

Arcotheres placunicola, a new species of pea crab (Crustacea: Brachyura: Pinnotheridae) from the window-pane shell, *Placuna ehippium* Philipsson, 1788 (Placunidae) in Singapore

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Abstract. A new species of pea crab *Arcotheres* Manning, 1993 (Pinnotheridae), is described from the window-pane shell, *Placuna ehippium* (Philipsson, 1788) (Placunidae) in Singapore. The species had previously been incorrectly identified as *Arcotheres similis* (Bürger, 1895) but with the redescription of the types by Ah Yong & Ng (2007), this is now known to be a very different taxon. *Arcotheres placunicola* n. sp. is superficially similar to *A. palaensis* (Bürger, 1895) and *A. guinotae* Campos, 2001, but can easily be distinguished by the structures of the third maxilliped, as well as proportions of the chelae and ambulatory legs. The only other species known to live exclusively in placunid shells, *A. placunae* (Hornell & Southwell, 1909) from India, is markedly different in the form of the carapace and ambulatory leg structures.

Key words. Pinnotheroidea, symbiosis, Placunidae, taxonomy, new species, Southeast Asia

INTRODUCTION

Three species of pinnotherid crabs are known to be associated with the Indo-West Pacific window-pane shells of the family Placunidae Rafinesque, 1815: *Arcotheres palaensis* (Bürger, 1895) (Bürger, 1895; Ah Yong & Ng, 2007), *A. placunae* (Hornell & Southwell, 1909) (Hornell & Southwell, 1909; Trivedi et al., 2018b), and *A. similis* (Bürger, 1895) (Gordon, 1936) (see also Schmitt et al., 1973). Of these, only *A. placunae* is known to be an obligate symbiont with *Placuna*. *Arcotheres palaensis* and *A. similis* have also been reported from a wide variety of bivalve hosts (Bürger, 1895; Gordon, 1936; Chuang, 1961; Schmitt et al., 1973; Ah Yong & Ng, 2007).

Gordon (1936) was the first to record *A. similis* from inside *Placuna placenta* (Linnaeus, 1758) (as “*Placenta placenta*”) from Singapore. In clarifying the identities of the extant material of Bürger (1895), Ah Yong & Ng (2007: 207–208) selected a lectotype of *A. similis* (Bürger, 1895), and commented that the material of Gordon (1936) identified as this taxon almost certainly belonged to an undescribed species instead. True *A. similis* has a different carapace shape and frontal margin, proportionately shorter ambulatory legs with a distinct structure of the dactylus and is almost certainly a synonym of *A. modiolicola* Bürger, 1895, as well as *A. spinidactylus* (Gordon, 1936), and are invariably

found in the mytilid mussel *Modiolus philippinarum* (Hanley, 1843) instead (Ah Yong & Ng, 2007; unpublished data). Its relationship with *A. palaensis* Bürger, 1895, the type species of the genus, is now being revised as a complex of species, all living in Arcidae and related taxa.

Over the last three years, the author has obtained a large series of specimens of *Arcotheres* from *Placuna* in Singapore. The window-pane shell in Singapore is not *Placuna placenta* but a similar species, *P. ehippium* (Philipsson, 1788), instead, and is now also regarded as the senior synonym of *Placuna sella* (Gmelin, 1791) (Huber, 2010).

In this paper, the *Arcotheres* from *Placuna ehippium* in Singapore is examined and confirmed to be an undescribed species. It has not been found in any other bivalves as yet. *Arcotheres placunicola* n. sp. is described, figured and compared to its closest congener, *A. placunae*, from India.

MATERIAL AND METHODS

The terminology used follows that by Manning (1993) and Davie et al. (2015). The following abbreviations are used: MXP3 = third maxilliped; P2–P5 = pereopods 2–5 (first to fourth ambulatory legs), respectively; G1 = male first gonopod; G2 = male second gonopod. The measurements provided (in millimetres) are of the maximum carapace width and length, respectively.

Specimens examined are deposited in the Zoological Reference Collection of the Lee Kong Chian Natural History Museum, National University of Singapore (ZRC); and Australian Museum, Sydney (AM).

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TAXONOMY

Family Pinnotheridae De Haan, 1833

Arcotheres Manning, 1993

Type species. *Pinnotheres palaensis* Bürger, 1895, subsequent designation by Manning, 1993.

Remarks. *Arcotheres* Manning, 1993, currently contains 27 species from the Indo-West Pacific, all of which are associated with bivalves (Ng et al., 2008, 2017; Trivedi et al., 2018a). The identities of many of these species, however, remain unclear, and the genus will need to be revised in the future (Ahyong & Ng, 2007; Ng et al., 2017).

Arcotheres placunicola n. sp.
(Figs. 1–6)

Pinnotheres similis – Tesch, 1918: 254 (list); Gordon, 1936: 172, fig. 3 (Singapore); Silas & Alagaraswami, 1967: 1210 (list) (not *Pinnotheres similis* Bürger, 1895).

Material examined. Holotype: ovigerous female (11.2 × 8.6 mm) (ZRC 2017.1009), off Changi beach, next to Carpark 7, near ferry terminal, 1.374223°N 104.006827°E, coll. S. K. Tan et al., 7 June 2016. Paratypes: 5 males (5.6 × 4.7 mm, 4.7 × 4.1 mm, 4.0 × 3.7 mm, 3.9 × 3.6 mm, 3.6 × 3.4 mm), 4 ovigerous females (10.4 × 8.3 mm, 8.7 × 7.5 mm, 7.5 × 6.1 mm, 7.0 × 5.5 mm), 1 female (8.8 × 6.9 mm), 3 females (with rhizocephalans) (8.6 × 6.3 mm, 8.6 × 7.1 mm, 9.0 × 6.9 mm), 2 juvenile females (3.6 × 2.9 mm, 6.2 × 5.1 mm) (ZRC 2017.1010), same data as holotype; 14 males (largest 5.1 × 4.4 mm, smallest 2.4 × 2.3 mm), 2 males (with rhizocephalans) (5.7 × 4.7 mm, 5.5 × 5.0 mm), 16 ovigerous females (largest 10.3 × 8.7 mm, smallest 7.7 × 6.3 mm), 1 ovigerous female (10.1 × 8.0 mm), 10 non-ovigerous females (largest 10.3 × 7.8 mm, smallest 5.4 × 4.5 mm), 2 females (with rhizocephalan) (6.3 × 4.9 mm, 7.8 × 5.8 mm), 1 juvenile female (3.8 × 3.7 mm) (ZRC 2017.1012), off Changi beach, next to Carpark 7, near ferry terminal, 1.374223°N 104.006827°E, coll. S. K. Tan et al., 8 June 2016; 1 male (4.2 × 3.8 mm), 2 ovigerous females (7.2 × 6.1 mm, 7.5 × 6.2 mm) (ZRC 2012.0432), off Changi beach, next to Carpark 7, near ferry terminal, 1.374223°N 104.006827°E, coll. P. K. L. Ng et al., 5 July 2012; 4 ovigerous females (largest 9.1 × 7.4 mm, smallest 6.5 × 5.4 mm), 3 non-ovigerous females (largest 8.9 × 6.9 mm, smallest 8.1 × 6.7 mm), 2 females (with rhizocephalan) (8.2 × 7.3 mm, 11.2 × 9.1 mm) (ZRC 2017.1013), off Changi beach, next to Carpark 7, near ferry terminal, 1.374223°N 104.006827°E, coll. P. K. L. Ng & P. Y. C. Ng, June 2016; 2 males (2.2 × 2.2 mm, 2.4 × 2.4 mm) (ZRC 2017.1014), Tanah Merah Ferry Terminal Beach, near Changi Point, coll. S. K. Tan et al., 17 November 2016; 1 male (with rhizocephalan) (5.6 × 5.1 mm), 3 ovigerous females (7.3 × 5.9 mm, 8.0 × 6.1 mm, 9.5 × 7.2 mm), 1 non-ovigerous female (with rhizocephalan) (9.0 × 7.4 mm) (ZRC 2017.1015), off Changi beach, next to Carpark 7, near ferry terminal, 1.374223°N 104.006827°E, coll. P. K. L. Ng & P. Y. C.

