

New record and new species of the hermit crab genus *Diogenes* Dana, 1851 (Decapoda: Anomura: Diogenidae) from Singapore

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Abstract. A new species of hermit crab, *Diogenes singaporenensis*, is described based on material from Pulau Ubin, East Johor Strait, Singapore. This new species resembles *D. goniochirus* Forest, 1956 in having a distal protuberance or elongated ridge each on the outer surface of the palm and the carpus of the left cheliped, but easily distinguished by the presence of a median crest on the outer surface of the palm of the left cheliped and a distal spine on the dorsal surface of the fourth segment of the antennal peduncle. Two other congeneric species *D. klaasi* Rahayu & Forest, 1995 and *D. moosai* Rahayu & Forest, 1995 are recorded for the first time from Singapore waters.

Key words. Pulau Ubin, Singapore, *Diogenes singaporenensis*, new species

INTRODUCTION

The hermit crabs of the genus *Diogenes* Dana, 1851 in the Indo-West Pacific are well studied. Subsequent to Gordan's (1956) list of hermit crabs species, 28 new species have been described, and more accurate interpretation and clarification of species identities have been done (Forest, 1956; Dechancé, 1964; Nayak & Neelakantan, 1985, 1989; Morgan, 1987, 1989; Morgan & Forest, 1991; Rahayu & Forest, 1995; Lemaitre & Ng, 1996; Rahayu, 1996, 2012; Rahayu & Horte, 2002; McLaughlin & Clark, 1997; McLaughlin & Dworschak, 2001; McLaughlin & Holthuis 2001; McLaughlin, 2002a, b, 2004, 2005; Siddiqui & McLaughlin, 2003; Siddiqui et al., 2004; Asakura, 2006; Asakura & Godwin, 2006; Korn et al., 2008; Asakura & Tachikawa, 2010; Komai et al., 2012, 2013). Currently 63 species are recognised from the world and 60 species have been recorded from the Indo-West Pacific (McLaughlin et al., 2010; Rahayu, 2012; Komai et al., 2012, 2013). Among them, 11 species are known to occur in Singapore waters: *D. avarus* Heller, 1865; *D. custos* (Fabricius, 1798); *D. fasciatus* Rahayu & Forest, 1995; *D. inglei* McLaughlin & Clark, 1997; *D. jubatus* (Nobili, 1903); *D. laevicarpus* Rahayu, 1996; *D. lophochir* Morgan, 1989; *D. pallescens* Whitelegge, 1897; *D. rectimanus* Miers, 1884; *D. jousseaumei* (Bouvier, 1897); *D. tumidus* Rahayu & Forest, 1995 (Lemaitre & Ng, 1996; Rahayu, 1996; McLaughlin & Clark, 1997, McLaughlin, 2002b).

Recent studies on the hermit crabs in Singapore have added two new records and one new species of *Diogenes* to the local

hermit crabs fauna, i.e., *D. klaasi* Rahayu & Forest, 1995, *D. moosai* Rahayu & Forest, 1995, and *D. singaporenensis* new species. The eight specimens of *D. klaasi* collected have provided the opportunity to show life coloration and additional specific characters that were not pointed out earlier. Specimens of *Diogenes moosai*, so far known only from Indonesian waters, included individuals smaller than the holotype and paratypes, and these were examined to determine character variation relating to size differences in individuals. *Diogenes singaporenensis*, a new species described here, belongs to the *D. edwardsii* group as defined by Asakura & Tachikawa (2010), which is characterised by the simple intercalary rostral process, non-bifurcate antennal acicles, antennal and antenniferous peduncles being distinctly longer than the ocular peduncles, and a long and setose antennal flagellum. At present the *edwardsii* group of *Diogenes* comprises 27 species (Nayak & Neelakantan, 1985; Rahayu, 1996, 2012; Asakura & Tachikawa, 2010; Komai et al., 2012, 2013).

Material used in this study are deposited in the Lee Kong Chian Natural History Museum, National University of Singapore (LKCNCNM; also ZRC), and selected paratypes of the new species are also deposited in the Museum Zoologi Bogor, Indonesian Institute of Sciences, Indonesia (MZB). Specimen size is indicated by length of the shield (sl), measured from the tip of the rostrum to the mid-point of the posterior margin, and to the nearest 0.1 mm. Terminology used in the diagnosis and description generally follows McLaughlin & Clark (1997). The abbreviations, stn and ovig, refer to station and ovigerous, respectively.

TAXONOMY

Family Diogenidae Ortmann, 1892

Genus *Diogenes* Dana, 1851*Diogenes klaasi* Rahayu & Forest, 1995

(Figs. 1, 7A)

Diogenes klaasi Rahayu & Forest, 1995: 395, fig. 3; Rahayu & Komai, 2000: 28; McLaughlin, 2002a: 419, Fig. 3D–F; Siddiqui et al., 2004: 187, fig. 14; McLaughlin et al., 2010: 21 (list); Naderloo et al., 2012: 65, fig. 3a; Naderloo & Türkay, 2012: 27.

Material examined. 1 male (sl 1.8 mm) (ZRC 2014.0326), Chek Jawa, Pulau Ubin, 21 September 2001; 2 males (sl 1.6mm, 2.2 mm), 1 ovig. female (sl 1.8 mm) (ZRC 2014.0327); 2 males (sl 1.8mm, 2.1 mm), 1 female (sl 1.8 mm) (MZB Cru 3984), Changi, coll. H. K. Lua, 16 February 1995; 1 individual, not sexed and measured, stn SW 53, Seringat-Kias, 1°13.630'N 103°51.218'E, coll. Y. L. Lee et al., 24 May 2013.

Color. Shield mottled with shade of white and light brown, two dark brown spots on dorsolateral surface. Ocular peduncle white with two brown stripes beginning on both sides of base, converging toward indentation posterior to corneas, light brown medially, corneas silver. Chelipeds mottled white, light and dark brown, fingers light brown. Second and third pereopods mottled brown and white, proximal dark brown band on dactyls; propodi, carpi and meri with median dark brown band (Fig. 7A).

Habitat. Intertidal area with sand and rock substrate, oyster bed and muddy-sand flat.

Distribution. Persian Gulf (Naderloo & Türkay, 2012), Pakistan (Siddiqui et al., 2004), Western Thailand (McLaughlin, 2002a), Indonesia (Rahayu & Forest, 1995), and now recorded from Singapore.

Remarks. The original description by Rahayu & Forest (1995) and subsequent diagnosis of *D. klaasi* by McLaughlin (2002a) and Siddiqui et al. (2004) are detailed enough to recognise the species, and therefore the description based on the present material is not repeated here. However, the row of strong spines on the ventrolateral margin of the merus of the left cheliped which extends to the ventral surface and ventromesial margin (Fig. 1B, C) was not clearly mentioned in the previous accounts of *D. klaasi*, although Siddiqui et al. (2004) showed the morphology in their figure 14B'. Furthermore, the lateral surfaces of the dactyls of the second and third pereopods have a longitudinal row of setae which extends, albeit sparsely, on the lateral surface of each propodus (Fig. 1E, F).

As discussed by Rahayu & Forest (1995), *D. klaasi* differs from *D. avarus* by the absence of the dorsal row of spines of each propodus of the second and third pereopods. Additionally, the fourth segment of the antennal peduncles

of *D. klaasi* is armed with a small spine on the dorsal surface distally (Fig. 1A), while this spine is absent in *D. avarus*.

