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Revision of *Polyonyx pedalis* Nobili, 1906 (Crustacea: Decapoda: Anomura: Porcellanidae), with descriptions of three new species

Masayuki Osawa[1*] & Peter K. L. Ng[2]

Abstract. The taxonomy of *Polyonyx pedalis* Nobili, 1906, is revised on the basis of the syntypes and additional material from various areas of the Indo-West Pacific. Examination of a large series of specimens revealed that *P. pedalis* s. str. is restricted to the waters of the Red Sea and the western Indian Ocean. Specimens from the western Pacific are here referred to three new species. The four species are superficially similar but can be distinguished by the shape and structure of the carapace, and comparative lengths of the meri of the ambulatory legs. There are indications that their preferred habitats also differ. *Polyonyx pedalis*, *P. heok*, new species, and *P. kumejima*, new species, live symbiotically with tube-dwelling polychaetes; the first two species are associated with species of the genus *Chaetopterus* (family Chaetopteridae), while *P. kumejima* is found with a species of Sabellidae. *Polyonyx planus*, new species, was obtained by brushing coral rubble or from the underside of rocks, and no symbiotic host was recorded.

Key words. Crustacea, Decapoda, Porcellanidae, *Polyonyx pedalis*, redescription, new species, Indo-West Pacific

INTRODUCTION

The poorly known porcelain crab *Polyonyx pedalis* Nobili, 1906, was originally described from Djibouti in the Gulf of Aden, and has been since recorded from the Kei Islands in Indonesia, New Caledonia and Mayotte in the southwestern Indian Ocean (Haig, 1964; Osawa, 2007a, b; Poupin et al., 2013). Among congeners, *P. pedalis* is characterised by the carpi of the chelipeds having no distinct subrectangular proximal angle on the dorso-anterior margin, the dactyli of the ambulatory legs each with the dorsal claw shorter and more slender than the ventral claw, the merus of the fourth pereopod (third ambulatory leg) at least with spines on the ventral margin, and the absence of gonopods in males (Werding, 2001; Osawa, 2007a).

Additional material provisionally referred to *P. pedalis* has recently been collected from Saudi Arabia, Singapore, Philippines, Ryukyu Islands in south Japan and Vanuatu. The recent specimens (including the types) from the Indian Ocean differed in several aspects from material from Southeast Asia and the western Pacific. Examination of all this material revealed that what is now called *P. pedalis* is actually a species complex of four species. *Polyonyx pedalis* s. str. is restricted to the Gulf of Aden, Red Sea and the western Indian Ocean, whereas specimens from Southeast Asia and the western Pacific belong to three undescribed species. In the present paper, these four species are described, compared and illustrated.

The specimens examined are deposited in the following museums: Florida Museum of Natural History, University of Florida, Gainesville (UF); Lee Kong Chian Natural History Museum, National University of Singapore, Singapore (formerly known as the Raffles Museum of Biodiversity Research, Zoological Reference Collection; ZRC); Muséum national d'Histoire naturelle, Paris (MNHH); Natural History Museum and Institute, Chiba (CBM); National Museum of the Philippines, Manila (NMCR); Ryukyu University Museum, Fujukan, Nishihara (RUMF); and Zoological Museum, Natural History Museum of Denmark, University of Copenhagen, Copenhagen (ZMUC).

Carapace length (cl), an indication of specimen size, was measured from the anterior median tip of the rostrum to the posteromedian margin of the carapace. Measurements of chelipeds were made as follows: length of carpus, along posterior margin and breadth, on dorsal transverse midline; length of chela, along anterior margin and height, along dorsodistal transverse line of palm; and length of dactylus, along posterior margin. Measurements of ambulatory legs were made as follows: length of merus, along dorsal margin and height, on lateral transverse midline; length of propodus, along dorsal margin and height, on lateral transverse line at base of distal round projection; and length of dactylus, along dorsal margin. Terminology mainly follows that of Osawa & Chan (2010), except for the uses of "dorsal" and "ventral" for "extensor" and "flexor" margins in the third maxilliped and

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ambulatory legs and "anterior" and "posterior" for "flexor" and "extensor" margins in the merus and carpus of the cheliped. A full description is given only for *P. pedalis* and diagnoses are provided for the three new species because of their close similarities. Although the typical morphological characters are omitted in the descriptions of new species, they are nevertheless fully illustrated.

SYSTEMATIC ACCOUNT

Family Porcellanidae Haworth, 1825

Genus *Polyonyx* Stimpson, 1858

Polyonyx pedalis Nobili, 1906

(Figs. 1–5, 15A, B)

Polyonyx pedalis Nobili, 1906a: 397 (type locality: Djibouti, Gulf of Aden). — Nobili, 1906b: 137, pl. 8, fig. 3 (no new record). — Johnson, 1958: 116 (no new record). — Lewinsohn, 1969: 161 (no new record). — Osawa & McLaughlin, 2010: 115 (list). — Poupin et al., 2013: 22, fig. 11B (Mayotte, Comoros).

Not *Polyonyx pedalis*: Haig, 1964: 381. — Osawa, 2007a: 26, fig. 3. — Osawa, 2007b: 37 (= *Polyonyx heok*, new species).

Type material. Lectotype: Djibouti, 1897, coll. M Jousseaume, 1 male (cl 5.8 mm), MNHN-IU-2008-13008 (= MNHN-Ga170). Paralectotype: 1 female (cl 4.7 mm), same data as lectotype, MNHN-IU-2013-7816 (= MNHN-Ga170).

Other material examined. Saudi Arabia. Mahama Island, Farasan Islands, 16.4892°N, 41.9443°E, reef and fringing slope, 4–17 m, 9 March 2013, coll. A Anker, P Norby & G Paulay, 1 male (cl 6.8 mm), 1 ovigerous female (cl 6.9 mm), UF 36876. Tiger Head Island, Farasan Islands, 16.791°N, 42.1987°E, karstic shore to fringing slope, 1–6 m, 10 March 2013, coll. A Anker, P Norby & G Paulay, 1 ovigerous female (cl 7.4 mm), UF 36949. Tiger Head Island, Farasan Islands, 16.791°N, 42.1987°E, karstic shore to fringing slope, 1–6 m, 10 March 2013, coll. A Anker, P Norby & G Paulay, 1 male (cl 7.0 mm), UF 36950. Off Thuwal, El Fahal, southern point, 22.2227°N, 38.9677°E, in tube of *Chaetopterus* sp., 20 March 2013, coll. J Moore & C Braun, 1 male (cl 5.1 mm), UF 37176. Farasan Banks, Whale Shark Reef, 20.117°N, 40.2149°E, 10 m, 22 March 2013, coll. A Anker, P Norby & J Moore, 1 male (cl 6.4 mm), 1 ovigerous female (cl 6.8 mm), UF 37182. Farasan Banks, Whale Shark Reef, 20.117°N, 40.2149°E, 10 m, in tube of *Chaetopterus* sp., 22 March 2013, coll. A Anker, P Norby & J Moore, 1 male (cl 5.2 mm), 1 ovigerous female (cl 6.3 mm), UF 37185. Farasan Banks, Whale Shark Reef, 20.117°N, 40.2149°E, 10 m, in tube of *Chaetopterus* sp., 22 March 2013, coll. A Anker, P Norby & J Moore, 1 male (cl 4.9 mm), UF 37206. Off Thuwal, Abu Shosha Reef, 22.2044°N, 39.047°E, exposed side, in tube of *Chaetopterus* sp., 7–8 m, 23 March 2013, coll. J Moore, J Bouwmeester & A Anker, 1 female (cl 6.6 mm), UF 37201. Off Thuwal, Abu Shosha Reef, 22.2044°N, 39.047°E, exposed side, in tube of *Chaetopterus* sp., 7–8 m, 23 March 2013, coll. J Moore, J Bouwmeester & A Anker, 1 ovigerous female (cl 5.4 mm), UF 37218. **Comoro Islands.** KUW MAYOTTE Fieldwork 2009, north of Handrema islet, Mayotte Island, St. 19, 12°40'21.00"S, 45°6'49.92"E, fringing reef and outer slope, 6–10 m, 11 November 2009, sediment suction pump, coll. M Bouchard, V Dinhut & J Dumas, 1 female (cl 4.5 mm), MNHN-IU-2009-1383.

Diagnosis. Carapace usually 1.0–1.1 times broader than long. Protogastric ridges weak, low. Rostrum transverse in dorsal view, weakly trilobate in frontal view; median lobe exceeding lateral lobe; margin between median and lateral lobes transverse. Branchial margins subparallel, somewhat constricted medially. Posterior margin with broad V-shaped median cleft. Third thoracic sternite with lateral lobes slightly exceeding or only reaching anterior margin of median lobe. Telson broader than long. Basal articles of antennular peduncles with anterior surface slightly concave and rugose; dorso-anterior margin broadly rounded in general outline. Antennal peduncle with first article rounded on anterior margin in lateral view. Third maxilliped with merus provided with broad, subrectangular lobe on ventral margin, anterior margin of lobe with short row of minute tubercles. Large cheliped with carpus 1.7–2.0 times as long as broad; chela 1.3–1.4 times as long as carpus, 1.9–2.3 times as long as broad; dactylus 0.5 length of chela. Smaller cheliped with carpus 1.9–2.0 times as long as broad; chela 1.4–1.6 times as long as carpus, 2.4–2.5 times as long as broad; dactylus 0.5–0.6 length of chela. Ambulatory legs with meri successively shortening posteriorly (third merus 0.8–0.9 length of second merus, fourth merus 0.8–0.9 length of third merus); length-height ratio of meri, 2.4–2.5 on second, 2.1–2.2 on third, 1.9–2.1 on fourth; propodi with length-height ratio, 3.4–3.7 on second, 3.3–3.8 on third, 3.3–3.9 on fourth, ventral margin with row of 5–7 (rarely 4) corneous spines and paired distal spines; dactyli 0.4–0.5 length of propodi, ventral margin with 2 or 3 small corneous spines.

Description. Carapace (Figs. 1A, B, 3A, B) pentagonoid in general outline, usually 1.0–1.1 (in ovigerous female of UF 36949, 1.3) times broader than long. Dorsal surface moderately convex, with scattered, very short striae; longer transverse striae present laterally on posterior branchial regions. Protogastric ridges weak, low or obsolete. Cervical grooves weakly demarcated. Rostrum (Figs. 1A, C, 3A–C) broad, transverse in dorsal view, weakly trilobate in frontal view, with row of dense plumose setae on anterior margin; no longitudinal groove on dorsal midline; median lobe low, subtriangular, exceeding lateral lobes, with rounded apex; lateral lobes each with broadly rounded apex; margin between median and lateral lobes transverse. Orbits shallow, supra-orbital margins oblique; outer orbital angles obtuse. Hepatic margins oblique, concave on posterior part. Branchial margins subparallel, usually somewhat constricted medially, each without distinct longitudinal ridge. Posterior margin with broad V-shaped median cleft.

Pterygostomial flaps (Fig. 3D) rugose, anteriorly narrowing with subacute tip.