Ng, 31 March 2017; 1 male (with *Sacculina*) (4.8 × 4.5 mm) (ZRC 2017.1016), off Changi beach, adjacent to National Service Recreational Country Club, coll. H. H. Tan et al., 26 May 2017; 4 females, 1 juvenile female (ZRC 2017.1011), 1 male, 2 females (AM), off Changi beach, next to Carpark 7, near ferry terminal, 1.374223°N 104.006827°E, coll. S. K. Tan et al., 25 July 2017; 1 male (with rhizocephalan), 3 females (ZRC 2017.1261), intertidal area, off Changi beach, next to Carpark 7, near ferry terminal, 1.374223°N 104.006827°E, coll. S. K. Tan et al., 26 June 2017; 1 female (ZRC 2017.1265), Telok Paku, beach, in “*Placuna sella*”, coll. 8 April 1965. All specimens collected from inside *Placuna ehippium* (Philipsson, 1788) (Placunidae) in shallow intertidal areas in Singapore.

Comparative material. *Arcotheres placunae* (Hornell & Southwell, 1909): Neotype female (11.0 × 8.1 mm) (ZRC 2017.1293), muddy shore, in *Placuna placenta* (Linnaeus, 1758) (Bivalvia: Ostreoida: Placunidae), Balapur Bay, Beyt Dwarka, Gulf of Kachchh, Gujarat, India, 22°27'08"N 69°08'09"E, coll. J. Trivedi, 6 January 2015; 1 male (7.0 × 5.8 mm) (ZRC 2017.1065), same data as neotype; 1 ovigerous female (11.5 × 7.9 mm), 9 females (largest 13.0 × 9.7 mm, smallest 9.2 × 6.9 mm) (ZRC 2017.1008), Korangi Creek, Karachi, 24.784°N 67.103°E, Pakistan, in *Placuna* sp., coll. 4 November 1998–25 October 1999. *Arcotheres tivelae* (Gordon, 1936): 1 ovigerous female (ZRC 2006.0051), Persian Gulf, Homozgan Province, Iram coll. H. H. Sahafi, 25 March 2004; 1 male (5.7 × 5.1 mm), 6 females (largest 9.1 × 8.0 mm), 1 ovigerous female (11.2 × 9.8 mm) (ZRC 2009.0831), from *Amiantis umbonella*, Bandar Abbas, Iran, Persian Gulf, coll. H. Saeedi, January 2009; 2 males, 2 females (ZRC 2011.155), Oman Sea, Iran, coll. E. Kamrani, 2011; 1 female (ZRC 2016.0162), Qeshm Island, Iran, coll. M. Safaie, May 2010.

Diagnosis. Female: Carapace subcircular, distinctly wider than long; dorsal and lateral surfaces smooth, glabrous; front usually projecting anteriorly beyond orbits, entire, margin slightly convex; anterior quarter of anterolateral margin gently sloping posteriorly, forming angle with rest of convex margin, (Figs. 1A, 2A). Eyes small, not visible in dorsal view; mobile, completely filling orbit (Figs. 1A–C, 2A). MXP3 outer surface with scattered short setae; ischiomerus completely fused, subrhomboidal, length about 2.5 times maximum width, inner margin angular at widest point; carpus short; propodus about 3 times as long as high, cylindrical, distinctly longer than carpus; dactylus subspatuliform, inserted at median point of propodus, tip not reaching propodal apex; exopod relatively slender, about one-third length of ischiomerus, flagellum 2-segmented (Fig. 3K, L). Chela slender, dactylus about half palm length; palm slender, proximal part narrower than distal part; outer surfaces of palm, fingers (except for distal part) almost smooth, with only scattered short setae; dactylus occlusal margin with large subproximal tooth; pollex occlusal margin with 1 low proximal tooth, 1 submedian tooth (Figs. 1D, 3J). Ambulatory legs dorsally, ventrally unarmed; outer surface covered with scattered very short setae or glabrous; ventral margins of propodus and dactylus more setose; relative lengths of meri P4>P3>P5>P2; left