Diogenes karwarensis Nayak & Neelakantan, 1989 known from Persian Gulf, Pakistan and India, also has a small spine on the fourth segment of each antennal peduncle as in *D. klaasi*, but the row of strong spines on the ventrolateral margin of the merus of the left cheliped does not extend to the ventral surface and ventromesial margin, unlike in the latter species. Additionally, the dorsal surfaces of the propodi of the second and third pereopods are unarmed in *D. klaasi* (Fig. 1E, F), while those have a row of spines in *D. karwarensis*.

Diogenes moosai Rahayu & Forest, 1995

(Figs. 2, 7B)

Diogenes moosai Rahayu & Forest, 1995: 392, fig. 2a, c–e, f, i; McLaughlin et al., 2010: 21 (list).

Material examined. 5 males (sl 2.8–4.2 mm), 1 female (sl 2.9 mm) (ZRC 2014.0328), 3 males (3.1–4.4 mm) (MZB Cru 3987), Sarimbun Beach, coll. Y. L. Lee, 14 February 2012; 1 male (sl 2.5 mm), 2 ovig. females (sl 2.0–2.7 mm) (ZRC 2014.0329), 1 male (sl 2.4 mm), 1 ovig. female (sl 3.2 mm) (MZB Cru 3988), DW 40, Changi, 1°23.797'–1°23.768'N, 103°58.751'–103°58.908'E, 15.6–24 m, dredge, 19 October 2012.

Diagnosis. Shield (Fig. 2A) with rounded rostral lobe weakly produced; dorsal surface with scattered small tubercles and setae; branchiostegites each with 6–8 spines on dorsal margin. Ocular peduncles 0.8 length of shield; corneal diameter about 0.2–0.3 length of ocular peduncles; ocular acicle with row of spinules not extending full length of anterior margin, one or two mesial spines prominent. Intercalary rostriform process shorter than acicles, simple, without ventral spine. Antennular peduncles longer than antennal peduncles, overreaching distal margins of corneas by half length of ultimate segments. Antennal peduncles overreaching distal margin of corneas by three quarter length of fifth segment, fourth segment unarmed. Antennal acicles slightly overreaching distal margin of fourth peduncular segment, each terminating in strong spine and with row of five or six spines on mesial margin. Antennal flagellum with long, plumose ventral setae. Left cheliped (Fig. 2B) with dactyl about same length as palm, arched; upper margin with row of spinules; outer face covered with small pointed tubercles. Fixed finger short, slightly deflexed; outer surface covered with pointed tubercles, lower margin with moderately large spines continued onto slightly sinuous lower margin of palm. Palm with convex outer surface, covered with spinules, slightly larger spinules forming short crest on midline, extending from proximal to at most mid-length of palm; upper margin with row of moderately small spines. Carpus with double row of strong spines on upper margin, outer surface covered with small tubercles, lower margin with row of small spines. Merus short, dorsal surface with transverse rows of small spines; ventral margin with row of spines, distal spines prominent. Right cheliped (Fig. 2C) with distinct hiatus between dactyl and fixed finger, all

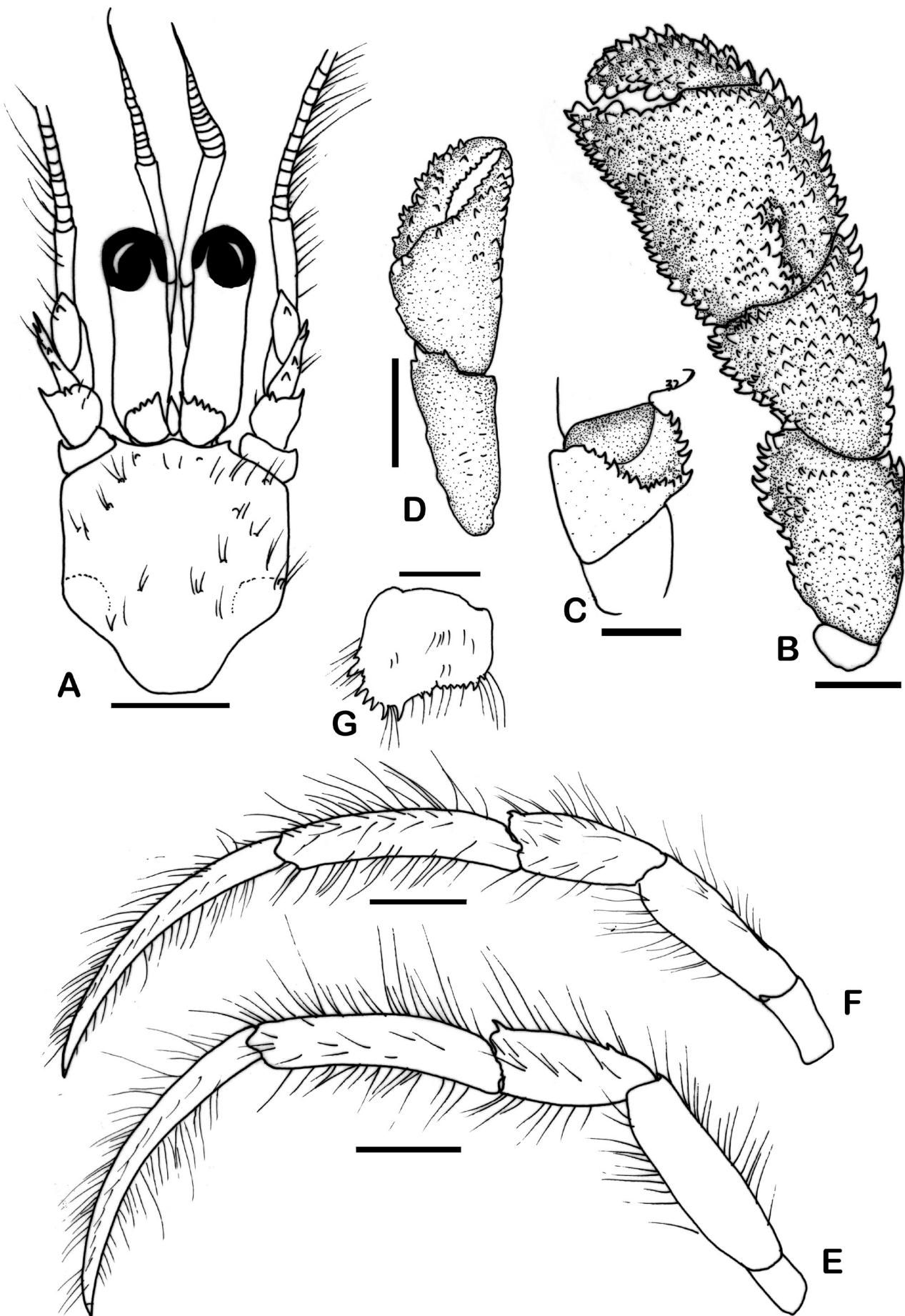


Fig. 1. *Diogenes kiaasi* Rahayu & Forest, 1995, male, sl 2.1 mm. A, shield and cephalic appendages, dorsal view; B, chela, carpus and merus of left cheliped, dorsal view; C, merus of left cheliped, ventral view; D, chela and carpus of right cheliped, dorsal view; E, left second pereopod, lateral view; F, left third pereopod, lateral view; G, telson. Scale bars = 1 mm [A-F]; 0.5 mm [G]. Setae partially omitted.

