson (Fig. 11E) with greatest width at about midlength, with 5 (left) or 6 (right) serrations on lateral margin, including 1 tiny posterolateral one; moderately small posteromedian tooth present.

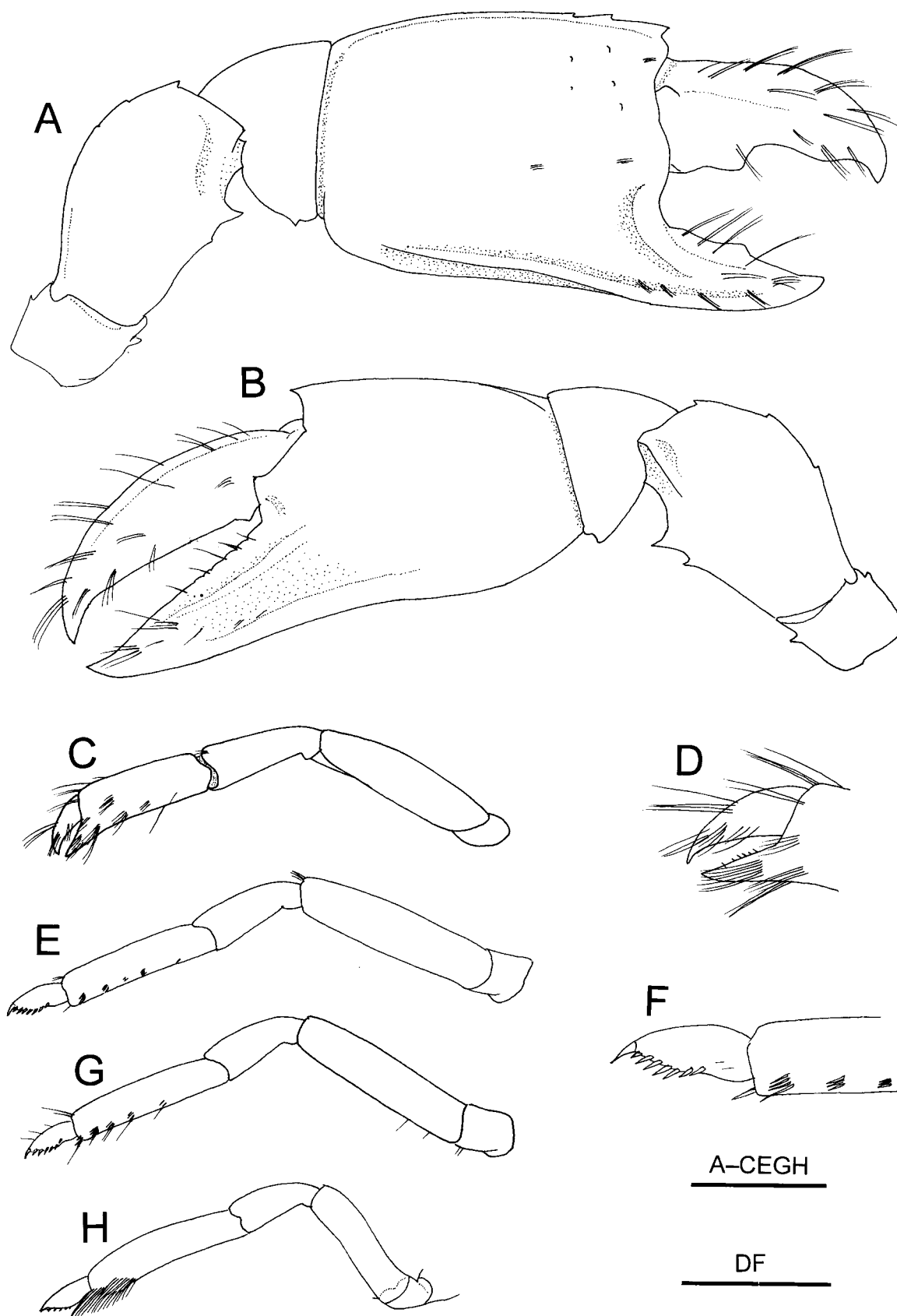
Eye (Fig. 11A, B) reaching midlength of rostrum; cornea subglobose, not faceted, lacking pigment. Antennular peduncle (Fig. 11A, B) with distal two segments subequal in length to first segment; flagella longer than carapace. Antennal peduncle (Fig. 11A, B) moderately stout; distolateral prolongation of second segment acute, overreaching distal margin of third segment of antennular peduncle; third segment with relatively large spine at ventromesial distal angle; antennal acicle large, acuminate, reaching nearly to distal margin of fifth segment of antennal peduncle or far overreaching distal margin of antennular peduncle; flagellum missing.