Third thoracic sternite (Figs. 1D, 3E) with anterior margin trilobate, bearing soft plumose setae on anterior surface;

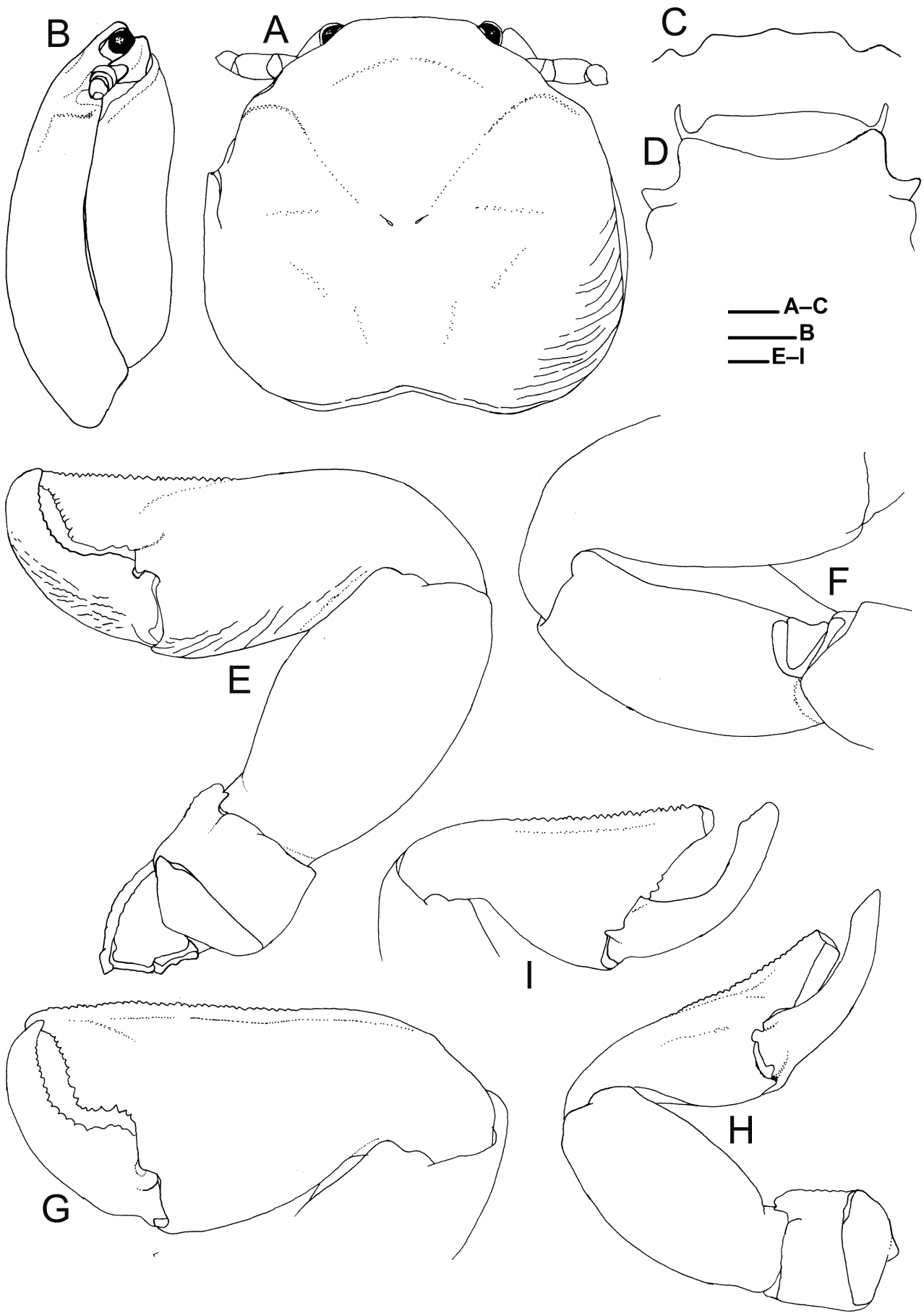

Fig. 1. *Polyonyx pedalis* Nobili, 1906, lectotype, male (cl 5.8 mm), MNHN-IU-2008-13008 (= MNHN-Ga170), Djibouti. A, carapace and ocular and antennal peduncles, dorsal view; B, same, right lateral view; C, rostrum, dorso-anterior view; D, third and fourth thoracic sternites, ventral view; E, larger cheliped, dorsal view; F, same, carpus, ventral view; G, same, chela, dorso-anterior view; H, smaller cheliped, dorsal view; I, same, chela, dorso-anterior view. All setae omitted. Scale bars = 1.0 mm.

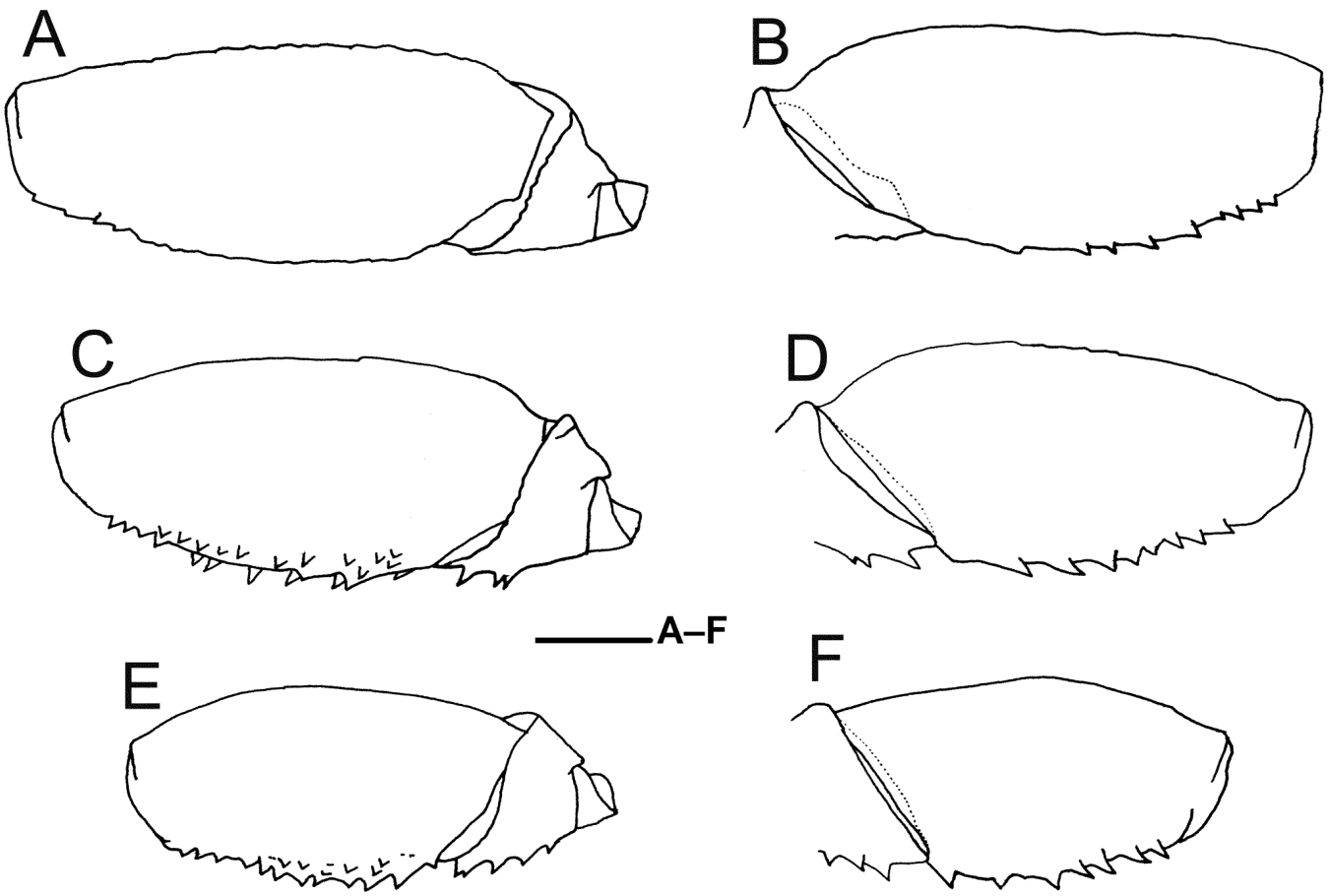

Fig. 2. *Polyonyx pedalis* Nobili, 1906, lectotype, male (cl 5.8 mm), MNHN-IU-2008-13008 (= MNHN-Ga170), Djibouti. Ishia and meri of left ambulatory legs. A, second pereopod, lateral view; B, same, mesial view; C, third pereopod, lateral view; D, same, mesial view; E, fourth pereopod, lateral view; F, same, mesial view. All setae omitted. Scale bar = 1.0 mm.

median lobe broad, low, concave medially on ventral surface; lateral lobes narrow, slightly exceeding or only reaching anterior margin of median lobe, each with rounded apex. Fourth thoracic sternite with transverse series of soft plumose setae along concave, anterior margin; ventral surface depressed medially.

Telson (Fig. 3F) broader than long, composed of seven plates; anterior margins of posterior plates broadly rounded.

Ocular peduncles (Figs. 1A, B, 3A, B, H) small; dorsal extension onto cornea weakly produced, rounded (occasionally hardly visible in dorsal view).

Basal articles of antennular peduncles (Fig. 3G) without distinct spines or teeth; anterior surface slightly concave, rugose; dorso-anterior margin broadly rounded in general outline; ventro-anterior margin slightly uneven; ventral surface with transverse ridge laterally on median part.

Antennal peduncles (Fig. 3H, G) short, slender, with faint, very short striae. First article largest, strongly produced forward, broadly in contact with lower orbital margin, with blunt marginal ridge; lateral surface slightly concave; anterior margin rounded in lateral view and subtriangular in ventral view. Second, third and fourth articles roundly subrectangular; third article somewhat elongate.

Third maxilliped (Fig. 3I) with coxa bearing distomedian projection rounded and not articulated. Basis articulating with ischium, roundly subtriangular. Ischium broad, with short striae and soft plumose setae on lateral surface; no distinct longitudinal ridge along dorsal margin; dorsodistal projection distinct. Merus with broad, subrectangular lobe on ventral margin, anterior margin of lobe bearing short row of minute tubercles; lateral surface with short striae. Carpus with subtriangular projection on median part of ventral margin. Propodus long, slender. Dactylus elongate, roundly subtriangular. Merus to dactylus with long plumose setae on ventral margin. Exopod with proximal article small, roundly subtriangular; distal article reaching to midlength of merus, laminate, robust, inflate proximally, with distal flagellum.

Chelipeds (first pereopods) (Figs. 1E–H, 4A–F) unequal in size, similar between male and female, subcylindrical, inflated, with scattered, short or very short striae on dorsal surface; striae most numerous on merus and palm; ventral surface with fewer striae; soft plumose setae present on anterior, posterior and dorsoproximal surfaces of merus, anterior and distal margins of carpus, dorso-anterior and ventral posterior surfaces of palm (including dorso-anterior surface of fixed finger) and cutting surfaces of fingers. Larger cheliped (Figs. 1E–G, 4A–C) with merus provided with rounded, transverse crest submedially on dorsal surface; dorso-anterior margin with small, rounded or roundly

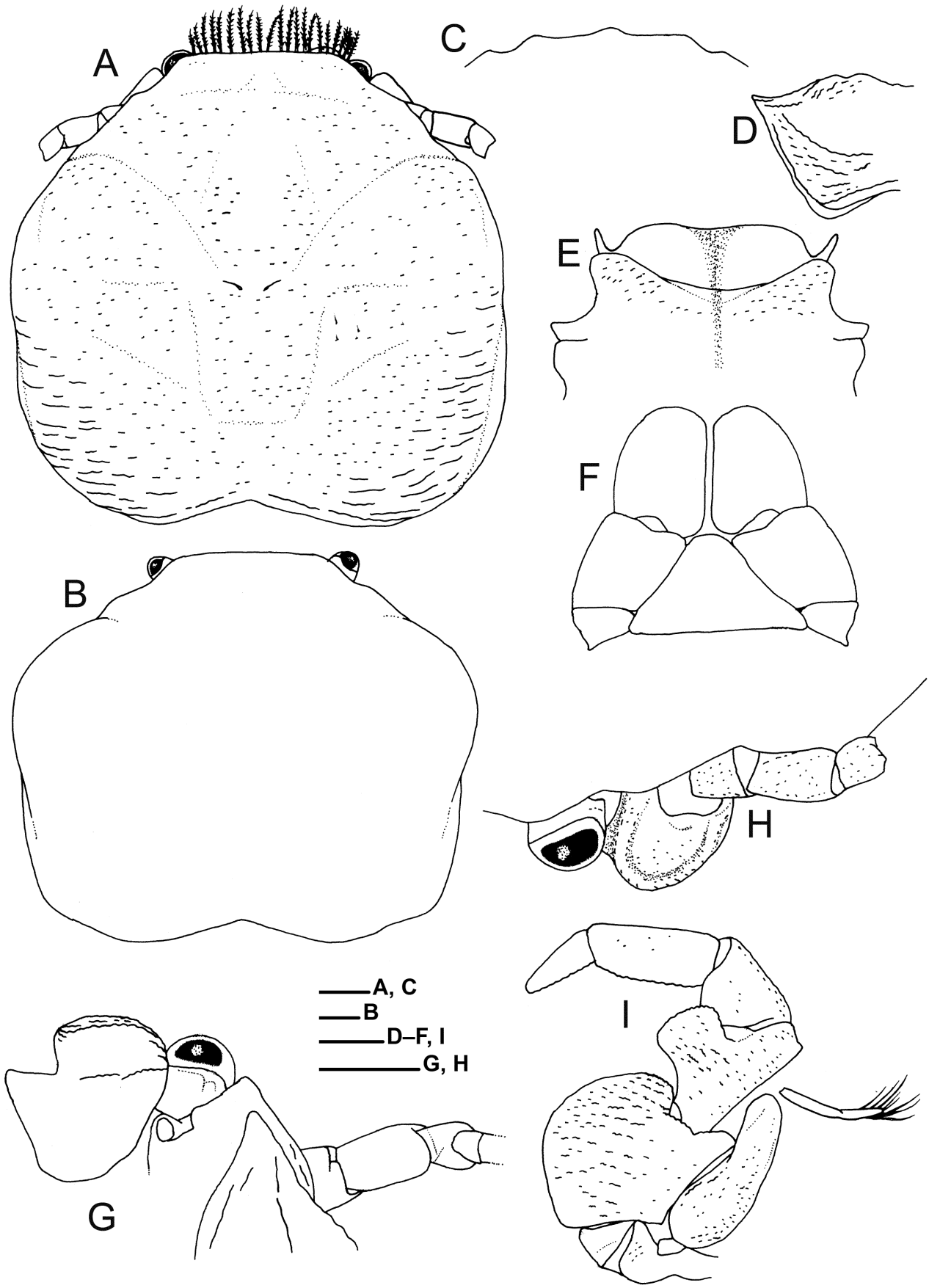

Fig. 3. *Polyonyx pedalis* Nobili, 1906. Male (cl 6.8 mm), UF 36876, Mahama Island, Saudi Arabia (A, C–I); ovigerous female (cl 7.4 mm), UF 36949, Tiger Head Island, Saudi Arabia (B). A, carapace and ocular and antennal peduncles, dorsal view; B, carapace and ocular peduncles, dorsal view; C, rostrum, dorso-anterior view; D, anterior part of left pterygostomial flap, ventrolateral view; E, third and fourth thoracic sternites, ventral view; F, telson, external view; G, left ocular and antennal peduncles, basal article of antennular peduncle and anterior part pterygostomial flap, ventral view; H, left ocular and antennal peduncles, dorsolateral view; I, left third maxilliped, lateral view. Most setae omitted. Scale bars = 1.0 mm.