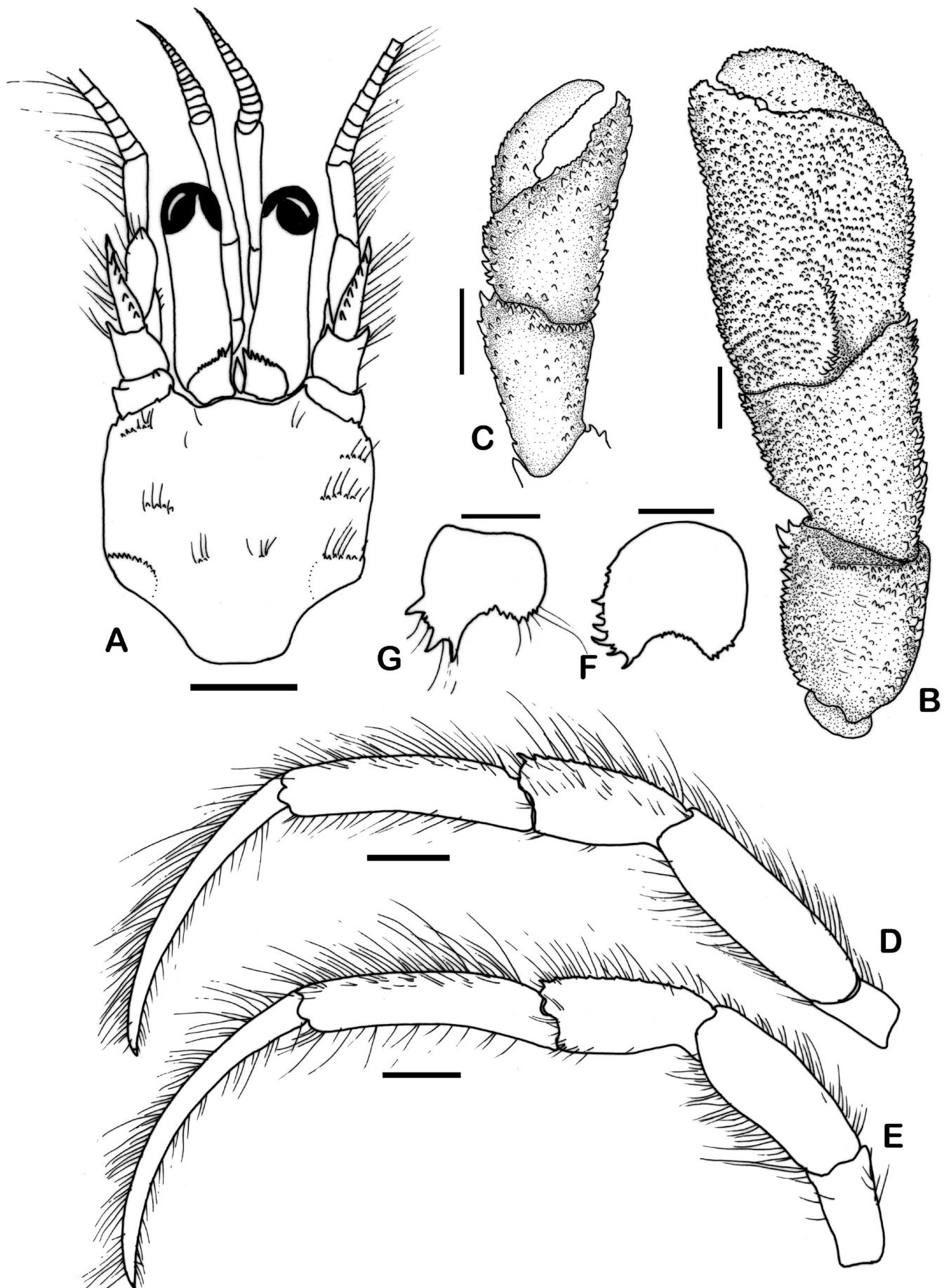


Fig. 2. *Diogenes moosai* Rahayu & Forest, 1995: A–F, male, sl 2.7 mm; G, male, sl 2.2 mm. A, shield and cephalic appendages, dorsal view; B, chela, carpus and merus of left cheliped, dorsal view; C, chela and carpus of right cheliped, dorsal view; D, left second pereopod, lateral view; E, left third pereopod, lateral view; F, G, telson. Scale bars = 1 mm [A–E]; 0.5 mm [F, G]. Setae partially omitted.

surfaces covered with long plumose setae; dactyl strongly arched, longer than palm; upper margins of dactyl, palm and carpus each with row of spines, outer surfaces of chela and carpus with scattered spinules. Second and third pereopods slender (Fig. 2D, E), with long plumose setae along dorsal and ventral margins; lateral faces of propodi and carpi also with rows of sparse long setae; dactyls arched, 1.3–1.7 times longer than propodi; propodi unarmed; carpi with row of small spinules on dorsal margin, sometimes not visible from lateral view. Female with paired gonopores. Telson (Fig. 2F, G) asymmetrical, with shallow median cleft; terminal margin of left lobe with large spines extending onto lateral margin, right lobe with small spines slightly extending to lateral margin.

Colour. Shield mottled with shade of white and light brown. Dorsal surface of ocular peduncle white with two brown stripes not reaching proximal portion and base of corneas; proximal portion with brown band, corneas silvery brown. Chelipeds mottled white and light brown. Second and third pereopods mottled brown and white, dactyls white; propodi, carpi and meri with large shade of white and light brown median band (Fig. 7B).

Habitat. The specimens examined were collected on sandy mud substratum in intertidal areas and by dredges operated at depths of 15–24 m depth.

Distribution. Previously known only from the north of Java, Indonesia (Rahayu & Forest, 1995), and herein recorded from Johor Strait, Singapore.

Remarks. The easily observable diagnostic characters of *D. moosai* are the long ocular peduncles with relatively small corneas, the long antennal acicles that overreach the distal end of the fourth peduncular segment, the long and arched dactyl of the right cheliped, and the arched dactyls of the second and third pereopods. However, in the small specimens examined (sl less than 2.6 mm) the corneal diameter is slightly larger (about 0.3 instead of 0.2 length of ocular peduncles in larger specimens), and the dactyls of the second and third pereopods are longer (1.5–1.7 times length of the propodi, unlike 1.3–1.5 times in larger specimens). On the other hand, the length of ocular peduncles that is about 0.8 length of shield, the dactyl of the right cheliped and of the second and the third pereopods that are strongly arched, and the antennal acicles that are long, overreaching the distal end of the fourth peduncular segment, do not vary with individual size and agree well with the identity of *D. moosai*.

Diogenes singaporenensis new species (Figs. 3–6)

Material examined. Holotype: female (sl 2.3 mm) (ZRC 2014.0330), Chek Jawa, Pulau Ubin, 1 July 2009. Paratypes: 4 males (sl 1.3–2.5 mm), 3 females (sl 1.4–1.7 mm), 4 ovig. females (sl 1.6–2.5 mm) (ZRC 2014.0331); 1 male (sl 1.6 mm) 1 females (sl 1.8 mm), 4 ovig. females (sl 1.6–2.9 mm) (MZB Cru 3989), same locality as holotype; 1 male

(sl 1.6 mm) (ZRC 2014.0332), same locality as holotype, 21 September 2001.