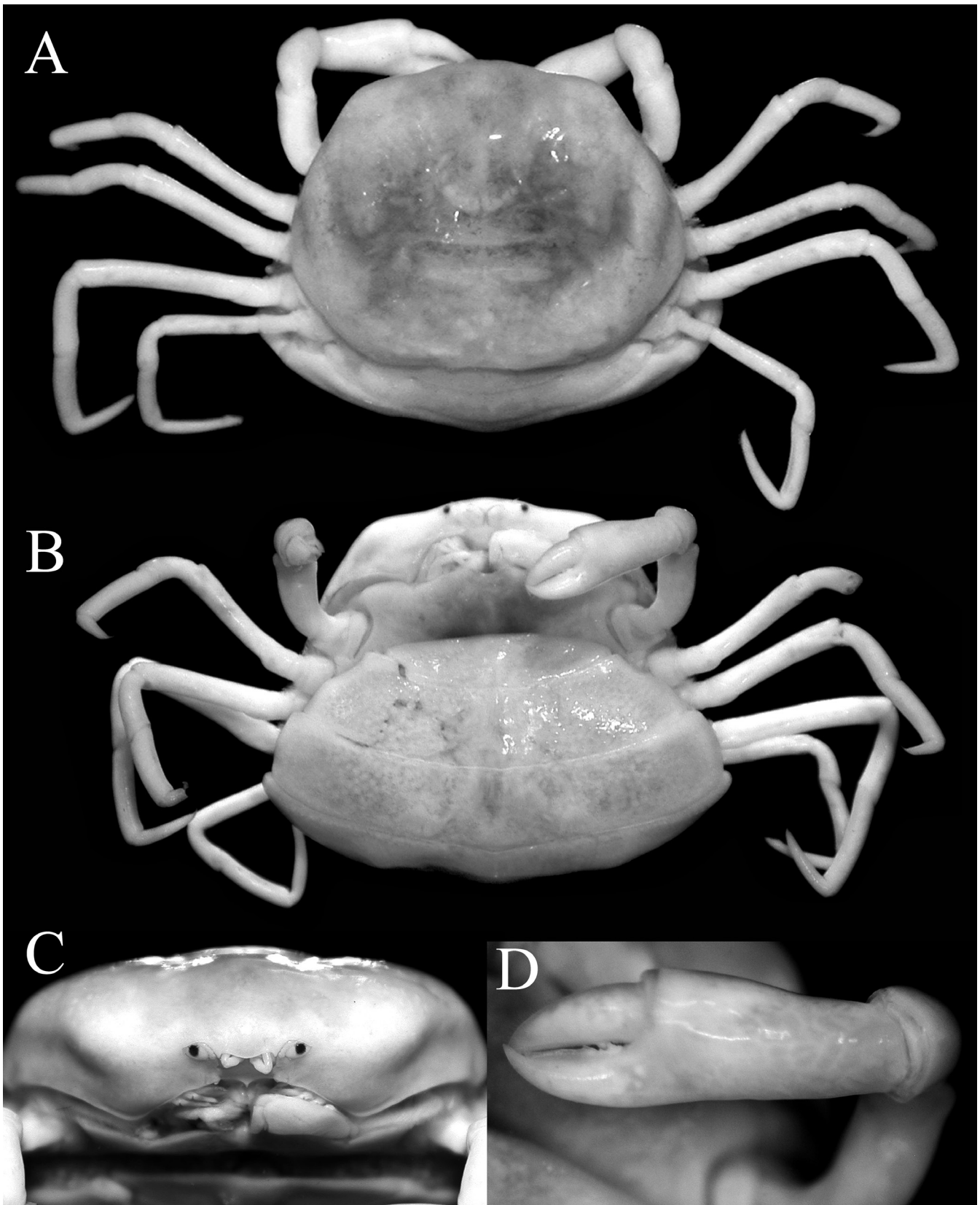


Fig. 1. *Arcotheres placunicola* n. sp., holotype ovigerous female (11.2 × 8.6 mm) (ZRC 2017.1009), Changi, Singapore. A, overall habitus; B, ventral view of cephalothorax; C, frontal view of cephalothorax; D, outer view of left chela.

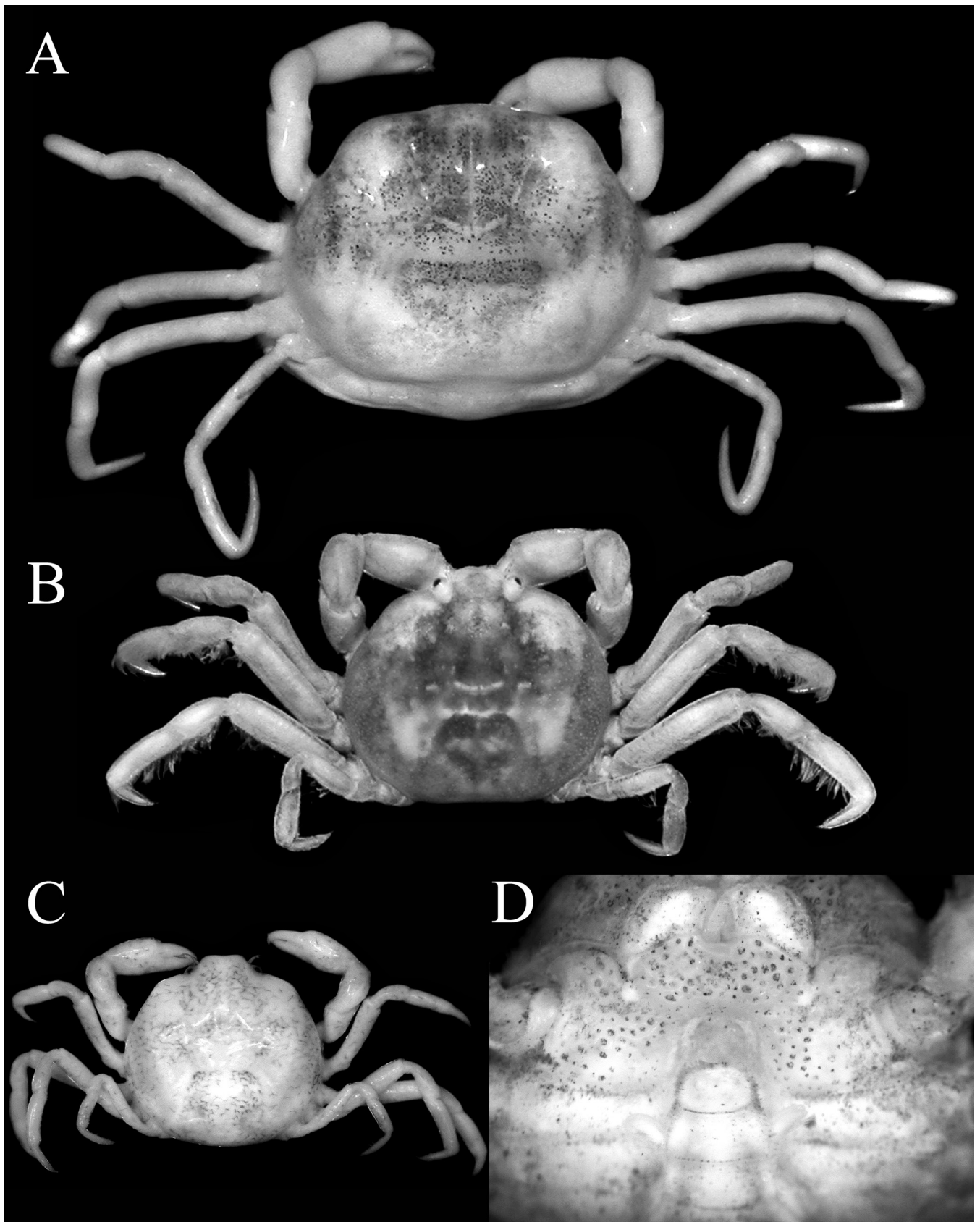


Fig. 2. *Arcotheres placunicola* n. sp. A, paratype ovigerous female (10.4 × 8.3 mm) (ZRC 2017.1010); B, paratype male (5.6 × 4.7 mm) (ZRC 2017.1010); C, paratype young male (2.4 × 2.4 mm) (ZRC 2017.1014); D, paratype male (4.7 × 4.1 mm) (ZRC 2017.1010). A–C, overall habitus; D, male anterior thoracic sternum. All specimens from Changi, Singapore.