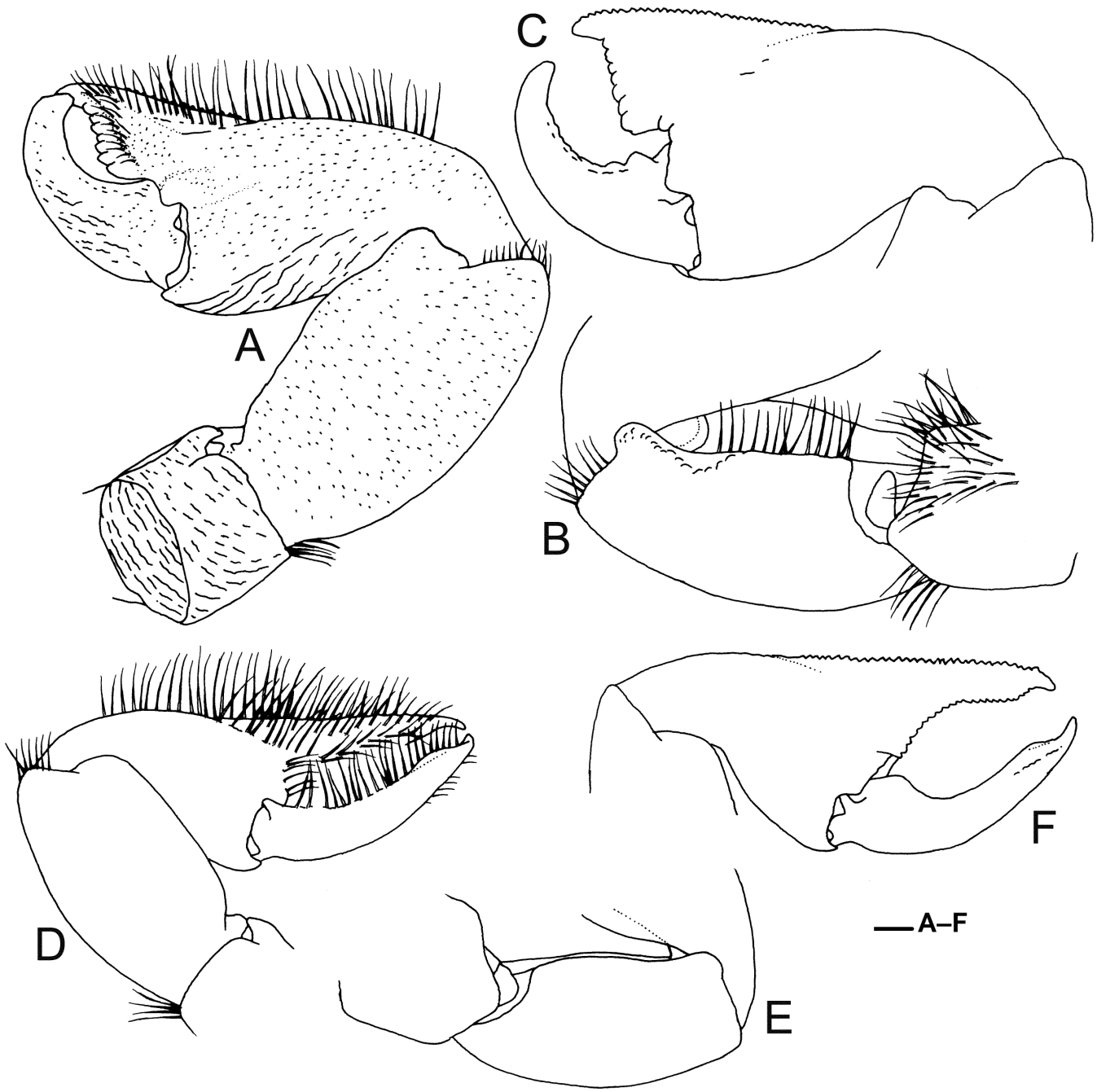

Fig. 4. *Polyonyx pedalis* Nobili, 1906, male (cl 6.8 mm), UF 36876, Mahama Island, Saudi Arabia. A, larger cheliped, dorsal view; B, same, carpus, ventral view; C, same, chela, dorso-anterior view; D, smaller cheliped, dorsal view; E, same, carpus, ventral view; F, same, chela, dorso-anterior view. Setae partially illustrated (A, B, D), setae omitted (C, E, F). Scale bars = 1.0 mm.

rectangular lobe distally; ventro-anterior margin unarmed. Carpus 1.7–2.0 times as long as broad; dorso-anterior margin slightly convex on median part, with proximal angle broadly rounded and distal angle obtuse; posterior margin rounded, with distal part broadly rounded; ventro-anterior margin slightly concave on distal third, with rounded distal projection. Chela relatively broad, ovate in general outline, 1.3–1.4 times as long as carpus, 1.9–2.3 times as long as broad; anterior margin delimited by row of small, blunt, subacute denticles on distal two-thirds (denticles low or obsolete on proximal part), usually slightly concave near base of fixed finger; dorsal surface rounded and convex on palm but depressed on fixed finger, with shallow sulcus along anterior margin; dorsoposterior margin of palm with row of oblique ridges; ventral surface convex, with low, longitudinal ridge proximally along midline. Fixed finger with short distal claw; cutting edge with large subtriangular projection on proximal third and row of small, blunt teeth. Dactylus 0.5 length of chela, opening at oblique angle, with strongly curved distal claw; dorsal surface rounded; dorsoposterior surface with irregular rows of short ridges; cutting edge concave, with moderately large rounded projection proximally and row of small blunt teeth.

Smaller cheliped (Figs. 1H, I, 4D–F) generally similar to larger cheliped in shape, but more slender and setose, particularly on chela. Carpus 1.9–2.0 times as long as broad; dorso-anterior margin nearly transverse or less convex than

that of larger cheliped. Chela 1.4–1.6 times as long as carpus, 2.4–2.5 times as long as broad. Fixed finger with narrowly rounded, distal claw; cutting margin with low, rounded or subtriangular teeth on proximal and distal parts, with row of small blunt denticles, margin between 2 teeth concave. Dactylus 0.5–0.6 length of chela, opening at more strongly oblique angle than in larger cheliped, with slender distal claw; cutting margin with low, subtriangular teeth on proximal and distal parts and with row of small obsolete denticles (denticles on proximal two-thirds only visible in high magnification), margin between 2 teeth strongly concave.

Ambulatory legs (second to fourth pereopods) (Figs. 2A–F, 5A–H) stout, with numerous soft plumose setae on margins of ischia to propodi and with sparse, short simple setae on dactyli; second pereopod longest. Ischia with small spines or denticles on ventral surface, spines weakest on second and strongest on fourth. Meri somewhat compressed lateromesially, elongate ovate, successively shortening posteriorly (third merus 0.8–0.9 length of second merus, fourth merus 0.8–0.9 length of third merus); length-height ratio, 2.4–2.5 on second, 2.1–2.2 on third, 1.9–2.1 on fourth; dorsal margin and adjacent surfaces with finely granular, short transverse ridges; ventolateral and ventromesial margins each with row of small spines, spines sometimes obsolete on ventrolateral margin of second and strongest on ventromesial margins of third and fourth; proximal parts of ventrolateral and ventral surfaces of third and fourth occasionally with additional few smaller spines or denticles; mesial surface with narrow decalcified part proximally. Carpi rounded on surfaces, somewhat elongate on second; dorsodistal margin unarmed; ventrodistal margin with 1–3 small denticles. Propodi subcylindrical; length-height ratio, 3.4–3.7 on second, 3.3–3.8 on third, 3.3–3.9 on fourth; dorsal margin nearly smooth; ventral margin with row of 5–7 (rarely 4) corneous spines; ventrodistal margin with paired spines subequal in size. Dactyli 0.4–0.5 length of propodi, each terminating in curved, bifurcate corneous-tipped claw, dorsal claw shorter and much more slender than ventral claw; ventral margin with 2 or 3 small corneous spines (when 3 spines present, proximalmost spine minute).

Fifth pereopod slender; carpus with tuft of short simple setae on ventrodistal margin; chela elongate, with numerous simple setae on dorsal and ventral surfaces of palm (setae denser on ventral surface), no scythe-like setae; dactylus with simple setae on dorsal surface.

Males without pleopods, no gonopods on second abdominal segment. Females with pairs of well-developed uniramous pleopods on third to fifth abdominal somites.

Colouration in life (Fig. 15A)**.** Carapace and pereopods generally whitish brown; plumose setae pale brown. Carapace with irregular, pale brown blotches entirely, and with dark brown marks on cardiac and posterior branchial regions (scattered reddish brown spots not belonging to surface colouration of *P. pedalis* but from minute epizoites present). Chelipeds with small, irregular, pale and dark brown blotches on dorsal surface; ventral surface scattered dark brown blotches. Ambulatory legs with irregular, pale brown lines on meri; carpi and propodi brown in most parts; dactyli pale yellow.

Habitat (Fig. 15B)**.** The material from Saudi Arabian coasts in the Red Sea indicates that *P. pedalis* occurs as a heterosexual pair and lives symbiotically with an undetermined tube-dwelling polychaete of the genus *Chaetopterus* Cuvier, 1830 (family Chaetopteridae).

Distribution. Gulf of Aden, Red Sea and Comoro Islands in the southwestern Indian Ocean; depths of 1–17 m.

Remarks. Nobili (1906a, b) described *P. pedalis* based on two specimens (sex not specified) from Djibouti and gave the measurement of one specimen (cl 6.5 mm). Both specimens are regarded as syntypes because no holotype was selected. The specimen that best agrees with the carapace length (here measured from the median tip of the rostrum to the level of the posterolateral carapace corner) given by Nobili (1906a, b) is here designated the lectotype of *P. pedalis*.

The paper by Nobili (1906a) is frequently cited as 1905 but the original paper notes that it was only published in January 1906 (see Ng et al., 2008: 25).

Polyonyx pedalis closely resembles the three new species described below in general appearance, but can be distinguished most easily by the form of the rostrum in dorsal view. In the new species, the median lobe of the rostrum is clearly visible and anteriorly produced in dorsal view (Figs. 6A, B, 9A, 12A) while it is not visible in *P. pedalis* (Figs. 1A, 3A, B), mainly because the rostrum is more prominently bent downwards. Additionally, in the frontal view, the margin between the median and lateral lobes of the rostrum is transversely straight in *P. pedalis* but somewhat more concave in the three new species. The posterior margin of the carapace has a broad V-shaped median cleft in *P. pedalis* (Figs. 1A, 3A, B) whereas in the other species, such a distinct cleft is absent, although the posterior margin is weakly to moderately concave medially (Figs. 6A, B, 9A, 12A). While the propodus of the third maxilliped in *P. pedalis* varies slightly in length, it is consistently relatively shorter (Fig. 3I) than those of the three new species (Figs. 6H, 9G, 12G). The meri of the amburatory legs are generally shorter in *P. pedalis* than in the other species, although there is variation and the proportions sometimes partially overlapped. The length-height ratios of the segments are 2.4–2.5 vs 2.5–2.9 on the second pereopod, 2.1–2.2 vs 2.2–2.6 on the third, 1.9–2.1 vs 2.0–2.4 on the fourth, respectively (Figs. 2A, C, E, 5A, E, G, 8A, D, F, 11A, C, F, 14A, D, F).

In addition to the morphology, the general colouration is also similar between *P. pedalis* and the three new species. However, the carapace and chelipeds of *P. pedalis* are more whitish and the chelipeds lack large, brown or dark brown blotches on the dorsal surface unlike in the latter three species.