Other material. 1 male (sl 1.7 mm) (ZRC 2014.0333), Changi, 18 January 1995; 2 males (sl 1.5 mm, 1.7 mm), 3 females (sl 1.8–1.6 mm), 6 ovig. females (sl 1.7–2.0 mm) (ZRC 2014.0334), 1 male (sl 1.5 mm) 2 ovig. female (sl 2 mm) (MZB Cru 3990), Chek Jawa, Pulau Ubin, 21 September 2001.

Description. Shield (Fig. 3A) slightly longer than broad; rostrum broadly rounded; anterior margin between rostrum and lateral projections somewhat concave; lateral projections triangular, slightly exceeding tip of rostral lobe, each with small marginal spine; anterolateral angle rounded; lateral margins glabrous; posterior margin truncate or slightly concave; dorsal surface with few small spines and tufts of sparse setae. Dorsal margins of branchiostegites each with row of five or six small spines.

Ocular peduncles (Fig. 3A) stout, cylindrical, about 0.7 length of shield, not inflated at proximal portion, each with tufts of very sparse setae dorsally; corneas not dilated, its diameter about 0.4 of peduncular length. Ocular acicles broad, subtriangular, basally separated by approximately 0.2 or less width of one acicle, with row of spinules on mesial half of terminal margin, most mesial spine largest. Intercalary rostriform process stout, usually simple at tip, not reaching tips of mesial spines of ocular acicles, with few long setae; no ventral spine.

Antennular peduncles (Fig. 3A), when fully extended, overreaching corneas by whole length of ultimate segments. Ultimate and penultimate segments unarmed, but with few short setae. Basal segment with few long setae.

Antennal peduncles (Fig. 3A) overreaching distal corneal margin by 0.5–0.7 length of fifth segment; fifth segment with row of long setae laterally; fourth segment with triangular dorsodistal margin, dorsal surface with small spine distally, few short setae ventrodistally; third segments short, stout, unarmed; second segment with dorsolateral distal angle produced into small but prominent spine, dorsomesial distal angle with or without small spine, mesial and lateral margins with few setae; first segment unarmed. Antennal acicle reaching to distal margin of fourth segment, with strong terminal spine; mesial margin with 4–5 moderately large spines and few setae. Antennal flagellum long, slightly overreaching tip of left cheliped; each article with 2 or 3 long plumose setae.

Third maxilliped with coxal plate unarmed; basis with two small spines on mesial margin; ischium with crista dentata composed of two small corneous teeth; merus, carpus and propodus approximately same length to each other, with dense, long setae on mesial margin, lateral margin with fewer setae; dactyl slightly shorter than propodus, with dense setae ventrally.

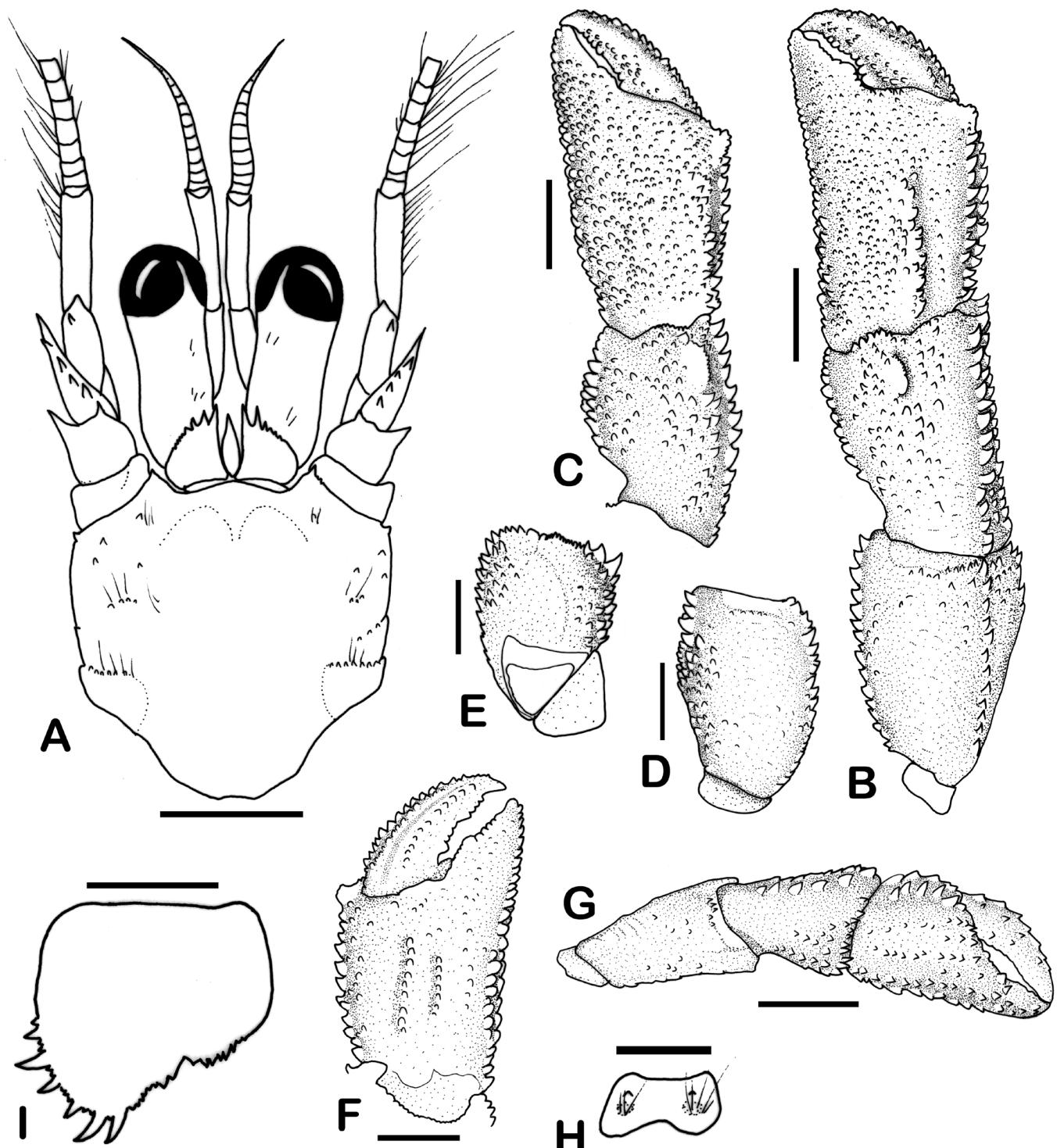


Fig. 3. *Diogenes singaporensis* new species, holotype, female, sl 2.3 mm. A, shield and cephalic appendages, dorsal view; B, chela, carpus and merus of left cheliped, dorsal view; C, chela and carpus of left cheliped, laterodorsal view; D, merus of left cheliped, lateral view; E, merus of left cheliped, mesial view; F, chela of left cheliped, ventral view; G, chela, carpus and merus of right cheliped, dorsal view; H, anterior lobe of sternite of third pereopods; I, telson. Scale bars = 1 mm [A–G], 0.5 mm [H, I]. Setae partially omitted.