(sometimes right) P4 distinctly longer than right side; P2 and P3 dactyli short, subequal; P4 dactylus elongate, falciform; P5 dactylus longest, distal half covered with short setae, inner margin of distal part with 2 rows of up to 11 spinules each (Fig. 3A–D', E–H''). Pleon extending to buccal region, covering bases of walking legs; telson recessed into distal margin of somite 6 (Fig. 1B). Male: Carapace almost circular, slightly wider than long; dorsal surface covered with scattered short setae or smooth; front distinctly projecting anteriorly, margin gently sinuous (Fig. 2B, C). Eyes distinctly visible in dorsal view (Fig. 2B, C). MXP3 as in female but ischiomerus proportionately shorter (Fig. 4D). Anterior thoracic sternum wide, sternites 1, 2 fused, partially sunken into buccal cavity; suture between sternites 2 and 3 shallow; sternites 3, 4 completely fused, separated only by shallow grooves; sterno-pleonal cavity reaching to junction between sternites 3 and 4 (Fig. 2D). Chela relatively stouter, shorter than in female, tip of fingers longer (Fig. 4A). Ambulatory legs dorsally, ventrally unarmed; outer surface covered with short setae; carpus and propodus with long natatory setae; left and right meri equal, relative lengths of meri $P4 > P3 > P2 > P5$; dactyli of P2–P4 progressively longer; left (sometimes right) P4 dactylus slightly longer, more slender than right side; P4 and 5 dactyli subequal to that of P3, completely covered with short setae (Fig. 4E–L'). Pleon slender, triangular, widest at somite 3, lateral margins of somite 4 distinctly concave, tapering distally to telson; telson semicircular with convex lateral margins, as long as wide (Fig. 4B, C). G1 long, tip gently curved upwards; margins lined with long setae (Fig. 4M, N, Q). G2 short, with flattened tip; exopod present as curved structure (Fig. 4O, P).

Colour. The colour is very variable. Females can be pale yellow to orange (Figs. 5D, 6C, D, G, H) or dirty white with brown patterns (Figs. 5A, B, E, 6A, B, F); while males are a more uniform brown to greenish-brown (Fig. 5A, C, F).

Variation. The good series of females and males of *A. placunicola* allows a good understanding of variation in the species. Female specimens are remarkably consistent in the diagnostic characters described here. The female front is usually distinct, being produced anteriorly (e.g., Figs. 1A, 6A, C), although in a few specimens, it is less distinct, being almost level with the anterolateral margins (Figs. 2A, 6G). The series of males is especially important as they are rarely collected for the genus. Smaller males of *A. placunicola* (carapace width ca. 3 mm and less, e.g., ZRC 2017.1014) have a carapace which appears more quadrate, with the anterolateral margin more angular and the front more produced (Fig. 2C), and the pleonal somite 6 and telson are also relatively wider and almost subrectangular in shape (Fig. 4C). In males exceeding 4.5 mm in carapace width (e.g., ZRC 2017.1010), the carapace is overall more rounded with the front less pronounced (Fig. 2B) and the male pleonal somite 6 and telson are more elongate with the telson semicircular (Fig. 4B versus Fig. 4C). The natatory setae on the ambulatory legs are also less pronounced in the smaller males. The G1 structures, however, remain almost identical, although the upcurved tip in smaller males is

proportionately shorter (Fig. 4Q versus Fig. 4M). While female ambulatory leg asymmetry is pronounced in species of *Arcotheres*, the condition for males is not well known. The left and right male P2–P5 of *A. placunicola* are almost symmetrical except for the P4 dactylus, which on one side, is slightly longer and more slender than the other (Fig. 4G, K).

Remarks. *Arcotheres placunicola* n. sp. is morphologically quite different from *A. placunae* (Hornell & Southwell, 1909) from India and Pakistan (Hornell & Southwell, 1909; Trivedi et al., 2018b), even though both species are living in the same host genus. *Arcotheres placunae* is not well known and there have been suggestions that the original description and figures are not accurate and that it may be conspecific with *A. tivelae* (Gordon, 1936) (see Naderloo & Türkay, 2012; Naderloo et al., 2015). There is no doubt, however, that they are separate taxa (see Naderloo, 2017). The original types of *A. placunae* are lost but Trivedi et al. (2018b) redescribed and figured the species at length from topotypic material, selected a neotype and its taxonomy is now clear. Most obvious is the fact that the adult female carapace of *A. placunae* is dorso-ventrally flattened such that the dorsal surface is only gently convex, with the frontal margin and anterior part of the anterolateral margin on the same plane (Fig. 7A–C). *Arcotheres placunicola*, on the other hand, has the dorsal carapace surface prominently convex, the front is protruding more anteriorly with the anterior part of the anterolateral margin gently sloping posteriorly (Figs. 1A, 2A). In addition, the male and female chelae of *A. placunicola* are more slender, with the proximal part narrower than the distal part (Figs. 1D, 3J, 4A) (versus chelae stouter with the proximal and distal parts subequal in height in *A. placunae*; Trivedi et al., 2018b: fig. 8J); the female ambulatory meri are distinctly longer (Figs. 1A, 2A, 3A–H) (versus ambulatory meri proportionately shorter in *A. placunae*; Figs. 7A–C, 8A–H; Trivedi et al., 2018b: fig. 4); the inner margin of the distal part of the P5 dactylus has a shorter rows, each with only a maximum of 11 spinules (versus the same margin has a longer row with up to 20 spinules in *A. placunae*; Fig. 8D', H', H''); Trivedi et al., 2018b: fig. 4H', L'); the male pleon is less triangular in shape with the lateral margin of somite 4 more concave (Fig. 4B, C) (versus pleon clearly triangular in *A. placunae*; Trivedi et al., 2018b: fig. 3B); and the tip of the G1 is upcurved (Fig. 4M, N, Q) (versus tip laterally directed in *A. placunae*; Trivedi et al., 2018b: fig. 3D).

In Southeast Asia, *Arcotheres placunicola* is also superficially similar to *A. palaensis* (Bürger, 1895) in the general carapace shape, but can easily be separated by its proportionately longer female P2–P5 meri (Fig. 3A–H) (versus proportionately shorter meri in *A. palaensis*, cf. Ah Yong & Ng, 2007: fig. 9A); the female chela is short and stout (Figs. 1D, 3J) (versus elongate and more slender in *A. palaensis*, cf. Ah Yong & Ng, 2007: fig. 9B); and the MXP3 dactylus is relatively shorter (Fig. 3K, L) (versus relatively longer in *A. palaensis*, cf. Ah Yong & Ng, 2007: fig. 9C). Significantly, the P5 dactylus of *A. placunicola* has a distinct row of subterminal spinules on the ventral margin (Fig. 3H', H''), which is absent in