Re-examination of the specimen from Mayotte Island of the Comoro Islands by Poupin et al. (2013) shows that it is

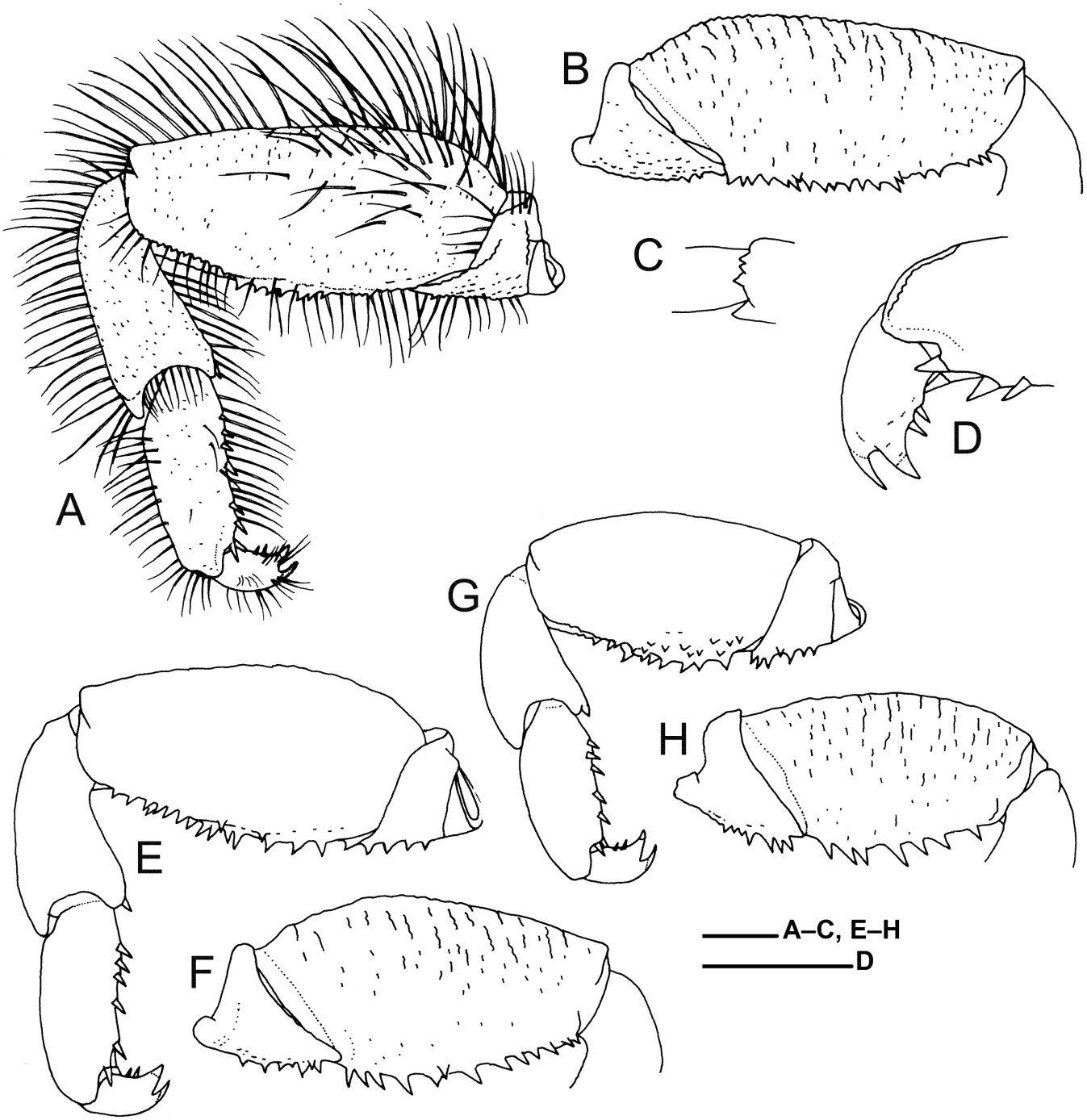

Fig. 5. *Polyonyx pedalis* Nobili, 1906, male (cl 6.8 mm), UF 36876, Mahama Island, Saudi Arabia. Left ambulatory legs. A, second pereopod, lateral view; B, ishium and merus, mesial view; C, same, distal part of carpus, ventral view; D, same, dactylus, lateral view; E, third pereopod, lateral view; F, ishium and merus, mesial view; G, fourth pereopod, lateral view; H, ishium and merus, mesial view. Setae omitted (B–H). Scale bars = 1.0 mm.

correctly identified to that species. Although Haig (1964) reported *P. pedalis* from the Kei Islands in Indonesia based on two lots, only one lot (ZMUC-CRU 2544) could be located in the collection of the Natural History Museum of Denmark and another lot may be lost (D Eibye-Jacobsen, personal communication). The preserved lot including two small specimens is identified as *P. heok*, new species. The New Caledonian material reported by Osawa (2007a, b) also corresponds to this new species.

***Polyonyx heok*, new species**
(Figs. 6–8, 15C, D)

Polyonyx pedalis: Haig, 1964: 381. — Osawa, 2007a: 26, fig. 3; 2007b: 37 (not *Polyonyx pedalis* Nobili, 1906a).

Type material. Holotype: **Singapore.** Singapore Strait, Pulau Jong, 1°12’54”N 103°47’12”E, 15.4 m, in tube of *Chaetopterus* aff. *pacificus*, in soft sandstone, coll. HH Tan, SCUBA, 4 June 2013, male (cl 9.0 mm), ZRC 2015.0034. Paratype: **Singapore.** Same data as holotype, 1 female (cl 8.9 mm), ZRC 2015.0035.

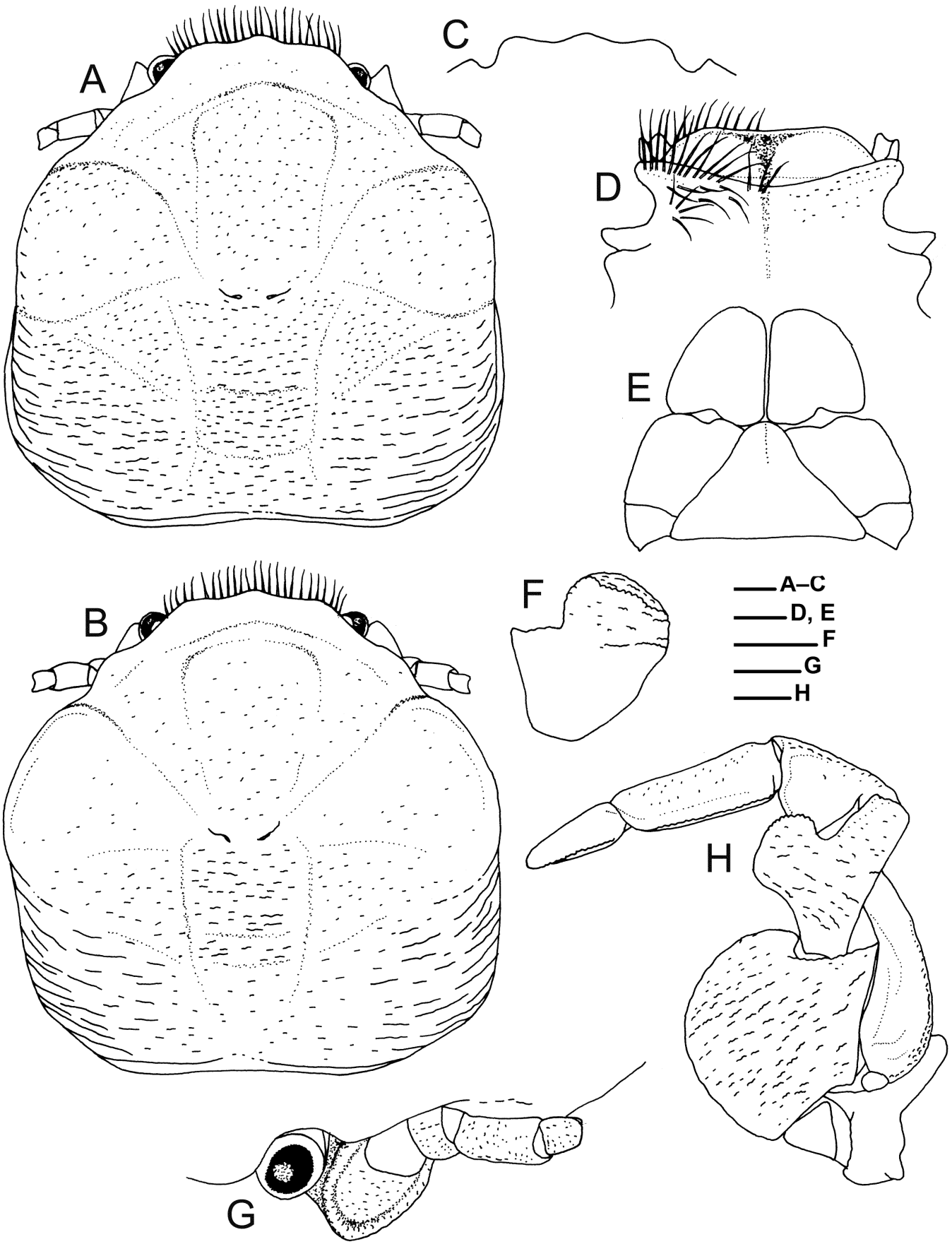

Fig. 6. *Polyonyx heok*, new species. Holotype, male (cl 9.0 mm), ZRC 2015.0034, Singapore Strait (A, C–H); paratype, female (cl 8.9 mm), ZRC 2015.0035, Singapore Strait (B). A, B, carapace and ocular and antennal peduncles, dorsal view; C, rostrum, dorso-anterior view; D, third and fourth thoracic sternites, ventral view; E, telson, external view; F, left basal article of antennular peduncle, ventral view; G, left ocular and antennal peduncles, dorsolateral view; H, left third maxilliped, lateral view. Most setae omitted. Scale bars = 1.0 mm.

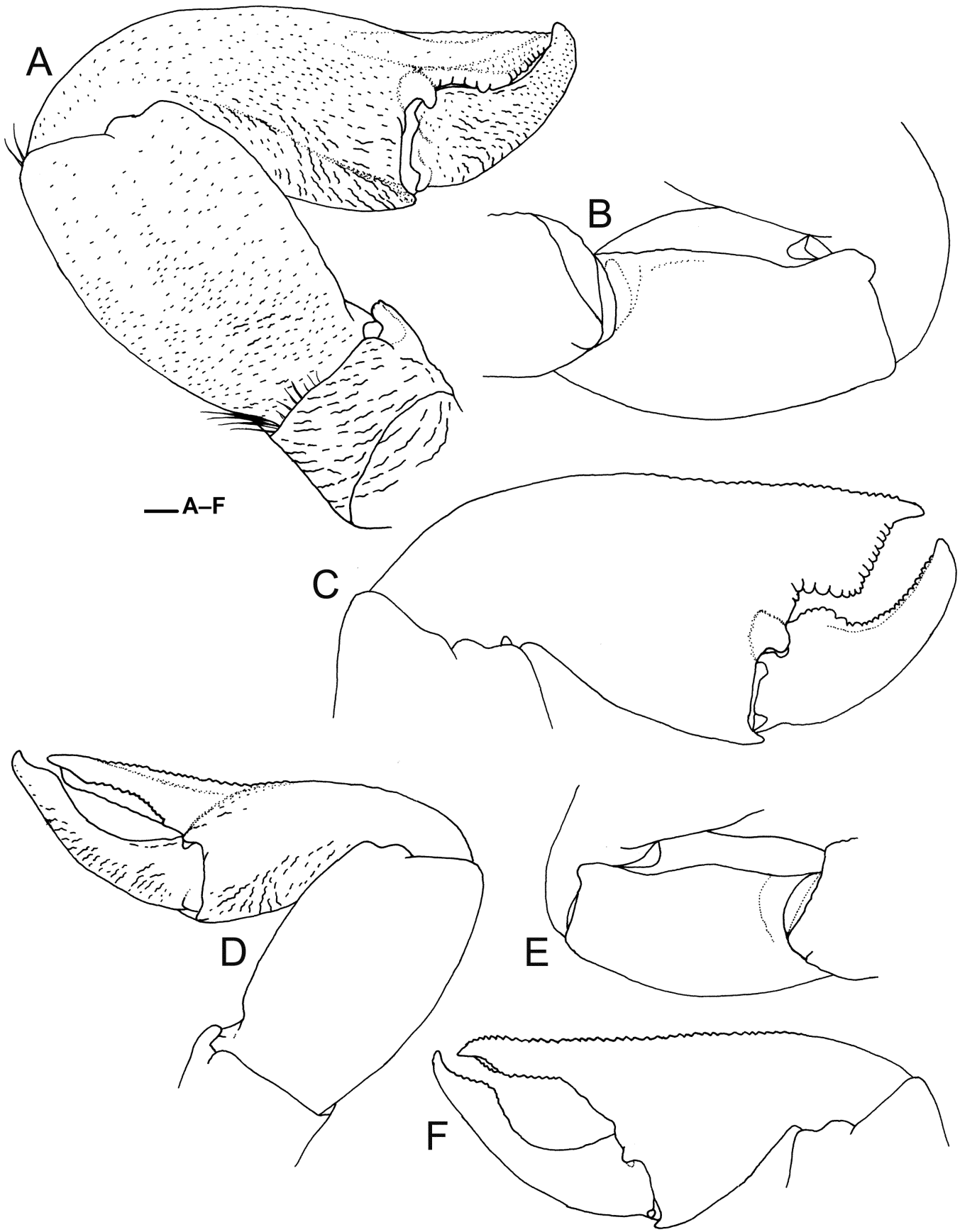

Fig. 7. *Polyonyx heok*, new species, holotype, male (cl 9.0 mm), ZRC 2015.0034, Singapore Strait. A, larger cheliped, dorsal view; B, same, carpus, ventral view; C, same, chela, dorso-anterior view; D, smaller cheliped, dorsal view; E, same, carpus, ventral view; F, same, chela, dorso-anterior view. Most setae omitted. Scale bars = 1.0 mm.