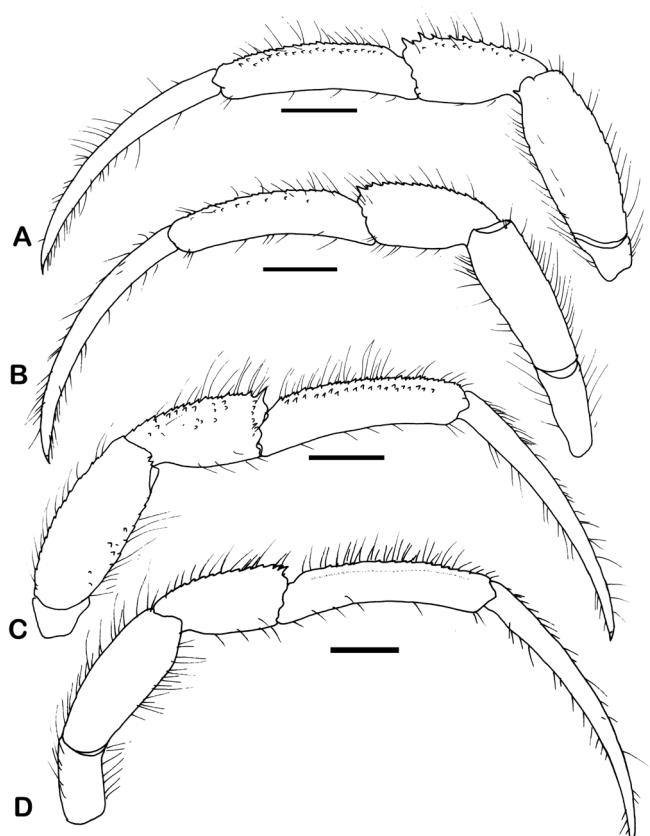


Fig. 4. *Diogenes singaporenensis* new species, holotype, female, sl 2.3 mm. A, left second pereopod, lateral view; B, left third pereopod, lateral view; C, right second pereopod, lateral view; D, right third pereopod, lateral view. Scale bars = 1 mm. Setae partially omitted.

Left cheliped (Figs. 3B–F, 5A–D) much larger than right, slight hiatus between dactyl and fixed finger. Dactyl 0.8 length of palm measured along upper margin, arched; cutting edge with row of blunt calcareous teeth slightly increasing in size proximally and bearing few tufts of short setae, terminating in small calcareous claw; outer surface with shallow longitudinal sulcus medially, with longitudinal row of tubercles near upper margin, and irregular row of tubercles near cutting edge; upper margin with row of small spines decreasing in size distally; inner surface usually with narrow longitudinal sulcus flanked by longitudinal row of tubercles near upper margin and row of tubercles medially (median row of tubercles absent in some paratypes, Fig. 5D). Fixed finger with outer surface covered with small blunt tubercles; lower margin delimited by row of moderately small spines, sparsely interspersed with short setae and forming straight line with similarly armed lower margin of palm, spines increasing in size proximally; inner surface with few scattered small tubercles, and with few short setae on midline and near cutting margin; cutting edge with row of calcareous teeth, large tooth subdistally and proximally; stronger spines on midline, spines largest proximally and decreasing in size distally, reaching to median portion; upper margin of palm with double row of prominent spines usually culminating in strong spinulose protuberance distally (Fig. 3B, C) or eroded and reduced into low, elongate ridge (Fig. 5A, B); lower outer surface of palm covered with flattened tubercles; lower margin delimited by row of strong, subacute spines; inner surface with two longitudinal rows of tubercles on

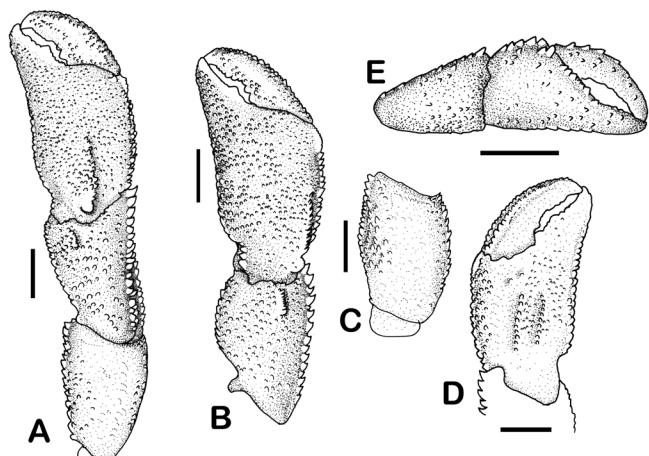


Fig. 5. *Diogenes singaporenensis* new species, paratype, male, sl 2.2 mm. A, chela, carpus and merus of left cheliped, dorsal view; B, chela and carpus of left cheliped, laterodorsal view; C, merus of left cheliped, lateral view; D, Chela of left cheliped, ventral view; E, chela and carpus of right cheliped, dorsal view. Scale bars = 1 mm. Setae omitted.

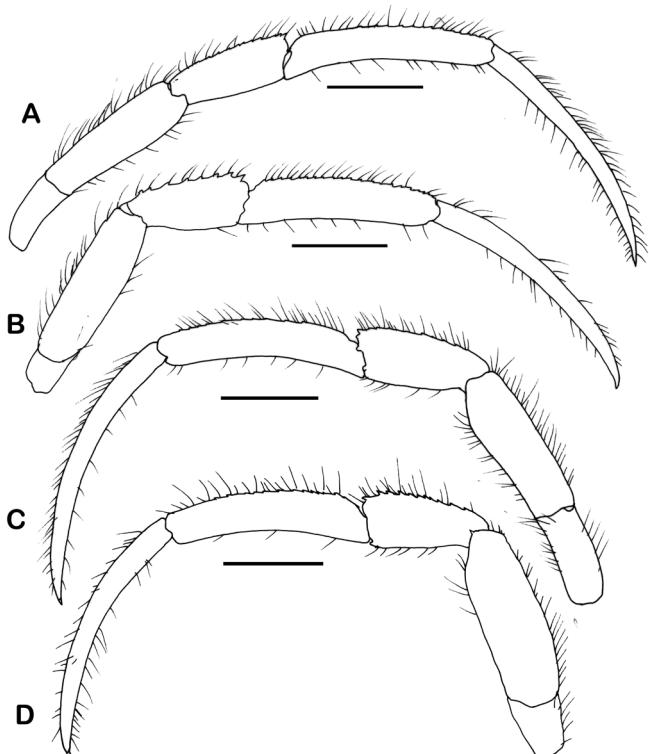


Fig. 6. *Diogenes singaporenensis* new species, paratype, male, sl 1.6 mm. A, right third pereopod, lateral view; B, right second pereopod, lateral view; C, left third pereopod, lateral view; D, left second pereopod, lateral view. Scale bars = 1 mm. Setae partially omitted.

midline and scattered smaller tubercles on remaining surface. Carpus equal in length or slightly longer than palm; upper surface with double row of prominent spines and sparse long setae; outer surface convex, covered with small tubercles, longitudinal row of small and large spines present on midline, culminating in strong spinulose protuberance; lower margin convex, armed with row of large subacute spines interspersed with setae; inner surface with flattened tubercles and sparse setae. Merus subtriangular in dorsal view; dorsodistal margin

with few small spines; dorsal surface with rows of moderately strong spines and tufts of long plumose setae; lateral face tuberculate, ventrolateral margin with row of moderately large spines, distal spines strongest and accompanied by long setae; mesial face tuberculate near dorsal and ventral margin, ventromesial margin with row of moderately large spines, distal spines strongest and accompanied by long setae; ventral surface tuberculate. Ischium with row of small protuberances on ventral margin and with sparse short setae on ventromesial margin.