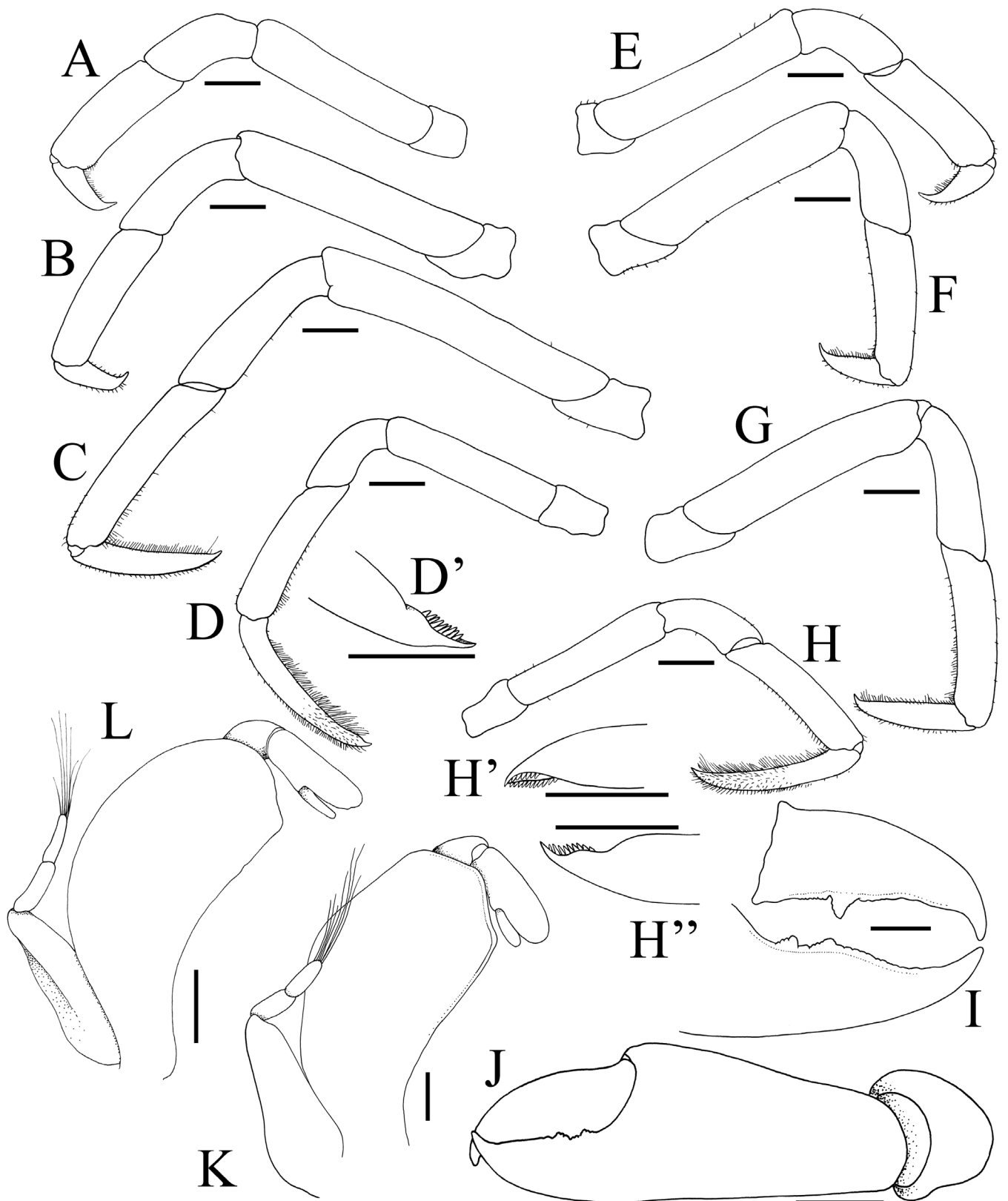


Fig. 3. *Arcotheres placunicola* n. sp. A, L, paratype ovigerous female (10.1 × 8.0 mm) (ZRC 2017.1012), Changi, Singapore; B–K, holotype ovigerous female (11.2 × 8.6 mm) (ZRC 2017.1009), Changi, Singapore. A–D, left P2–P5, respectively; E–H, right P2–P5, respectively; D', distal part of dactylus of left P5 showing stiff subdistal spinules (dorsal view, soft setae not drawn); H', distal part of dactylus of right P5 showing stiff subdistal spinules (ventral view, soft setae not drawn); H'', distal part of dactylus of left P5 showing stiff subdistal spinules (dorsal view, soft setae not drawn); I, fingers of right chela (setae denuded); J, left chela and carpus; K, L, outer view of right MXP3. Scales: A–H, J = 1.0 mm; D', H', H'', I, K, L = 0.5 mm.