Third maxilliped moderately slender for genus; ischium with crista dentata consisting of row of tiny denticles.

Major (right) cheliped (Fig. 12A) massive. Ischium with 1 tiny tooth subterminally on dorsal and ventral margins respectively. Merus strongly compressed laterally; dorsal margin strongly convex, sharply carinate, bearing 1 minute denticle distal to midlength, but otherwise smooth, terminating distally in tiny tooth; ventromesial margin sharply carinate, with 1 relatively large subterminal tooth and 1 minute denticle; distolateral projection blunt. Carpus cup-shaped, much higher than long, ventral angle faintly dentate. Chela slightly longer than carapace (including rostrum). Palm 1.2 times longer than high, dorsal margin distinctly carinate, terminating distally in small acute tooth, with 2 tiny denticles somewhat proximal to dorsodistal tooth, lateral surface convex with few scattered tubercles proximal to base of dactylus; ventrolateral carina sharp, extending to distal 0.25 of fixed finger, accompanied with deep groove; distinct submarginal carina along finger cleft; mesial surface also with few scattered tubercles. Fixed finger nearly straight with distal part very slightly curved, with 1 blunt, distinct tooth arising at about mid-length, otherwise nearly smooth; finger cleft shallowly excavate; lateral face slightly concave. Dactylus shorter than palm, terminating in curved calcareous claw, dorsal margin sharply carinate; lateral surface faintly sulcate along dorsal carina; cutting edge with 1 large, obtuse tooth proximally and with broad convexity subdistally.

Minor (left) cheliped (Fig. 12B) subequal in length to and less stout than major cheliped. Ischium with 1 tiny subdistal denticle on dorsal and ventral margins respectively. Merus strongly compressed laterally; dorsal margin strongly convex, distinctly carinate, bearing 2 minute denticles in distal half, terminating distally in minute denticle; ventromesial margin sharply carinate, with 1 relatively large subdistal tooth accompanying by 1 tiny tooth; distolateral projection subacute. Carpus cup shaped, much wider than long, ventral angle faintly dentate. Chela slightly longer than carapace (including rostrum). Palm slightly becoming wider distally, 1.1 times longer than high; dorsal surface weakly carinate in distal half, rounded in proximal half, entire, terminating distally in small tooth; lateral surface generally convex, smooth; ventrolateral carina distinct, but not very sharp, extending from midlength of palm to midlength of fixed finger. Fixed finger slightly deflexed, almost straight but distally slightly curved, cutting edge very faintly dentate; finger cleft with sharply pointed, triangular cusp; lateral face shallowly concave, flanked by distinct upper ridge along cutting edge and ventrolateral ridge shallowly concave. Dactylus about 1.3 times longer than palm, terminating in curved calcareous claw, dorsal margin bluntly carinate; lateral surface smooth; cutting edge with 1 small subacute tooth proximally, but otherwise nearly entire.

Second to fourth pereopods of similar length, moderately stout. Second pereopod (Fig. 12C) unarmed on ischium to carpus; chela about 1.5 times longer than carpus, with scattered tufts of setae; fixed finger slightly deflexed, with row of minute corneous spinules on cutting edge (Fig. 12D); dactylus about 0.5 times as long as palm, with some tufts of long setae and with row of minute corneous spinules on cutting edge (Fig. 12D). Third pereopod (Fig. 12E) unarmed on ischium to carpus; propodus about 1.5 times longer than carpus, with 4 sets of slender spiniform setae (each consisting of 2 or 3 spiniform setae) and 1 spiniform seta on lateral surface ventrally and 1 spiniform seta at ventrodistal margin (Fig. 12F); dactylus (Fig. 12F) strongly



**FIGURE 12.** *Eiconaxius kensleyi* n. sp., holotype, male (cl 3.1 mm), NTOU A00111. A, right (major) cheliped, lateral view; B, left (minor) cheliped, lateral view; C, left second pereopod, lateral view; D, same, chela of left second pereopod, lateral view; E, left third pereopod, lateral view; F, same, dactylus and distal part of propodus, lateral view; G, left fourth pereopod, lateral view; H, left fifth pereopod, lateral view. Scale bars: A–C, E, G, H = 1 mm; D, F = 0.5 mm.