Right cheliped (Figs. 3G, 5E) reaching proximal third portion of palm of left cheliped; relatively broad hiatus between dactyl and fixed finger. Dactyl distinctly longer than palm, slightly or strongly arched; upper margin with row of spines and numerous long setae; outer surface with irregular rows of small spines obscured by moderately dense long setae; cutting edge with row of low calcareous teeth, terminating in moderately large calcareous claw overlapped by fixed finger. Palm with row of moderately large spines and tufts of long setae on upper margin; outer surface with irregular rows of large and small spines, denser spines near lower margin, obscured by mixture of long, simple or plumose setae; outer surface of fixed finger with irregular row of small subacute spines obscured by long simple setae; lower margin with row of small subacute spines and sparse long setae; cutting edge with row of small calcareous teeth, large tooth usually present medially, terminating in moderately large calcareous claw. Carpus with row of large spines on upper margin partially obscured by long setae; outer face with irregular rows of large and small spines accompanied by sparse long setae, distal row of small spines along articulation with palm; lower margin not delimited; inner and lower surfaces with sparse long setae. Merus with numerous long, simple or plumose setae arising from low protuberances or tubercles on dorsal margin; ventromesial and ventrolateral margins each with row of small spines and long, simple and plumose setae. Ischium unarmed, but with few long setae.

Second and third pereopods (Figs. 4, 6) slender. Second pereopods (Figs. 4A, C, 6B, D) with dactyls 1.3–1.4 times longer than propodi, somewhat curved ventrally, but not twisted in dorsal view, terminating in moderately small corneous claw; dorsal and ventral margins each with sparse, short and long simple setae; mesial surfaces each with row of setae near dorsal margin. Propodi 1.4–1.5 times as long as carpi, each with row of small spines and sparse long setae on dorsal margin; ventral margins unarmed; lateral faces usually with scattered small spines; mesial faces each with few short setae near dorsal margins. Carpi 0.8 length of meri; dorsal margins each with row of small spines and sparse setae; ventral margins unarmed; lateral faces usually with scattered small tubercles. Meri each with row of tiny spinules and sparse setae on dorsal margin; ventral margins with 1 distal spine, and usually with row of spinule on right, unarmed on left but with row of sparse setae. Ischia unarmed, each with sparse setae. Third pereopods (Figs. 4B, D, 6A, C) with dactyls same as in second pereopods; propodi each with dorsal row small spinules and sparse

long and short setae, lateral face of left usually with row of spinules near dorsal margin, lateral face of right usually with shallow sulcus near dorsal margin; carpi 0.8 times as long as meri, with prominent dorsodistal spine, followed by dorsal row of small spines, and sparse setae, lateral face of left with row of spinules near dorsal margin, unarmed on right; ventral margins unarmed; meri and ischia also unarmed but with few setae.

Fourth pereopods semichelate. Anterior lobe of sternite of third pereopods (Fig. 3H) divided into two lobes by shallow median groove, each lobe with or without a small spine and setose protuberance. Female with paired gonopores.

Telson (Fig. 3I) with shallow median cleft; left longer than right, left terminal margin with row of small spines continued onto lateral margin bearing 4–6 large spines; right terminal margin also with row of small spines, but those not continued onto lateral margin; long setae at outer angles continued onto lateral margins.

Variation. The morphological variation related to the size is observed in the armature of pereopods. In the small specimens examined (sl less than 1.8 mm), the tubercles on the lateral faces of propodi, carpi and meri, and the ventrodistal spine on right third pereopod are absent, and the dorsal row of spines on the propodi of the second and third pereopods is barely visible (Fig. 6).

Colour. Unknown.

Habitat. Sandy mud substratum.

Etymology. Named after the type locality, Singapore.

Remarks. *Diogenes singaporenensis* new species, shares a number of characters with four species of the *D. edwardsii* group defined by Asakura & Tachikawa (2010): *D. avarus*, *D. foresti* Rahayu & Horte, 2002, *D. goniochirus* Forest, 1956, and *D. klaasi*. However, the new species mostly resembles *D. goniochirus*. Both *D. singaporenensis* and *D. goniochirus* have a distomedian spinulose protuberance on the outer surface of the carpus and distal spinulose protuberance on the upper margin of the palm of the left cheliped, albeit the latter protuberance in the new species is sometimes reduced into a low ridge. Differences of these two species are as follows: the outer face of the palm of the left cheliped has a median crest that reaches to the midlength in *D. singaporenensis* new species, while such a crest is absent in *D. goniochirus*; the fourth segment of the antennal peduncles is armed with a small dorsodistal spine in the *D. singaporenensis* new species, but it is unarmed in *D. goniochirus*. At least in the specimen with shield length larger than 1.8 mm, the new species also differs from *D. goniochirus* in the armature of the propodi and carpi of the second pereopod, particularly in the lateral surface bearing rows of small spines or tubercles. In *D. goniochirus* distinct spines are present only on the dorsal margin of the carpus and dorsal spines on the propodus are indistinct.