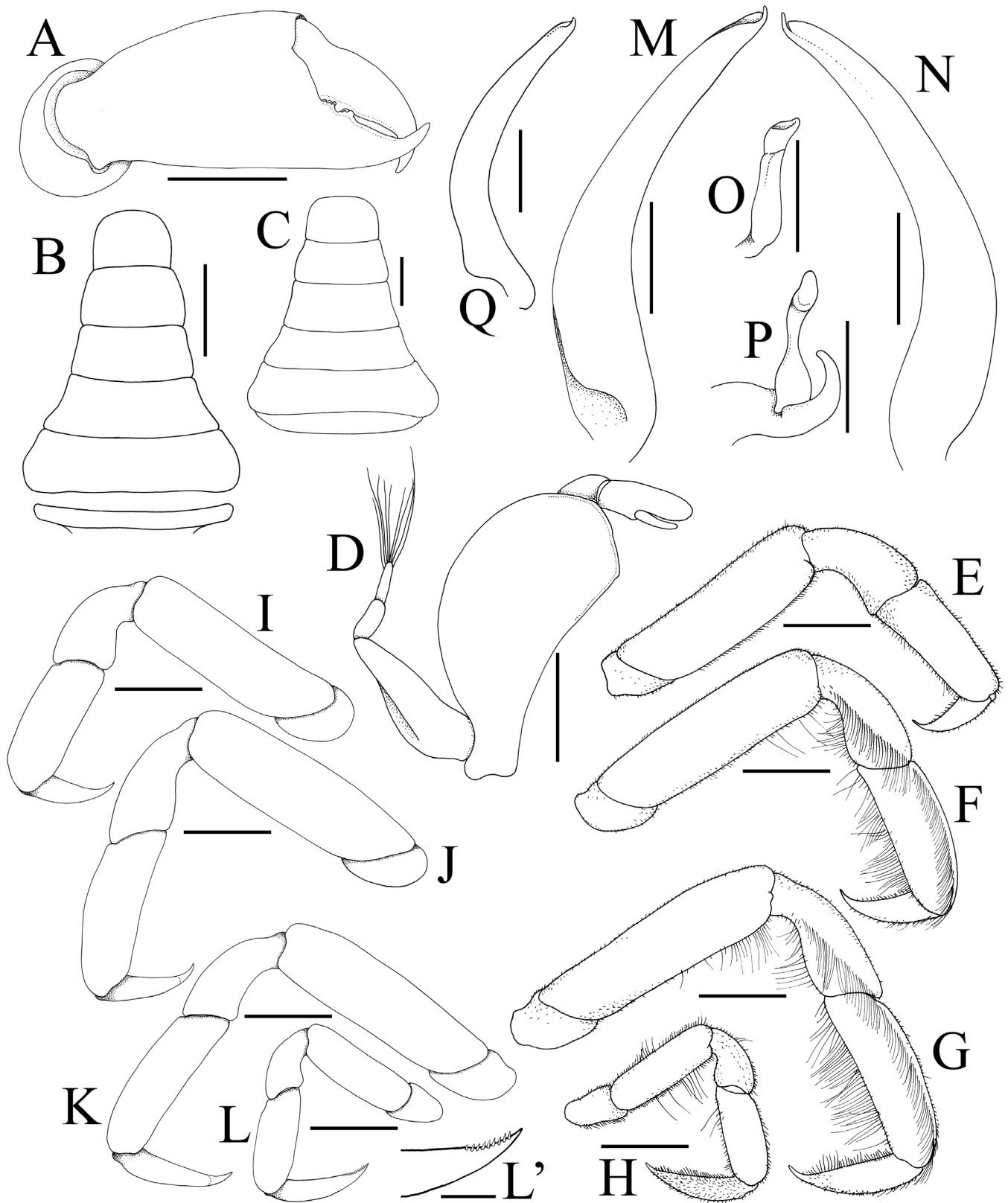


Fig. 4. *Arcotheres placunicola* n. sp. A, B, D–P, paratype male (5.6 × 4.7 mm) (ZRC 2017.1010); C, Q, paratype young male (2.4 × 2.4 mm) (ZRC 2017.1014). Both specimens from Changi, Singapore. A, right chela and carpus (setae not drawn); B, C, male pleon; D, right MXP3 (setae not drawn); E–H, right P2–P5, respectively; I–L, left P2–P5, respectively (setae not drawn); L', distal part of P5 dactylus (dorsal view, soft setae not drawn); M, left G1 (ventral view, setae not drawn); N, left G1 (dorsal view, setae not drawn); O, left G2 (setae not drawn); P, right G2 (mesial view showing exopod, setae not drawn). Scales: A, B, E–L = 1.0 mm; M–P = 0.5 mm; C, L', Q = 0.25 mm.

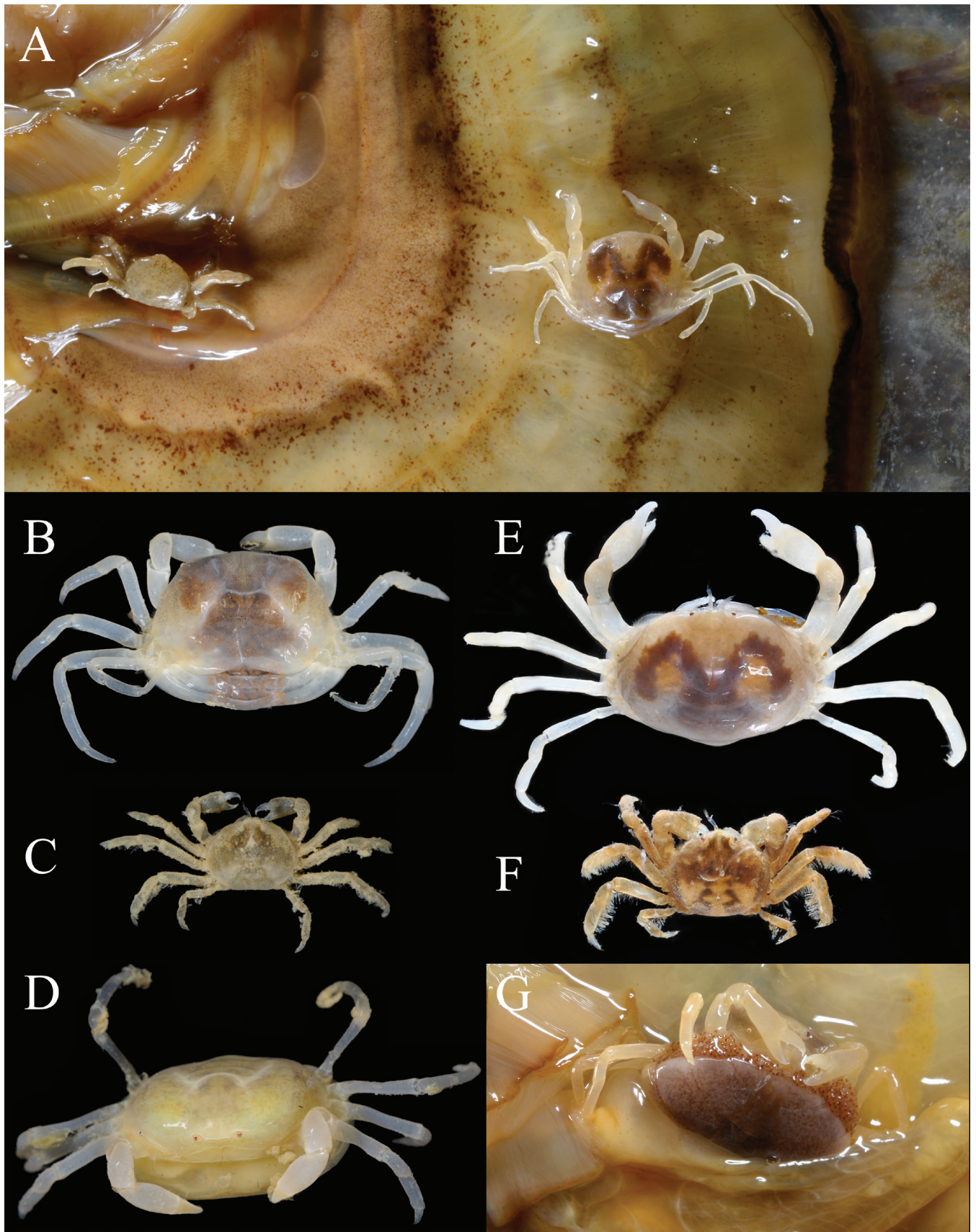


Fig. 5. *Arcotheres placunicola* n. sp. Colour in life. A–D, G, paratype specimens from ZRC 2017.1010, Changi, Singapore; E, paratype female (8.8 × 6.9 mm) (ZRC 2017.1010), Changi, Singapore; F, paratype male (4.7 × 4.1 mm) (ZRC 2017.1010), Changi, Singapore. A, G, in situ on *Placuna ephippium* Philipsson, 1788 (Placunidae).