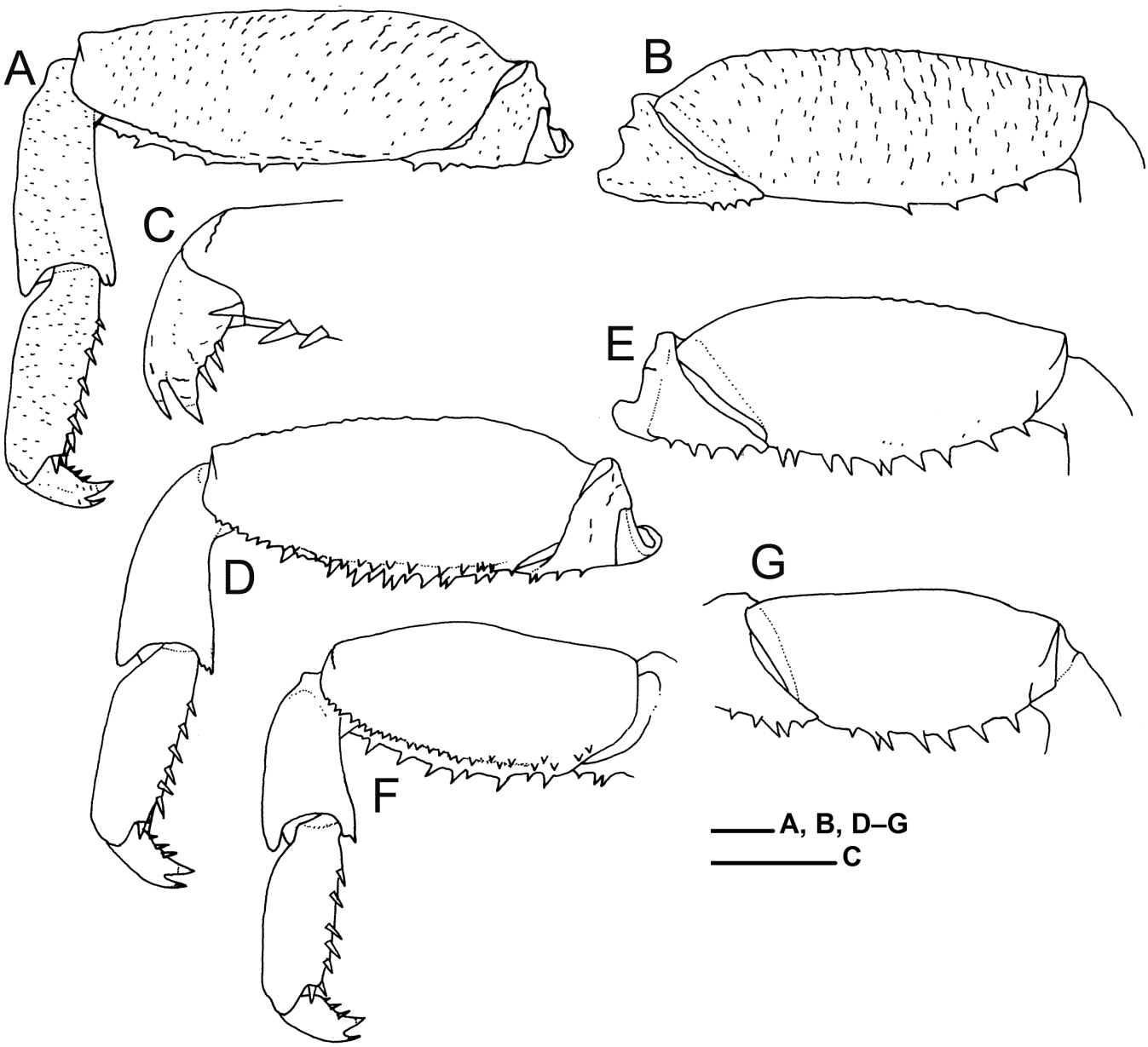

Fig. 8. *Polyonyx heok*, new species, holotype, male (cl 9.0 mm), ZRC 2015.0034, Singapore Strait. Left ambulatory legs. A, second pereopod, lateral view; B, ishium and merus, mesial view; C, same, dactylus, lateral view; D, third pereopod, lateral view; E, ishium and merus, mesial view; F, fourth pereopod, lateral view; G, ishium and merus, mesial view. Setae omitted. Scales: 1.0 mm.

Other material examined. Japan. Oura, Nago, Okinawa Island, Ryukyu Islands, St. D13, 20 m, sand, in tube of *Chaetopterus* sp., suction pump, 25 June 2009, coll. Y Fujita, 1 male (cl 7.2 mm), RUMF-ZC 3735. **Indonesia.** Kei Islands Expedition, Doe Roa Basin, Kei Islands, St. 20, about 50 m, sand, shells, 14 April 1922, 1 male (cl 2.2 mm), 1 female (cl 2.5 mm), ZMUC-CRU 2544. **New Caledonia.** South of Grand Récif, St. DW572, 22°52'S, 167°00'E, 62–67 m, 17 July 1985, coll. B Richer de Forges/ORSTOM, 1 female (cl 5.0 mm), MNHN-IU-2013-13155. St. DW1235, 22°24.08'S, 166°55.44'E, 51–52 m, 9 March 1993, coll. B Richer de Forges, 1 female (cl 4.9 mm), MNHN-IU-2013-13150. Nouville, St. 1363, 22°16.3'S, 166°23.8'E, 18–20 m, tube of Eunicidae, 1 April 1993, coll. P Bouchet, 1 male (cl 3.5 mm), MNHN-IU-2013-13154. Grande Rade, St. 1366, 22°15.3'S, 166°24.0'E, 10–11 m, 14 April 1993, coll. P Bouchet, 1 female (cl 3.3 mm), MNHN-IU-2013-13151. Maitre Islet, 22°19.61'S, 166°24.07'E, 10 m, 14 November 1995, coll. I Takeuchi, 1 male (cl 4.5 mm), MNHN-IU-2013-13153. Campagne PALEO-SURPRISES, N/O "Alis", St. CP1376, 18°27.2'S, 163°09.2'E, 39 m, 9 May 1999, coll. B Richer de Forges-IRD, 1 female (cl 4.4 mm), MNHN-IU-2013-13152. **Vanuatu.** Santo Marine Biodiversity Survey 2006. Northwest of Urélapa Island, St. DB20, 15°30.5'S, 167°01.4'E, 22–25 m, sand with coral patches, 15 September 2006, 1 female (cl 2.1 mm), MNHN-IU-2008-13561. Southwest of Matewulu, St. DB75, 15°22.9'S, 167°11.9'E, 20 m, sand and dead corals, 28 September 2006, 1 male (cl 3.3 mm), MNHN-IU-2008-13565. Segond Channel, mouth of Wambu river, St. DS91, 15°33.7'S, 167°018.4'E, 7 m, muddy sand with corals, sponges and algae, 6 October 2006, 1 female (cl 3.2 mm), MNHN-IU-2008-13564.

Diagnosis. Carapace (Fig. 6A, B) 1.0–1.2 times as broad as long. Protogastric ridges blunt but elevated; anterior gastric region inflated (particularly prominent in large specimens). Rostrum (Fig. 6C) weakly trilobate in dorsal and frontal views; median lobe slightly exceeding lateral lobe; margin between median and lateral lobes slightly concave. Branchial margins subparallel, usually somewhat constricted medially. Posterior margin weakly to moderately concave medially. Third thoracic sternite (Fig. 6D) with lateral lobes reaching or just failing to reach anterior margin of median lobe. Telson (Fig. 6E) broader than long. Basal articles of antennular peduncles (Fig. 6F) with anterior surface slightly concave and rugose; dorso-anterior margin broadly rounded in general outline. Antennal peduncle (Fig. 6G) with first article rounded in lateral view subtriangular in ventral view on anterior margin. Third maxilliped (Fig. 6H) with merus provided with broad, subrectangular lobe on ventral margin, anterior margin of lobe with short row of minute tubercles. Large cheliped (Fig. 7A–C) with carpus 1.6–1.8 times as long as broad; chela 1.4–1.5 times as long as carpus, 2.1 times as long as broad; dactylus 0.5 length of chela. Smaller cheliped (Fig. 7D–F) with carpus 1.7–1.9 times as long as broad; chela 1.5–1.7 times as long as carpus, 2.4–2.6 times as long as broad; dactylus 0.6 length of chela. Ambulatory legs (Fig. 8A–G) with meri successively shortening posteriorly (third merus 0.9–1.0 length of second merus, fourth merus 0.8 length of third merus); length-height ratio of meri, 2.6–2.9 on second, 2.4–2.6 on third, 2.1–2.3 on fourth; propodi with length-height ratio, 3.8–4.3 on second, 3.3–3.9 on third, 2.9–3.9 on fourth, ventral margin with row of 5–7 corneous spines and paired distal spines; dactyli 0.3–0.5 length of propodi, ventral margin usually with 3 (rarely 2) small corneous spines.

Colouration in life (Fig. 15C, D)**.** Carapace and chelipeds generally creamy or reddish brown; plumose setae pale brown. Carapace with pale brown or white areas in midline (at least extending to cardiac region) and anterior branchial regions, and with scattered, irregular dark brown blotches; front whitish. Chelipeds with irregular, pale brown or white marks, and with small dark brown blotches on dorsal surface. Ambulatory legs white; meri and carpi brown on proximal halves and with small brown blotches on distal halves; propodi each with brown band on median part; dactyli mostly white.

Habitat. The specimens recently collected from Singapore and Okinawa Island in south Japan show that *P. heok*, new species, lives symbiotically with tube-dwelling polychaetes of the genus *Chaetopterus*. The specimens of *P. heok* from Singapore were collected by SCUBA from the tubes of *C.* aff. *pacificus* Nishi, 2001, living on sandstone in subtidal reefs. The inner surface of the parchment tube was bright purple. In Singapore, another porcellanid *Eulenaeios cometes* (Walker, 1887) was known to be associated with *Chaetopterus* species living in muddy substratum (see Ng & Nakasone, 1993). The host for *E. cometes* is an undetermined species of *Chaetopterus*, but it is clearly different from that of *P. heok*. In any case, the taxonomy of *Chaetopterus* is still unsettled (see Nishi, 2001) and a revision of known Indo-West Pacific species is clearly necessary.

Distribution. Singapore, Indonesia, New Caledonia, Vanuatu and Japan; depths of 7–65 m.

Etymology. The species is named after the collector of the Singapore material, Dr Tan Heok Hui – "Heok" to all who work with him. In the marine expeditions in Singapore, he collected many interesting specimens. The specific name is used as a noun in apposition.

Remarks. *Polyonyx heok*, new species, is closely allied to *P. planus*, new species, but differs in the dorsal structure of the carapace and comparative length of the merus of the second pereopod. The protogastric ridges of the carapace are blunt and elevated, making the anterior gastric region relatively more inflated in *P. heok* (particularly prominent in large specimens; Fig. 6A, B), whereas they are weak or obsolete and relatively lower in *P. kumejima*, new species, *P. pedalis*, and *P. planus* (Figs. 1A, 3A, 9A, 12A). The merus of the second pereopod is also relatively more slender in *P. heok* than in *P. planus*, being 2.6–2.9 instead of 2.5 times longer than the distal height (Figs. 8A, 14A).

The preferred habitats of *P. heok* and *P. planus* also appear to be different. The specimens recently collected from Singapore and Okinawa Island in south Japan show that *P. heok* lives symbiotically with tube-dwelling polychaetes of *Chaetopterus*, whereas *P. planus* inhabits coral rubble or on the underside of rocks, and symbiotic animals have not been recorded. Clearly, however, there were no chaetopterids in the habitat of *P. planus*, although the presence of other small tube-dwelling polychaetes cannot be discounted.