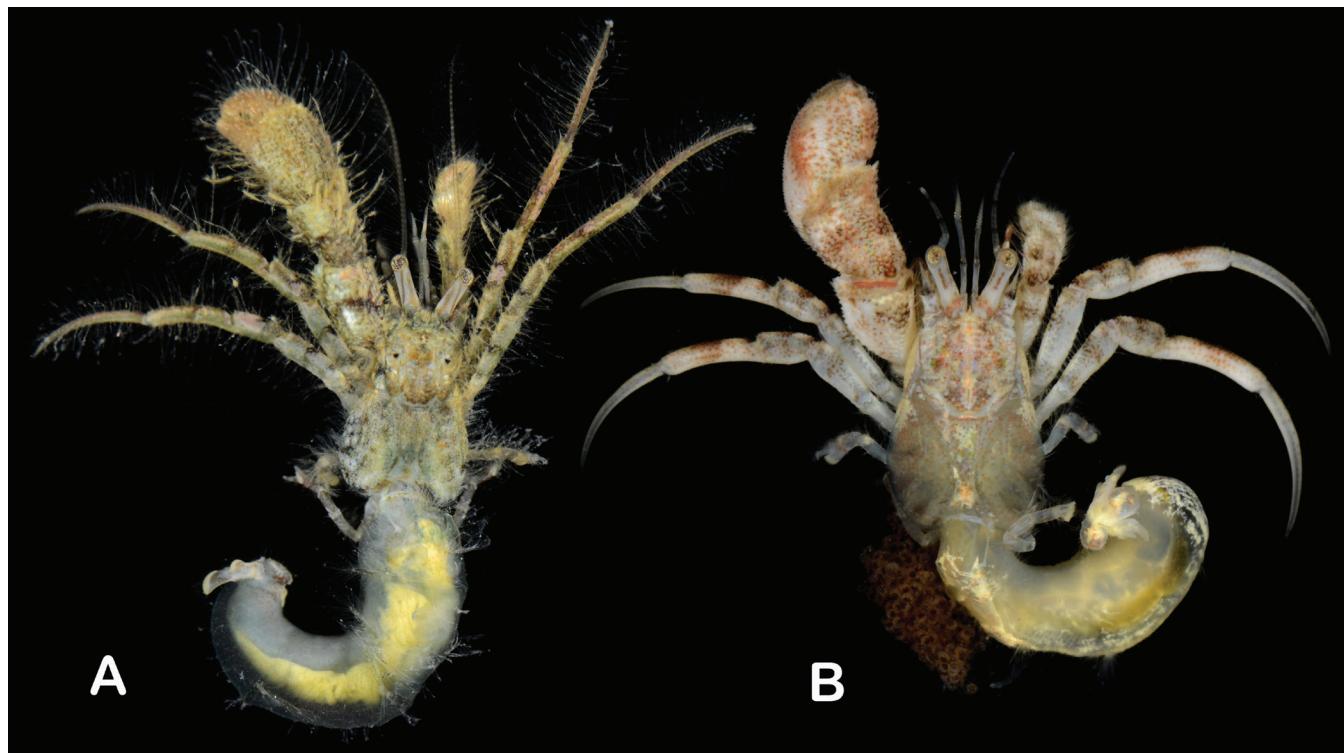


Fig. 7. A, *Diogenes klaasi*, stn SW 53, Seringat-Kias, 1°13.630'N 103°51.218'E; B, *Diogenes moosai*, 1 ovig. female, sl 2.7 mm. DW 40, Changi, 1°23.797'–1°23.768'N, 103°58.751'–103°58.908'E, 15.6–24 m, dredge, 19 October 2012.

The presence of a median crest that reaches the midlength of the palm of the left cheliped, and the rows of spines on the dorsal margins of the propodi and carpi of the second and third pereopods, are shared between *D. avarus* and *D. singaporenensis*, new species, but both species are clearly distinguishable. In *D. singaporenensis* new species, the outer surface of the carpus of the left cheliped has a median row of spines culminating in a distal spinose protuberance, whereas in *D. avarus* it is covered with small tubercles or spinules and lacks a median row of spines or a distal protuberance. The fourth segment of the antennal peduncle is armed with distal small spine on the dorsal surface in *D. singaporenensis* new species, but there is no spine in *D. avarus*.

Diogenes klaasi and *D. foresti* are allied to *D. singaporenensis* new species, in having a median crest that reaches the midlength of the palm of the left cheliped and a distal small spine on the dorsal surface of the fourth antennal segment. However, *D. klaasi* seems to be distinguished by having a row of strong spines on the ventrolateral margin of the merus of the left cheliped that extends to the ventral surface and mesial margin. In *D. singaporenensis* new species, the strong spines are only on the lateral and mesial margins, and there are no spines on the ventral surface. *Diogenes foresti* differs from the new species in the morphology of ocular peduncle and second and third pereopods. The corneas of *D. foresti* are dilated, unlike in *D. singaporenensis* new species, and their diameters are larger, about 0.3 instead of 0.4 length of the ocular peduncle. The second and third pereopods have longer and more slender dactyls in *D. foresti* than in the new species, and the propodi are entirely unarmed in *D. foresti*

but armed with a row of small spines at least on each dorsal margin in *D. singaporenensis* new species.

Distribution. Known only from Pulau Ubin and Changi, East Johor Strait, Singapore, intertidal.

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LITERATURE CITED

Asakura A (2006) Shallow water hermit crabs of the families Pylochelidae, Diogenidae, Paguridae (Crustacea: Decapoda: Anomura) from the Sea of Japan, with a description of a new species of *Diogenes*. Bulletin of the Toyama Science Museum, 29: 23–103.

Asakura A & Godwin S (2006) *Diogenes patae* n. sp. a new species of hermit crab (Crustacea, Decapoda, Anomura, Diogenidae) from American Samoa. *Zoosystema*, 28: 457–463.

Asakura A & Tachikawa H (2010) *Diogenes holthuisi*, a new species of hermit crab (Decapoda: Anomura: Diogenidae) from shallow water of the Ogasawara (Bonin) Islands, Japan. In: Fransen C, De Grave S & Ng PKL (eds.) *Studies on Malacostraca: Lipke Bijdeley Holthuis Memorial Volume*. Crustaceana Monographs, 14: 133–144.

Bouvier E-L (1897) Sur deux Paguriens nouveaux trouvés par M. Coutière dans le récif madréporiques à Djibouti. *Bulletin du Muséum d'Histoire Naturelle*, Paris 3: 228–233.

Dana JD (1851) *Conspectus Crustaceorum quae in orbis terrarium circumnavigatione, Carolo Wilkes e classe Reipublicae Foederatae duce, lexit et descripcit. Paguridea*. Proceeding of the Academy of Natural Sciences, Philadelphia, 5: 267–272.

Dechanché M (1964) Sur une collection des Crustacés Pagurids de Madagascar et des Comores. *Cahiers O.R.S.T.O.M. (Série Océanographie)*, 2: 27–45.

Fabricius JC (1798) *Supplementum Entomologiae systematicae. Hafniae*. 572 pp.

Forest J (1956) Les Pagures du Viet-Nam. I. Le genre *Diogenes* Dana. *Bulletin du Muséum national d'Histoire naturelle* (2) 28: 524–532.

Gordan J (1956) A bibliography of pagurids crabs, exclusive of Alcock, 1905. *Bulletin of the American Museum of Natural History*, 108: 253–352.

Heller C (1865) Crustaceen. In: *Reise der Österreichischen Fregatte Novara um die Erde in den Jahren 1857, 1858, 1859 unter den Befehlen des Commodors B. von Wüllerstorf-Urbair. Zoologischer Theil*. 2(3): 1–280, pls 1–25. Kaiserlich-königlichen Hof-und Staatsdruckerei, Wien.

Komai T, Liang J & Yang T (2012) Records of four species of the shallow water hermit crab genus *Diogenes* (Crustacea: Decapoda: Anomura: Diogenidae) from southern China, with description of a new species. *Journal of Natural History*, 46 (19–20): 1219–1248.

Komai T, Reshma R & Kumar AB (2013) A new species of the hermit crab genus *Diogenes* (Crustacea: Decapoda: Anomura: Diogenidae) from southern India. *Zootaxa*, 3613(4): 380–390.

Korn OM, Kornienko ES & Komai T (2008) A reexamination of adult and larval stage of *Diogenes nitidimanus* (Crustacea: Decapoda: Anomura: Diogenidae). *Zootaxa*, 1693: 1–26.

Lemaitre R & Ng PKL (1996) Rediscovery and redescription of the rare hermit crab, *Diogenes jubatus* (Nobili, 1903) (Crustacea: Decapoda: Anomura: Diogenidae), from Singapore. *The Raffles Bulletin of Zoology*, 44(2): 323–333.