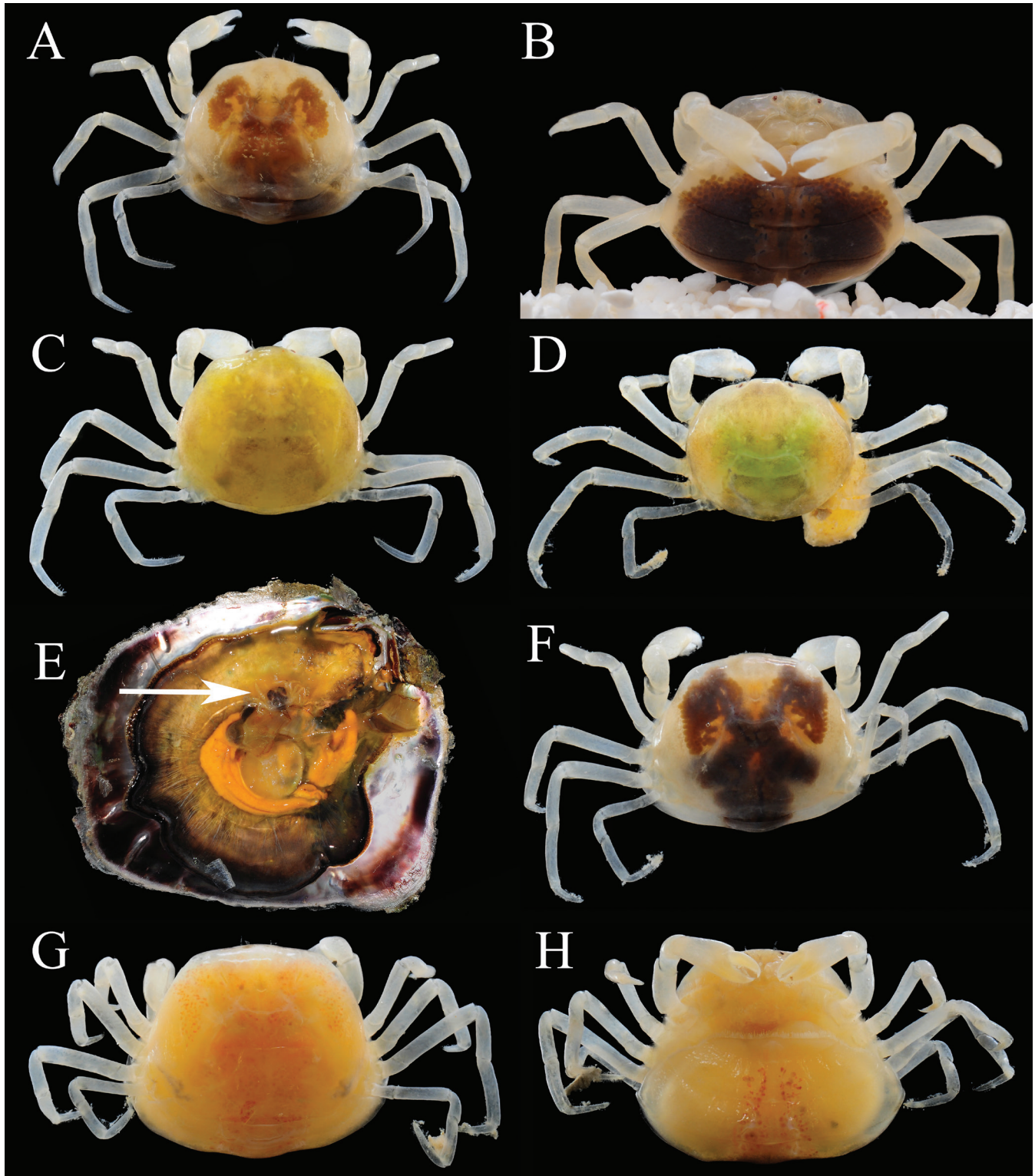


Fig. 6. *Arcotheres placunicola* n. sp. Colour in life. A, B, paratype ovigerous female (8.0×6.1 mm); C, paratype non-ovigerous female with rhizocephalan (9.0×7.4 mm); D, paratype male with rhizocephalan (5.6×5.1 mm); E, F, paratype ovigerous female (7.3×5.9 mm) (crab indicated by arrow); G, H = paratype ovigerous female (9.5×7.2 mm). E, in situ on *Placuna ehippium* Philipsson, 1788 (Placunidae). All material from ZRC 2017.1015, Changi, Singapore.

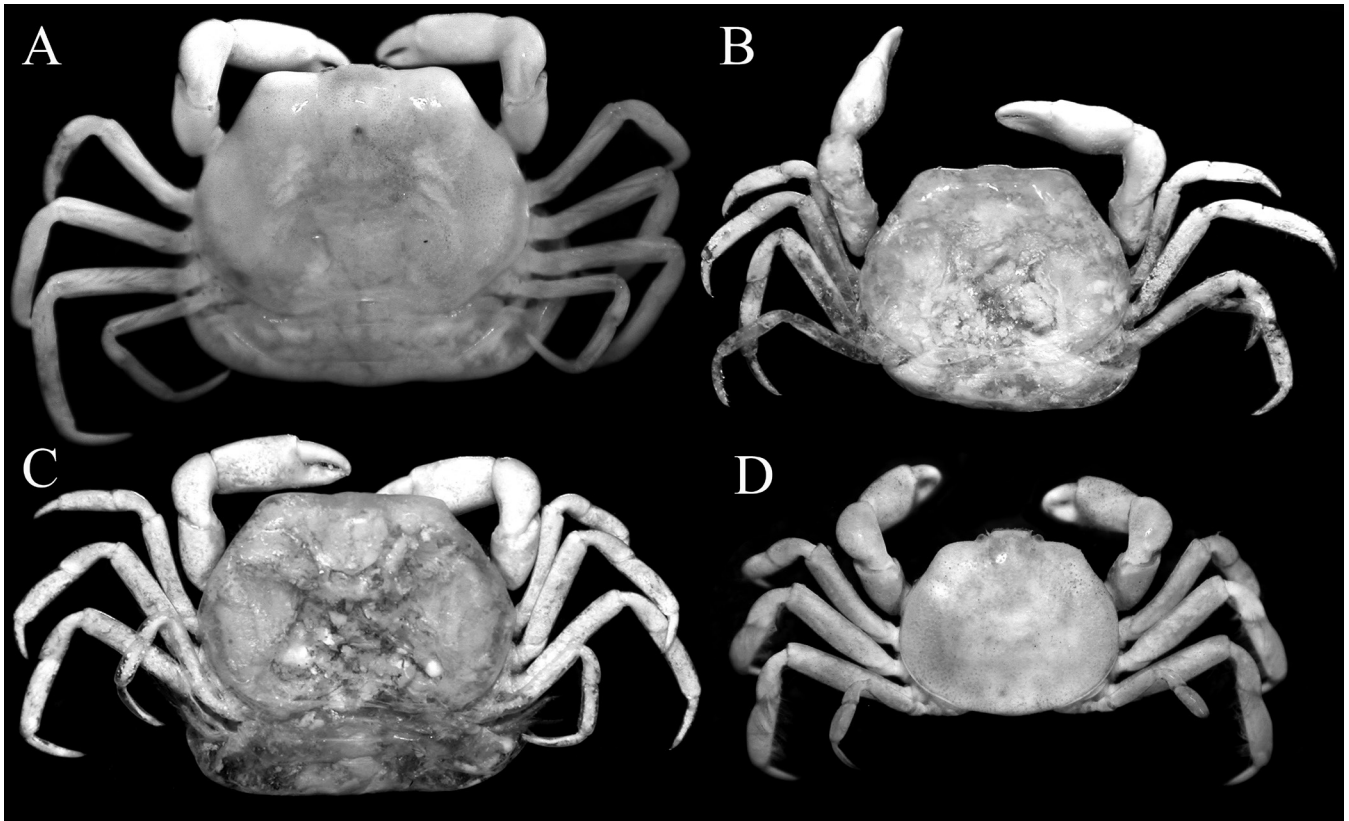


Fig. 7. *Arcotheres placunae* (Hornell & Southwell, 1909), overall habitus. A, neotype ovigerous female (11.0 × 8.1 mm) (ZRC 2017.1293), India; B, ovigerous female (9.2 × 6.9 mm) (ZRC 2017.1008), Pakistan; C, ovigerous female (11.5 × 7.9 mm) (ZRC 2017.1008), Pakistan; D, male (7.0 × 5.8 mm), (ZRC 2017.1065), India.