Polyonyx kumejima, new species
(Figs. 9–11, 15E)

Type material. Holotype: **Japan.** KUMEJIMA 2009 Marine Biodiversity Expedition, east of North Line, Kume Island, Ryukyu Islands, St. Dive 2, 26°21.23'N, 126°53.11'E, 5–50 m, sand, in tube of unidentified polychaete species of Sabellidae, coll. D Uyeno, 9 November 2009, male (cl 6.5 mm), RUMF-ZC 3736.

Diagnosis. Carapace (Figs. 9A) as broad as long. Protogastric ridges weak, low. Rostrum (Fig. 9B) weakly trilobate in dorsal and frontal views; median lobe slightly exceeding lateral lobe; margin between median and lateral lobes slightly concave. Branchial margins slightly convex. Posterior margin shallowly concave medially. Third thoracic sternite (Fig. 9C) with lateral lobes slightly exceeding anterior margin of median lobe. Telson (Fig. 9D) broader than long. Basal articles of antennular peduncles (Fig. 9E) with anterior surface slightly concave, minutely tuberculate; dorso-anterior margin broadly rounded in general outline, with small projection mesially. Antennal peduncle (Fig. 9F) with first article broadly rounded on anterior margin in lateral view. Third maxilliped (Fig. 9G) with merus provided with broad,

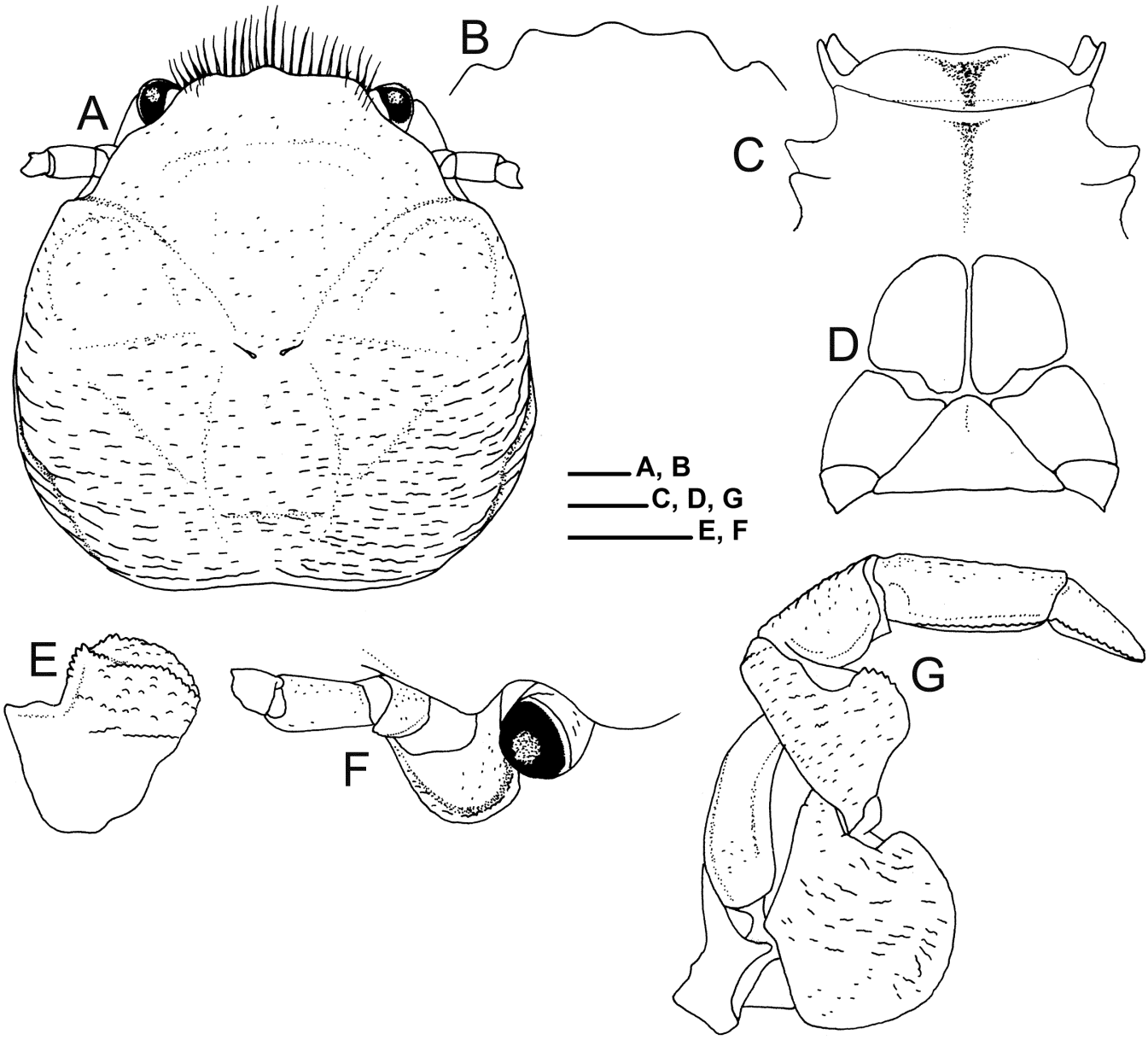

Fig. 9. *Polyonyx kumejima*, new species, holotype, male (cl 6.5 mm), RUMF-ZC 3736, Kume Island, Japan. A, carapace and ocular and antennal peduncles, dorsal view; B, rostrum, dorso-anterior view; C, third and fourth thoracic sternites, ventral view; D, telson, external view; E, left basal article of antennular peduncle, ventral view; F, right ocular and antennal peduncles, dorsolateral view; H, right third maxilliped, lateral view. Setae on frontal margin of carapace only illustrated. Scale bars = 1.0 mm.

subrectangular lobe on ventral margin, anterior margin of lobe with short row of small denticles. Large cheliped (Fig. 10A–C) with carpus 1.8 times as long as broad; chela 1.5 times as long as carpus, 2.1 times as long as broad; dactylus 0.5 length of chela. Smaller cheliped (Fig. 10D–F) with carpus 2.0 times as long as broad; chela 1.5 times as long as carpus, 2.5 times as long as broad; dactylus 0.6 length of chela. Ambulatory legs (Fig. 11A–G) with meri successively shortening posteriorly (third merus 0.9 length of second merus, fourth merus 0.8 length of third merus); length-height ratio of meri, 2.8 on second, 2.5 on third, 2.2 on fourth; propodi with length-height ratio, 4.4 on second, 4.2 on third, 3.9 on fourth, ventral margin with row of 5 or 6 corneous spines and paired distal spines; dactyli 0.4 length of propodi, ventral margin with 3 small corneous spines.

Colouration in life (Fig. 15E)**.** Carapace and pereopods mottled brown and white; plumose setae pale brown. Carapace with white areas in midline (extending to cardiac region) and anterior branchial regions, and with scattered, irregular dark brown blotches; front whitish. Chelipeds with dark brown blotches on dorsal surface, blotches along margins of carpi and palms large. Ambulatory legs white; meri each with irregular, brown band on median part and small brown spots on other parts; carpi with broad brown band proximally, and with small brown spots on distally; propodi each with brown band on median part; dactyli entirely white.

Habitat. The holotype was collected from a tube of an undetermined polychaete of the family Sabellidae. Unfortunately, the polychaete was not preserved.

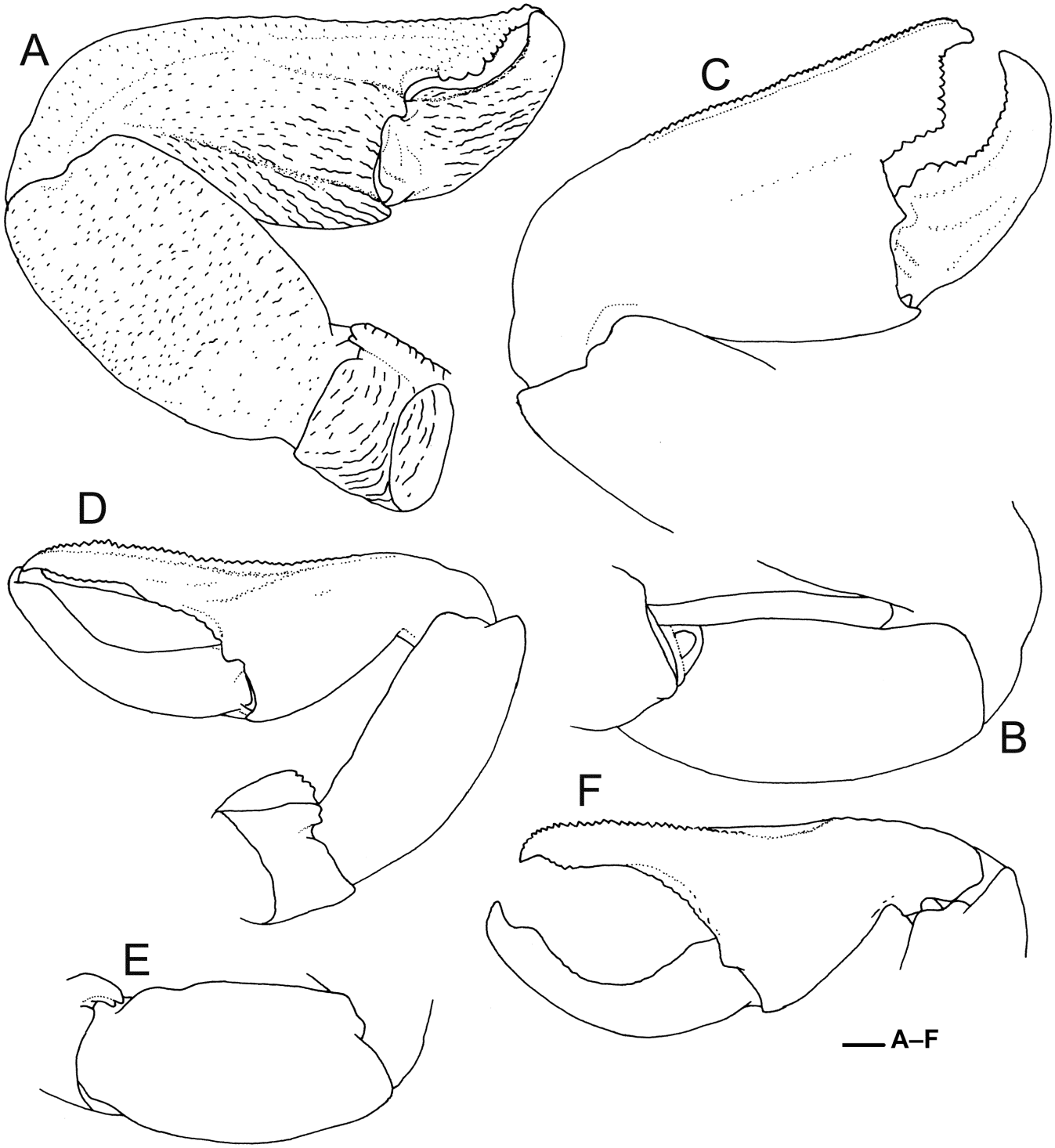

Fig. 10. *Polyonyx kumejima*, new species, holotype, male (cl 6.5 mm), RUMF-ZC 3736, Kume Island, Japan. A, larger cheliped, dorsal view; B, same, carpus, ventral view; C, same, chela, dorso-anterior view; D, smaller cheliped, dorsal view; E, same, carpus, dorsoposterior view; F, same, chela, dorso-anterior view. Setae omitted. Scale bars = 1.0 mm.