McLaughlin PA (2002a) A review of the hermit crab (Decapoda: Anomura: Paguridea) fauna of southern Thailand, with particular emphasis on the Andaman Sea, and descriptions of three new species. In: Bruce N, Berggren M & Bussawarit S (eds.), *Proceedings of the international workshop on the Crustacea in the Andaman Sea*, Phuket Marine Biological Center 29 November–20 December, 1998. Phuket Marine Biological Center Special Publication, 23(2): 385–460.

McLaughlin PA (2002b) *Diogenes pallidescens* Whitelegge, *D. gardineri* Alcock, *D. serenei* Forest (Decapoda; Anomura; Diogenidae): morphological variant or distinct species? *The Raffles Bulletin of Zoology*, 50: 81–94.

McLaughlin PA (2004) A description of the first complete specimen of *Diogenes guttatus* Henderson, 1888 (Decapoda: Anomura: Paguroidea; Diogenidae). *Zootaxa*, 466: 1–8.

McLaughlin PA (2005) The “*Troglopagurus* group” of *Diogenes* (Decapoda: Anomura: Paguroidea: Diogenidae) revisited. *Journal of Crustacean Biology*, 25: 598–619.

McLaughlin PA & Clark P (1997) A review of the *Diogenes* (Crustacea, Paguroidea) hermit crabs collected by Bedford and Lanchester from Singapore, and from the ‘Skeat’ Expedition to the Malay Peninsula, with a description of a new species and notes on *Diogenes intermedius* De Man, 1892. *Bulletin of the Natural History Museum, London (Zoology)*, 63: 33–49.

McLaughlin PA & Dworschak PC (2001) Reappraisal of hermit crab species (Decapoda: Anomura: Paguridea) reported by Camill Heller in 1861, 1862 and 1865. *Annalen des Naturhistorischen Museums in Wien*, 103B: 135–176.

McLaughlin PA & Holthuis LB (2001) In pursuit of J. F. W. Herbst’s species of *Diogenes* (Anomura: Paguroidea: Diogenidae). *Journal of Crustacean Biology*, 21: 257–273.

McLaughlin PA, Komai T, Lemaitre R & Rahayu DL (2010) Annotated checklist of Anomuran Decapod Crustaceans of the world (Exclusive of the Kiwaoidea and families Chirostylidae and Galatheidae of the Galatheoidea) -Part I – Lithodoidea, Lomisoidea and Paguroidea. In: Low MEY & Tan SH (eds.) *Checklists of Anomuran Decapod Crustaceans of the world (Exclusive of the Kiwaoidea and families Chirostylidae and Galatheidae of the Galatheoidea) and Marine Lobsters of the World*. The Raffles Bulletin of Zoology, Supplement 23: 5–107.

Miers E (1884) Crustacea In: *Report on the Zoological Collections Made in the Indo-Pacific Ocean during the Voyage of H.M.S. “Alert” 1881–2*. British Museum, London. Pp. 178–322, 513–575.

Morgan GJ (1987) Hermit crabs (Decapoda, Anomura: Coenobitidae, Diogenidae, Paguridae) of Darwin and Port Essington, Northern Australia. *The Beagle, Record of the Northern Territory Museum of Art and Sciences*, 4(1): 165–186.

Morgan GJ (1989) Hermit crabs (Decapoda; Anomura; Diogenidae, Paguridae) of southwestern Australia, with description of two new species. *Record of the Western Australian Museum*, 14: 391–417.

Morgan GJ & Forest J (1991) Seven new species of hermit crabs from Northern and Western Australia (Decapoda, Anomura, Diogenidae). *Bulletin du Muséum national d'Histoire naturelle*, Paris, (4)(A)12: 649–689.

Naderloo R, Moradmand M, Sari A & Türkay M (2012) An annotated check list of hermit crabs (Crustacea: Decapoda: Anomura) of the Persian Gulf and the Gulf of Oman with five new records and an identification key to the North Indian Ocean genera. *Zoosystematics & Evolution*, 80(1): 63–70.

Naderloo R & Türkay M (2012) Decapod crustaceans of the littoral and shallow sublittoral Iranian coast of the Persian Gulf: Faunistics, biodiversity and zoogeography. *Zootaxa*, 3374: 1–67.

Nayak VN & Neelakantan B (1985) *Diogenes mclaughlinae* (Crustacea: Decapoda: Anomura) A new species of hermit crab from Karwar Area with a description of first zoeal stage. *The Indian Zoologist*, 9(1, 2): 15–21.

Nayak VN & Neelakantan B (1989) A new species of hermit crab *Diogenes karwarensis* (Decapoda: Anomura) from the west coast of India. *Journal of the Bombay Natural History Society*, 86: 71–76.

Nobili G (1903) *Crostacei di Singapore*. *Bollettino dei Musei di Zoologia ed Anatomia comparata della R. Università di Torino*, 18(455): 1–39.

Ortmann A (1892) Die Decapodes-Krebse des Strassburger Museum, mit besonderer Berücksichtigung der von Herrn Dr. Döderlein bei Japan und bei Liu-Kiu-Inseln gesammelten und zur Zeit im Strassburger Museum aufbewahrten Formen. IV. Die Abtheilungen Galatheidea und Paguridea. Zoologische Jahrbücher. (Abteilung für Systematik, Geographie und Biologie der Thiere), 6: 241–326.

Rahayu DL (1996) Notes on littoral hermit crabs (excluding Coenobitidae) (Crustacea: Decapoda: Anomura) mainly from Singapore and Peninsular Malaysia. The Raffles Bulletin of Zoology, 44(2): 335–355.

Rahayu DL (2012) A new species of the hermit crab genus *Diogenes* Dana, 1851 (Decapoda, Anomura, Diogenidae) from Lombok, Indonesia. In: Komatsu H, Okuno J & Fukuoka K (eds.) Studies on Eumalacostraca: A homage to Masatsune Takeda. Crustaceana Monographs, 17: 263–274.

Rahayu DL & Forest J (1995) Le genre *Diogenes* (Crustacea, Decapoda, Diogenidae) en Indonésie, avec la description de six espèces nouvelles. Bulletin Muséum National d'Histoire Naturelle, Paris, 16(2–4): 383–415.

Rahayu DL & Horte KG (2002) The genus *Diogenes* (Decapoda, Anomura, Diogenidae) from Irian Jaya, Indonesia with description of a new species. Crustaceana, 75(3–4): 609–619.

Rahayu DL & Komai T (2000) Shallow-water hermit crabs (Crustacea: Decapoda: Anomura: Diogenidae and Paguridae) of Phuket, Thailand. Phuket Marine Biological Center Research Bulletin, 63: 21–44.

Siddiqui FA & McLaughlin PA (2003) A new species of the hermit crab genus *Diogenes* (Decapoda: Anomura: Paguroidea: Diogenidae) from Pakistan, with a comparative diagnosis of *D. guttatus* Henderson, 1888. Proceeding of Biological Society of Washington, 116(4): 956–966.

Siddiqui FA, Kazmi OB & McLaughlin PA (2004) Review of the Pakistani species of *Diogenes* Dana, 1951 (Decapoda Anomura Paguroidea Diogenidae). Tropical Zoology, 17: 155–200.

Whitelegge T (1897) The fauna of Funafuti [6] The Crustacea. Australian Museum Memoirs, 3: 7–151.