compressed laterally, suboval, terminating in clearly demarcated claw, with 7 accessory spinules on flexor margin; lateral surface unarmed. Fourth pereopod (Fig. 12G) similar to third pereopod; propodus with 4 sets of slender spiniform setae and 1 ventrodiscal spiniform seta; dactylus with 7 spiniform setae on flexor margin; lateral surface unarmed. Fifth pereopod (Fig. 12H) shorter than preceding pereopods; dactylus suboval, terminating in clearly demarcated claw, armed with 5 spiniform setae on flexor margin; propodus with grooming apparatus ventrodistally.

First pleopod absent. Second to fifth pleopods slender, biramous, each with appendix interna; appendix masculina on second pleopod subequal to appendix interna, bearing about 6 stiff setae. Uropodal endopod (Fig. 11E) with about 10 serrations, more closely spaced posteriorly; exopod (Fig. 11E) with about 14 serrations on lateral and posterior margins, posteriormost one slightly larger than others, mesial margin nearly regularly convex.

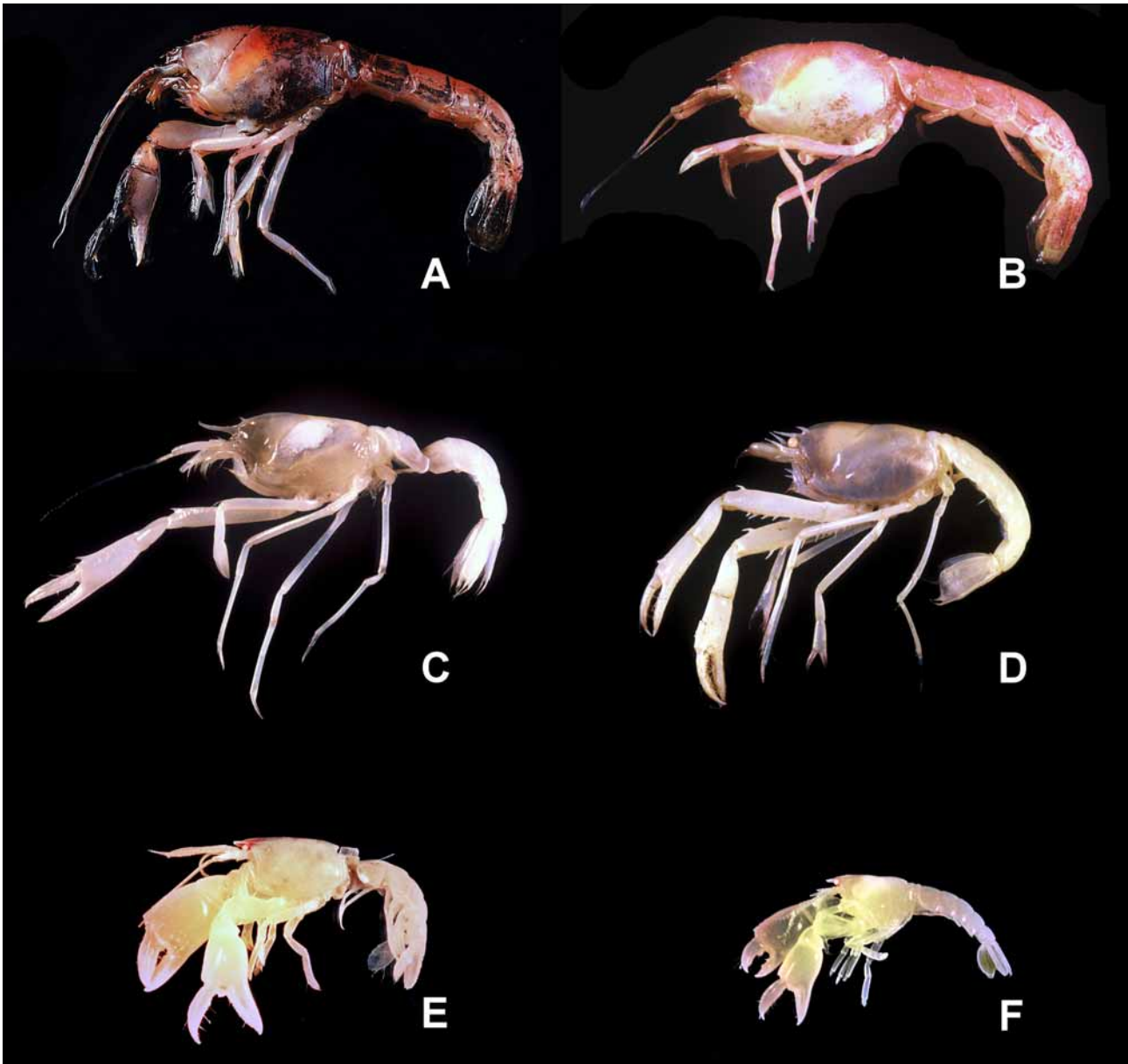
**Coloration.** Body including eyes whitish overall, except base of rostrum reddish.