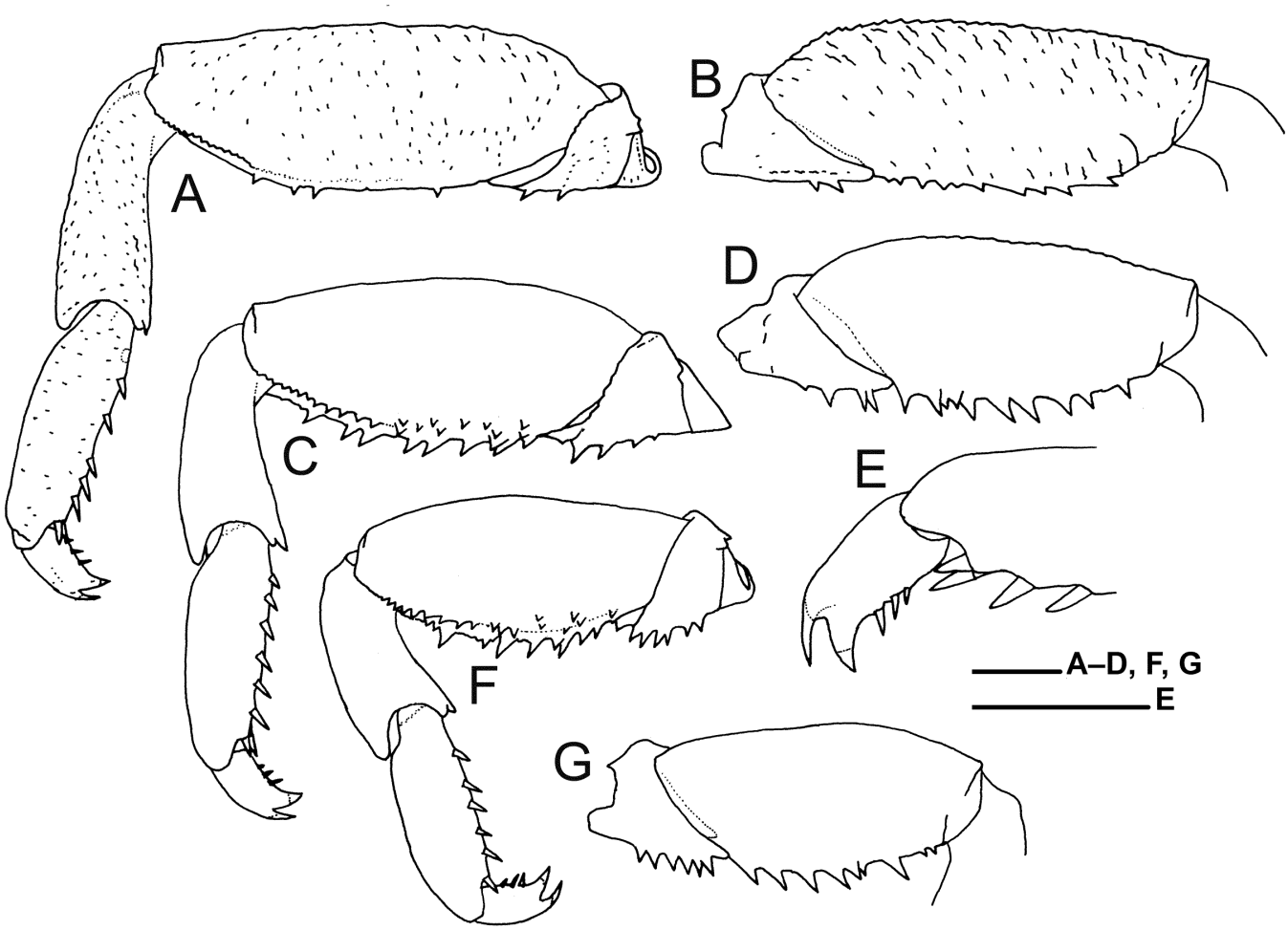

Fig. 11. *Polyonyx kumejima*, new species, holotype, male (cl 6.5 mm), RUMF-ZC 3736, Kume Island, Japan. Left ambulatory legs. A, second pereopod, lateral view; B, ischium and merus, mesial view; C, third pereopod, lateral view; D, ischium and merus, mesial view; E, same, dactylus, lateral view; F, fourth pereopod, lateral view; G, ischium and merus, mesial view. Setae omitted. Scale bars = 1.0 mm.

Distribution. Only known from Kume-jima (Kume Island), Ryukyu Islands; precise collection depth unknown, ranging from 5 to 50 m.

Etymology. The new species is named after the KUMEJIMA 2009 expedition by which the holotype was collected. The name is used as a noun in apposition.

Remarks. *Polyonyx kumejima*, new species, is distinguished from *P. pedalis* and other two new species by the characters of the carapace and basal article of the antennular peduncle. The carapace branchial margins are convex in *P. kumejima* (Fig. 9A), unlike straight in the other species (Figs. 1A, 3A, B, 6A, B, 12A); as a result, this species appears to be more laterally inflated. The antennular basal article has a small projection mesially on the anterior margin in *P. kumejima* (Fig. 9E), but such a projection is absent in the other species (Figs. 3G, 6F, 12E).

The colouration of the carapace is generally similar between *P. kumejima* and other two new species, but the chelipeds are more whitish and have large dark brown blotches adjacent to the extensor margins of the carpi and palms (Fig. 15E) unlike the condition in the others (Fig. 15C, D, F).

The host polychaetes may also distinguish *P. kumejima* from *P. heok*, new species, and *P. pedalis*. *Polyonyx kumejima* is obtained from a tube of an undetermined species of the family Sabellidae, whereas *P. heok* and *P. pedalis* live in tubes of *Chaetopterus* (family Chaetopteridae).

Polyonyx planus, new species
(Figs. 12–14, 15F)

Type material. Holotype: **Philippines.** PANGLAO 2004 Marine Biodiversity Project, Pamilacan Island, 9°29.4'N, 123°56.0'E, 2–4 m, coral rubble, 11 June 2004, male (cl 7.3 mm), NMCR.

Other material examined. Japan. Maeda, Onna, Okinawa Island, Ryukyu Islands, 6 m, coral rubble, under rock, 6 July 2012, coll. Y Yamada, 1 female (cl 7.7 mm), CBM-ZC 12043. Awa, Nago, Okinawa Island, Ryukyu Islands, 5–10 m, 25 April 2013, coll. S Komai, 1 male (cl 6.7 mm, infested by unidentified bopyrid), CBM-ZC 11856.

Diagnosis. Carapace (Figs. 12A) 1.0–1.1 times as broad as long. Protogastric ridges weak, low, appearing relatively flat from frontal view. Rostrum (Fig. 12B) weakly trilobate in dorsal and frontal views; median lobe only reaching anterior margin of lateral lobe; margin between median and lateral

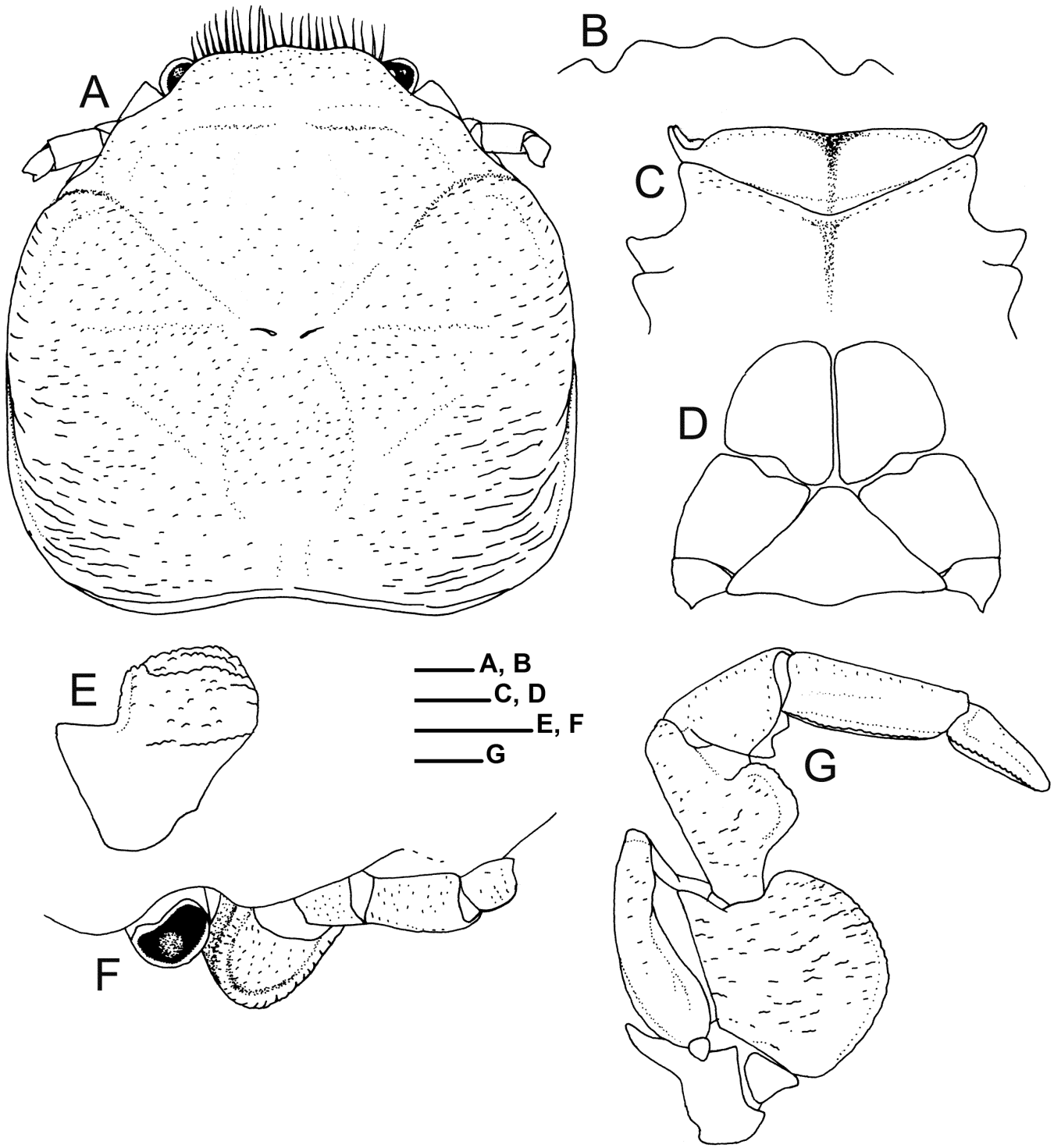

Fig. 12. *Polyonyx planus*, new species, holotype, male (cl 7.3 mm), NMCR, Pamilacan Island, Philippines. A, carapace and ocular and antennal peduncles, dorsal view; B, rostrum, dorso-anterior view; C, third and fourth thoracic sternites, ventral view; D, telson, external view; E, left basal article of antennular peduncle, ventral view; F, left ocular and antennal peduncles, dorsolateral view; G, right third maxilliped, lateral view. Setae on frontal margin of carapace only illustrated. Scale bars = 1.0 mm.

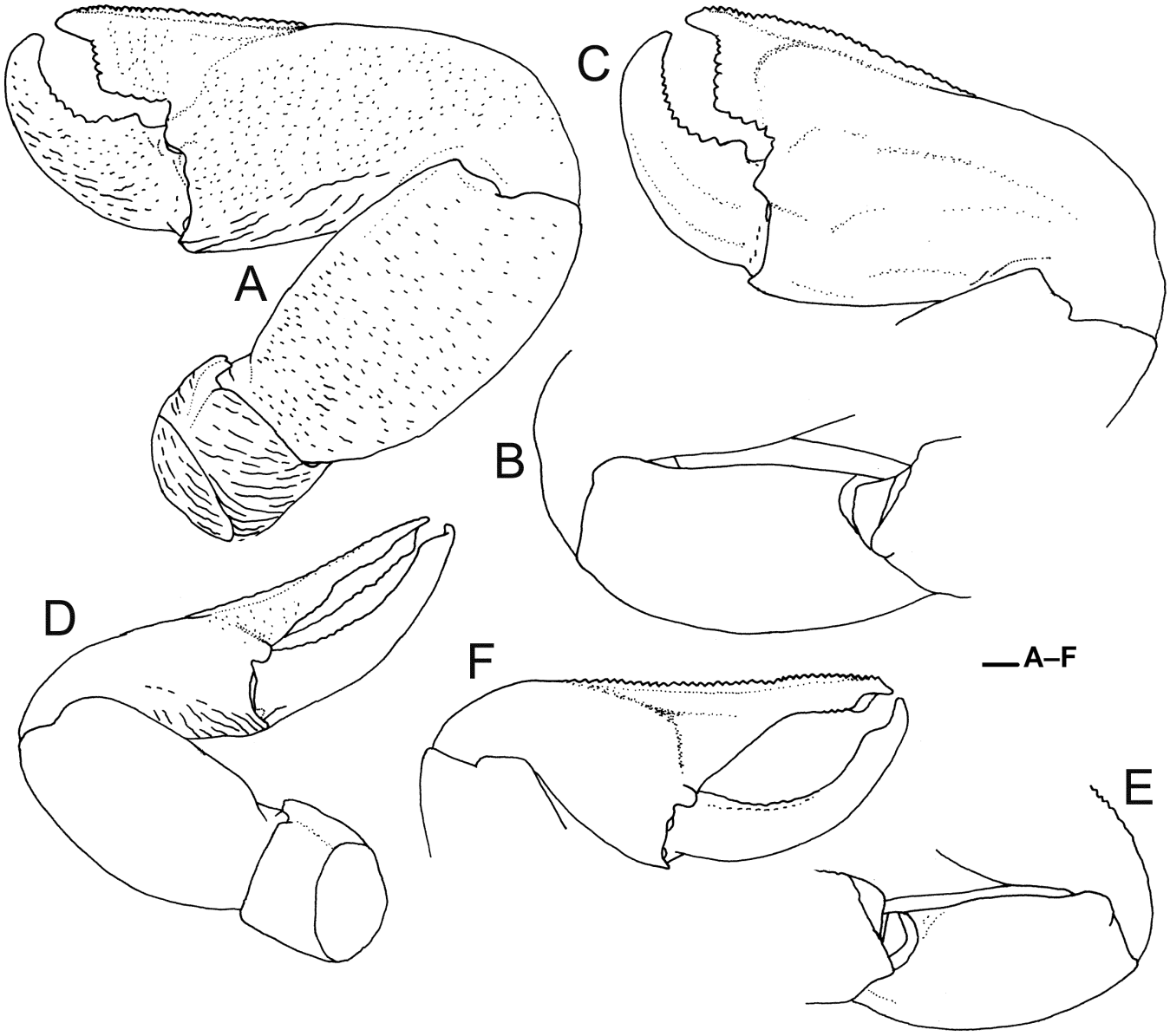

Fig. 13. *Polyonyx planus*, new species, holotype, male (cl 7.3 mm), NMCR, Pamilacan Island, Philippines. A, larger cheliped, dorsal view; B, same, carpus, ventral view; C, same, chela, dorso-anterior view; D, smaller cheliped, dorsal view; E, same, carpus, ventral view; F, same, chela, dorso-anterior view. Setae omitted. Scale bars = 1.0 mm.