**Distribution.** Known only from southeastern Taiwan; at depth of 439 m.

**Remarks.** The two new species described in this study appear close to *E. laccadivensis* (Alcock & Anderson, 1894) and *E. mortenseni* Sakai, 1992 in the entire median carina on the carapace, which is not bifurcate but slightly broadened posteriorly, and the non-acuminate pleura of the second to fifth abdominal somites. From *E. laccadivensis*, these two new species differ in the rostrum only slightly overreaching the distal margin of the first segment of the antennular peduncle, rather than reaching the distal segment of the antennular peduncle in *E. laccadivensis* (cf. Alcock 1901; Alcock & McGilchrist 1905). Alcock (1901) noted that the cutting edge of the fixed finger of *E. laccadivensis* carried two enlarged teeth separated by a characteristic notch near the finger cleft, although which cheliped is not specified. Concerning the general pattern of the armature found in species of *Eiconaxius*, it can be assumed that Alcock (1901) mentioned the major cheliped. In the two new species, the cutting edge of the fixed finger of the major cheliped is armed only with one blunt tooth at the midlength. Furthermore, the lateral margin of the rostrum is entire in *E. rubrirostris* n. sp., but microscopically serrulate in *E. laccadivensis* (cf. Alcock 1901) and *E. kensleyi* n. sp. The two new species are distinguished from *E. mortenseni* by the shape of the rostrum. The rostrum is lanceolate with a narrow, blunt apex in the two new species, while it is rounded in *E. mortenseni*; the lateral margin is serrulate in *E. kensleyi* n. sp. but entire in *E. mortenseni* and *E. rubrirostris* n. sp. The minor cheliped of *E. rubrirostris* n. sp. is provided with a distinct median carina on the lateral surface of the dactylus, which is absent in *E. mortenseni* or obsolete in *E. kensleyi* n. sp. Furthermore, the ventrolateral carina extending from palm to fixed finger of the minor cheliped seems to be more pronounced in *E. rubrirostris* n. sp. than in *E. mortenseni* and *E. kensleyi* n. sp. *Eiconaxius rubrirostris* n. sp. further differs from *E. kensleyi* n. sp. in the slightly constricted lateral carinae on the carapace, the possession of three tiny denticles on the posterodorsal margin of the sixth abdominal somite, the lack of a sharp dorsodistal tooth on the palm of the major cheliped, and the more strongly denticulate cutting edge of the minor chela. In *Eiconaxius kensleyi* n. sp., the lateral carinae of the carapace are not constricted; the posterodorsal margin of the sixth abdominal somite is unarmed; the palm of the major cheliped is armed with a small, but distinct dorsodistal tooth; the cutting edge of the minor chela is only faintly denticulate. The armament of the ventral margin of the merus of the major cheliped may be also significant, although some degree of variation is seen in other species of the genus (T. Komai, personal observation). *Eiconaxius rubrirostris* n. sp. possesses only a minute subterminal denticle on the ventral margin of the merus of the major cheliped, whereas *E. kensleyi* n. sp. has a conspicuous subterminal tooth on that margin.

*Eiconaxius andamanensis* (Alcock, 1901) is also rather similar to the two new species. Nevertheless, *E. andamanensis* seems to differ from these two new species by the short antennal acicle, which does not reach the distal margin of the fifth segment of the antennal peduncle, and the sharply pointed posterolateral angles of the second to fourth pleura (Alcock 1901). In the two new species, the second to fourth pleura are angular or rounded; and the antennal acicle nearly reaches the distal margin of the fifth segment of the antennal peduncle.

**Etymology.** This new species is dedicated to the late Brian Kensley of the National Museum of Natural History, Smithsonian Institution, in recognition of his significant contributions to the systematics of malacostracan crustaceans, particularly Axiidea.



**FIGURE 13.** A, *Formosaxius dorsum* n. gen., n. sp., holotype, female (cl about 12.0 mm), NTOU A01087; B, *Formosaxius dorsum* n. gen., n. sp., paratype, female (cl 12.6 mm), NTOU A00023; C, *Ambiaxius propinquus* n. sp., holotype, hermaphrodite (cl 11.8 mm), NTOU A00110; D, *Calastacus formosus* n. sp., holotype, hermaphrodite (cl 7.6 mm), NTOU A00083; E, *Eiconaxius rubrirostris* n. sp., holotype, male (cl 5.4 mm), NTOU A00114; F, *Eiconaxius kensleyi* n. sp., holotype, male (cl 3.1 mm), NTOU A00111.

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## References

- Alcock, A. (1901) *A descriptive catalogue of the Indian deep-sea Crustacea Decapoda Macrura and Anomala, in the Indian Museum. Being a revised account of the deep-sea species collected by the Royal Indian Marine Survey Ship Investigator*. Trustees of the Indian Museum, Calcutta, 286 pp.
- Alcock, A. & McArdle, S.B. (1901) *Crustacea, Part XIX. Illustrations of the Zoology of the Royal Marine Surveying Steamer "Investigator"*. Trustees of the Indian Museum, Calcutta, pls 49–55.
- Barnard, K.H. (1950) Descriptive catalogue of South African decapod Crustacea (crabs and shrimps). *Annals of the South African Museum*, 38, 1–837.
- Borradaile, L.A. (1903) On the classification of the Thalassinidea. *Annals and Magazine of Natural History*, (7) 12, 534–551 + addendum on p. 638.
- Bouvier, E.L. (1905) Sur les Thalassinidés recueillies par le Blake dans la mer des Antilles et le golfe du Mexique. *Comptes Rendus Hebdomadaires de Séances de l'Académie des Sciences, Paris*, 141, 802–806.
- Clark, P.F., Galil, B.S. & Poore, G.C.B. (2007) A new species of *Calaxius* Sakai & de Saint Laurent, 1989, from West Africa (Crustacea, Decapoda, Axiidae) and synonymy of *Manaxius* Kensley, 2003. *Proceedings of the Biological Society of Washington* 120, 63–73.
- De Grave, S., Pentcheff, N.D., Ah Yong, S.T., Chan, T.Y., Crandall, K.A., Dworschak, P.C., Felder, D.L., Feldmann, R.N., Fransen, C.H.J.M., Goulding, L.Y.D., Lemaitre, R., Low, M.E.Y., Martin, J.W., Ng, P.K.L., Schweitzer, Tan, S.H., Tshudy, D. & Wetzer, R. (2009) A classification of living and fossil genera of decapod crustaceans. *Raffles Bulletin of Zoology*, Supplement 21, 1–109.
- Kensley, B. (1989) New genera in the thalassinidean families Calocarididae and Axiidae (Crustacea: Decapoda). *Proceedings of the Biological Society of Washington*, 102, 960–967.
- Kensley, B. (1996a) New species of Calocarididae from the Caribbean Sea and Gulf of Mexico (Crustacea: Decapoda: Thalassinidea). *Bulletin of Marine Science*, 59, 158–168.
- Kensley, B. (1996b) New thalassinidean shrimp from the Pacific Ocean (Crustacea: Decapoda: Axiidae and Calocarididae). *Bulletin of Marine Science*, 59, 469–489.
- Kensley, B. (2003) Axioid shrimps from Guam (Crustacea, Decapoda, Thalassinidea). *Micronesica*, 35/36, 359–384.
- Kensley, B. & Chan, T.Y. (1998) Three new species of thalassinidean shrimps (Crustacea, Axiidae and Calocarididae) from Taiwan. *Zoosystema*, 20, 255–264.
- Kensley, B., Lin, F.J. & Yu, H.P. (2000) Further records of thalassinidean shrimps from Taiwan (Decapoda: Axiidae and Calocarididae), with descriptions of three new species. *Journal of Crustacean Biology*, 20 (Special Number 2), 207–217.
- Komai, T., Lin, F.J. & Chan, T.Y. (2009) A new mud shrimp species of *Calastacus* (Crustacea: Decapoda: Thalassinidea) from the South China Sea. *Zootaxa*, 2088, 24–30.
- Komai, T. & Tachikawa, H. (2007) New genus and species of axiid shrimp (Crustacea, Decapoda, Thalassinidea) from Japan. *Bulletin of the National Museum of Nature and Science*, 33, 113–126.
- Komai, T. & Tachikawa, H. (2008) Thalassinidean shrimps (Crustacea: Decapoda) from the Ogasawara Islands, Japan. *Natural History Research*, 10, 19–52.
- Lin, F.J., Kensley, B. & Chan, T.Y. (2000) The rare axiid genus *Oxyrhynchaxius* Parisi, 1917 (Decapoda: Thalassinidea), with a description of a new species from Australia. *Journal of Crustacean Biology*, 20 (Special Number 2), 199–206.
- Lin, F.J. & Komai, T. (2006) A new calocaridid shrimp of the genus *Calaxiopsis* Sakai & de Saint Laurent, 1989 (Crustacea, Decapoda, Thalassinidea) from deep waters off Taiwan. *Zoosystema*, 28, 399–408.
- McArdle, A.F. (1900) Natural history notes from the Royal Indian Marine Survey Ship 'Investigator'. — Series III. , No. 4. Some results of the dredging season 1899–1900. *Annals and Magazine of Natural History*, (7) 6, 471–478.
- Ngoc-Ho, N. (2003) European and Mediterranean Thalassinidea (Crustacea, Decapoda). *Zoosystema*, 25, 439–555.
- Poore, G.C.B. (1994) A phylogeny of the families of Thalassinidea (Crustacea: Decapoda) with keys to the families and genera. *Memoirs of the Museum of Victoria*, 54, 79–120.
- Poore, G.C.B. & Collins, D.J. (2009) Australian Axiidae. *Memoirs of Museum Victoria*, 66, 221–287
- Robles, R., Tudge, C.C., Dworschak, P.D., Poore, G.C.B. & Felder, D.L. (2009) Molecular phylogeny of the Thalassinidea based on nuclear and mitochondrial genes. In: Martin, J.W., Crandall, K.A., and Felder, D.L. (eds), *Crustacean Issues Vol. 18: Decapod Crustacean Phylogenetics*. CRC Press, Boca Raton. Pp. 309–326.
- Saint Laurent, M. de (1972) Un thalassinide nouveau du golfe de Gascogne, *Calastacus laevis* sp. nov. Remarques sur le genre *Calastacus* Faxon (Crustacea Decapoda Axiidae). *Bulletin du Muséum national d'Histoire naturelle, Série 3, Zoology*, 29, 347–356.
- Sakai, K. (1994) Eleven species of Australian Axiidae (Crustacea: Decapoda: Thalassinidea) with descriptions of one new genus and five new species. *The Beagle, Occasional Papers of the Northern Territory Museum of Arts and Sciences*, 11, 175–202.
- Sakai, K. (1995) A new record of the axiid, *Ambiaxius alcocki* (McArdle, 1900) (Crustacea, Anomura, Thalassinidea)