lobes slightly concave. Branchial margins subparallel, somewhat constricted medially. Posterior margin weakly to moderately concave medially. Third thoracic sternite (Fig. 12C) with lateral lobes slightly overreaching median lobe. Telson (Fig. 12D) broader than long. Basal articles of antennular peduncles (Fig. 12E) with anterior surface slightly concave and rugose; dorso-anterior margin broadly rounded in general outline. Antennal peduncle (Fig.12F) with first article rounded on anterior margin in lateral view. Third maxilliped (Fig. 12G) with merus provided with broad, subrectangular lobe on ventral margin, anterior margin of lobe with short row of small tubercles. Large cheliped (Fig. 13A–C) with carpus 1.6–1.8 times as long as broad; hela 1.5 times as long as carpus, 2.0–2.2 times as long as broad.; dactylus 0.5 length of chela. Smaller cheliped (Fig. 13D–F) with carpus 1.8–1.9 times as long as broad.; chela 1.6 times as long as carpus, 2.4–2.6 times as long as broad; dactylus 0.6 length of chela. Ambulatory legs (Fig. 14A–G) with meri successively shortening posteriorly (third merus 0.9–1.0 length of second merus, fourth merus 0.8 length of third merus); length-height ratio of meri, 2.5 on second, 2.2–2.5 on third, 2.0–2.4 on fourth; propodi with length-height ratio, 4.0–4.4 on second, 3.6–4.0 on third, 3.8 on fourth, ventral margin with row of 6 or 7 corneous spines and paired distal spines; dactyli 0.4–0.5 length of propodi, ventral margin with 3 small corneous spines.

Colouration in life (Fig. 15F)**.** Carapace and chelipeds generally reddish brown; plumose setae pale brown. Carapace with white areas in midline (extending to cardiac region) and anterior branchial regions; front whitish. Chelipeds with irregular white marks and with small dark brown blotches on dorsal surface. Ambulatory legs with irregular banded pattern of brown and white; meri and carpi brown on proximal halves and with small brown blotches on distal halves; propodi each with brown band on median part; dactyli mostly white.

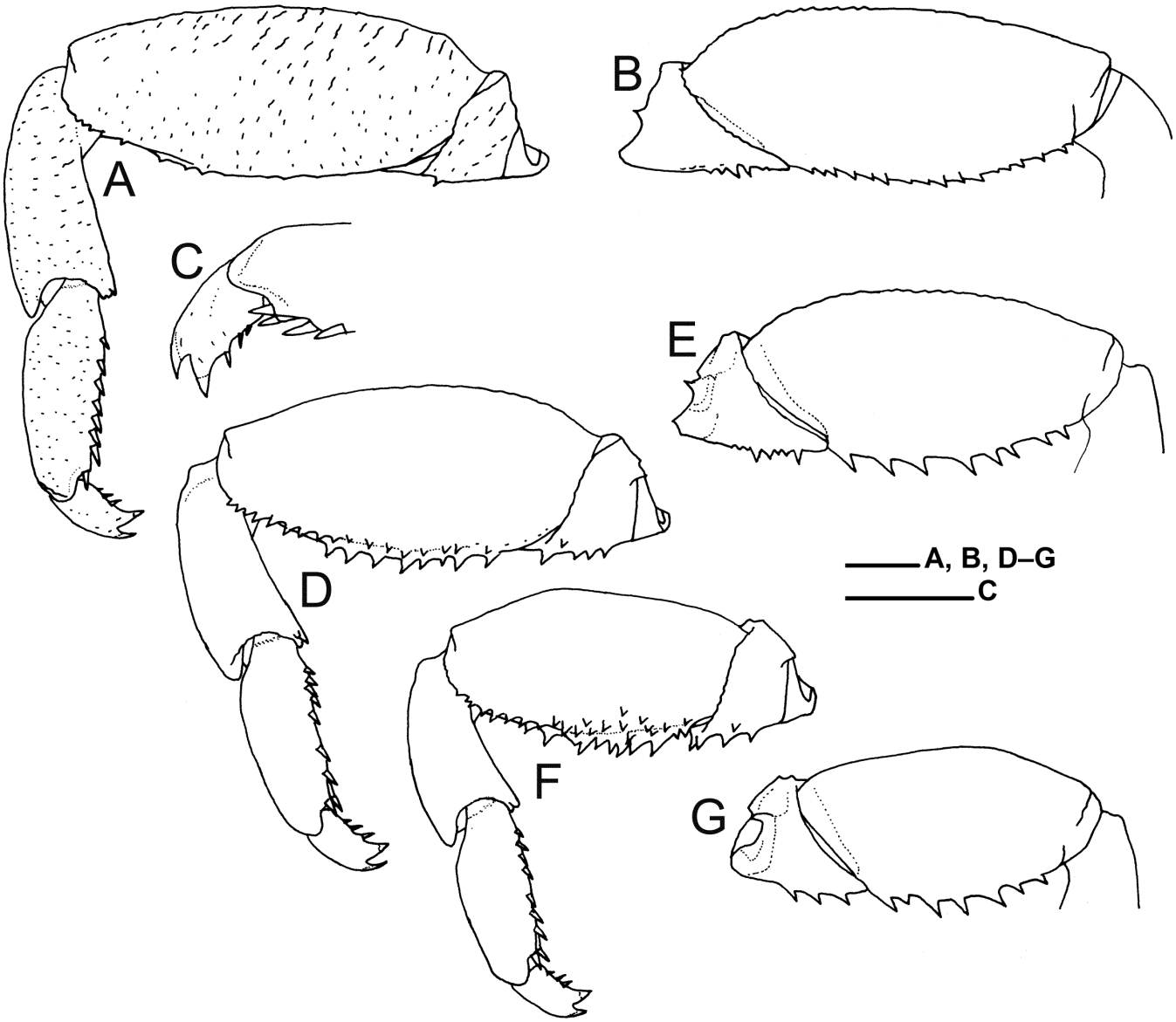

Fig. 14. *Polyonyx planus*, new species, holotype, male (cl 7.3 mm), NMCR, Pamilacan Island, Philippines. Left ambulatory legs. A, second pereopod, lateral view; B, ishium and merus, mesial view; C, same, dactylus, lateral view; D, third pereopod, lateral view; E, ishium and merus, mesial view; F, fourth pereopod, lateral view; G, ishium and merus, mesial view. Setae omitted. Scale bars = 1.0 mm.

Habitat. The available specimens were collected by brushing coral rubble or from underside of rocks. No symbiotic animals were recorded, although the possible presence of small tube-dwelling polychaetes cannot be discounted.

Distribution. Philippines and Okinawa Island in the Ryukyu Island; depths of 2–10 m.

Etymology. The specific name is derived from the Latin, *planus* (flat), referring to the comparatively smoother and flatter protogastric ridges of the carapace.

Remarks. The distinctions between *P. planus*, new species, and the similar *P. heok*, new species, have been discussed in the **Remarks** section of the latter species.

The male specimen from Okinawa Island (CBM-ZC 11856) is provisionally referred to *P. planus* because it is infested with an unidentified bopyprid in the left gill chamber that strongly deforms the carapace. Therefore, we have doubts about its actual identity.

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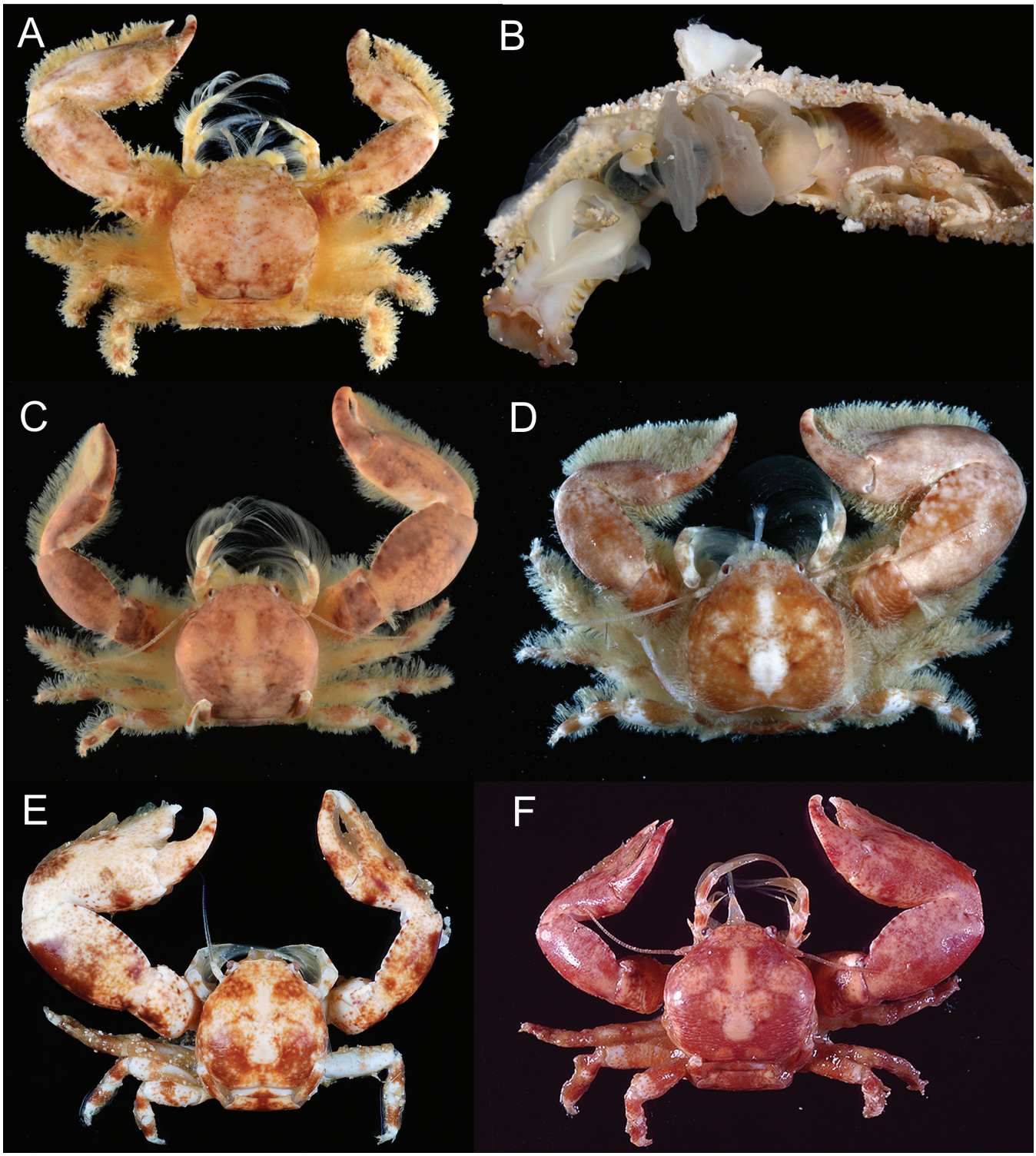

Fig. 15. Colouration in life of four *Polyonyx* species, entire animal, dorsal view (A, C–F). A, *P. pedalis* Nobili, 1906, female (cl 6.6 mm), UF 37201, off Thuwal, Saudi Arabia; B, *P. pedalis* Nobili, 1906 (female, cl 6.6 mm, UF 37201) living symbiotically with tube-dwelling polychaete, *Chaetopterus* sp.; C, *P. heok*, new species, holotype, male (cl 9.0 mm), ZRC 2015.0034, Singapore Strait; D, *P. heok*, male (cl 7.2 mm), RUMF-ZC 3735, Okinawa Island, Japan; E, *P. kumejima*, new species, holotype, male (cl 6.5 mm), RUMF-ZC 3736, Kume Island, Japan; F, *P. planus*, new species, holotype, male (cl 7.3 mm), NMCR, Pamilacan Island, Philippines.

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