- from Suruga Bay, Japan. *Bulletin of the National Science Museum, Ser. A (Zoology)*, 21, 79–86.
- Sakai, K. & de Saint Laurent, M. (1989) A check list of Axiidae (Decapoda, Crustacea, Thalassinidea, Anomala), with remarks and in addition descriptions of one new subfamily, eleven new genera and two new species. *Naturalists, Publications of Tokushima Biological Laboratory, Shikoku University*, 3, 1–104.
- Sakai, K. & Ohta, S. (2005) Some thalassinid collections by R/V "Hakuhou-Maru" and R/V "Tansei-Maru", University of Tokyo, in the Sulu Sea, Philippines, and in Sagami Bay and Suruga Bay, Japan, including two new species, one new genus, and one new family (Decapoda, Thalassinidea). *Crustaceana*, 78, 67–93.
- Stebbing, T.R.R. (1915) South African Crustacea, Part VIII. *Annals of the South African Museum*, 15, 57–104, pls. 13–25.
- Stebbing, T.R.R. (1917) South African Crustacea, Part IX. *Annals of the South African Museum*, 17, 23–46, pls. 1–8.
- Tsang, L.M., Lin, F.J., Chu, K.H. & Chan, T.Y. (2008) Phylogeny of Thalassinidea (Crustacea, Decapoda) inferred from three rDNA sequences: implications for morphological evolution and superfamily classification. *Journal of Zoological Systematics & Evolutionary Research*, 46, 216–223.