A. palaensis (cf. Ah Yong & Ng, 2007: fig. 9A). The same differences apply to *A. guinotae* Campos, 2001, a species closely related to and possibly synonymous with *A. palaensis*.

Bürger (1895: 373) also recorded *A. palaensis* from “*Placuna sella*” in Ubay in the Philippines but this record is doubtful. Ah Yong & Ng (2007: 201) re-examined the types and selected a female specimen from Palau as the lectotype of *A. palaensis*, commenting that the specimens from Ubay belonged to *A. guinotae* instead. *Arcotheres palaensis* and *A. guinotae* are very similar and are probably synonyms (unpublished data). The author has a good collection of both species from Singapore and Peninsular Malaysia from the arcid genera *Anadara* and *Barbatia*; and none have been found in *Placuna*. The condition of the Bürger (1895) type material in any case is generally poor and some of the associated data may not be reliable (see Ah Yong & Ng, 2007: 192). As has been discussed above, however, *A. placunicola* differs markedly from the lectotype of *A. palaensis* so the identities of these two species is not in question.

Prior to the study of the type material by Ah Yong & Ng (2007), the identity of *A. similis* was been unclear, and records of this species from *Crassostrea* sp. or *Saccostrea* sp. (Ostreidae) (cf. Rathbun, 1924), and *Staveila subdistorta* Récluz, 1852 (Mytilidae) and *Pinna* sp. (Pinnidae) (cf. Ah Yong & Brown, 2003) will all need to be re-examined to ascertain their actual identity (see also Ward, 1967; Davie, 2002).

ACKNOWLEDGEMENTS

The author is most grateful to Tan Siong Kiat, curator of molluscs at the Lee Kong Chian Natural History Museum, for helping him obtain so many specimens as well as advice on the taxonomy of *Placuna*. Thanks are also due to the many other curators in the museum for their help in field work, as well as to Tan Heok Hui (ZRC) for most of the colour photographs of the freshly collected specimens. The author also thanks Quddusi Kazmi (Karachi) and Jignesh Trivedi (Gujarat) for kindly sending comparative material of *Arcotheres placunae*. The constructive comments by Tohru Naruse, Shane Ah Yong, and an anonymous referee are gratefully acknowledged.

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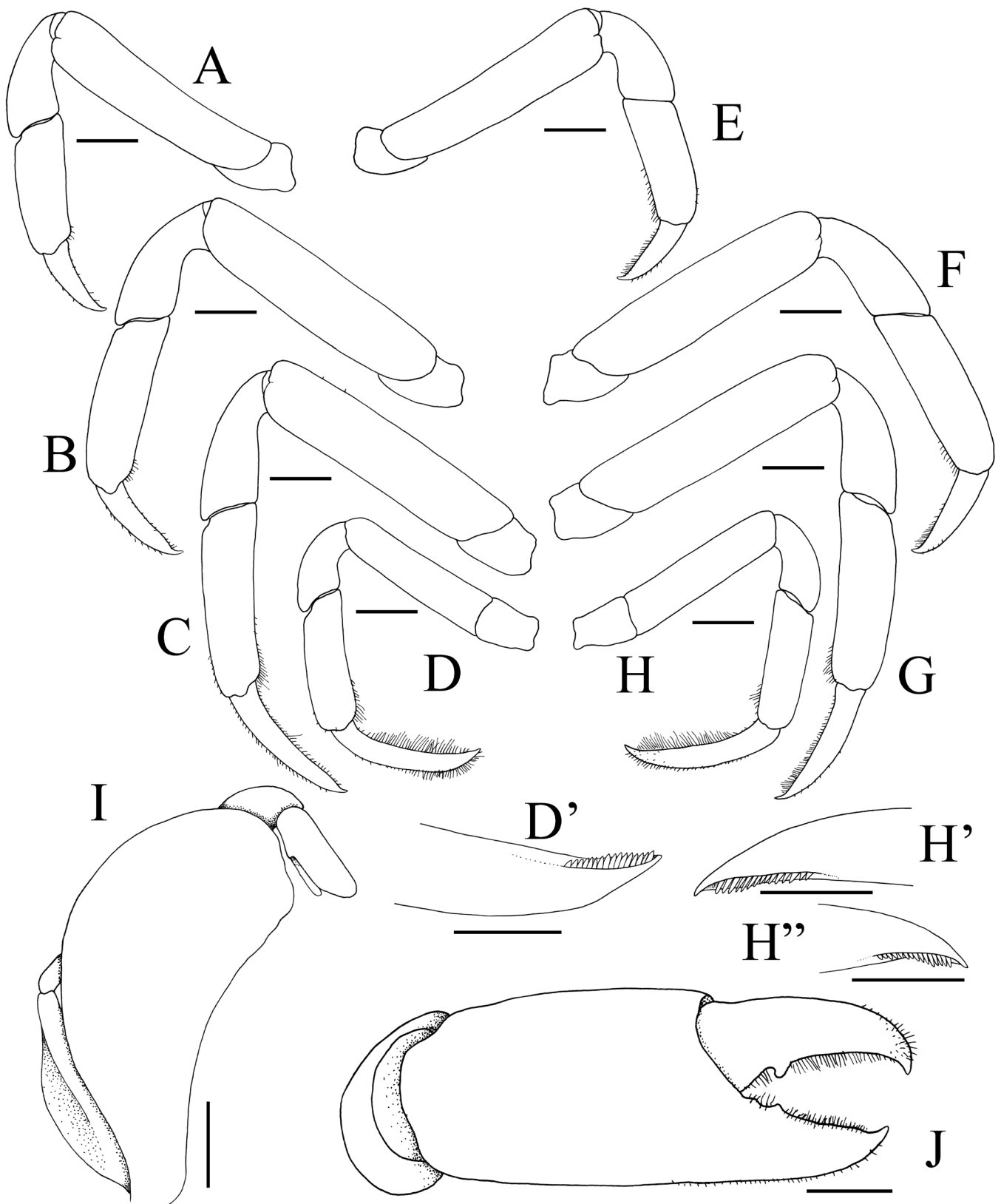


Fig. 8. *Arcotheres placunae* (Hornell & Southwell, 1909), ovigerous female (11.5 × 7.9 mm) (ZRC 2017.1008), Pakistan. A–D, left P2–P5, respectively; E–H, right P2–P5, respectively; D', distal part of dactylus of left P5 showing stiff subdistal spinules (dorsal view, setae not drawn); H', distal part of dactylus of left P5 showing stiff subdistal spinules (ventral view, setae not drawn); H'' = distal part of dactylus of right P5 showing stiff subdistal spinules (dorsal view, setae not drawn); I, outer view of right MXP3; J, right chela and carpus. Scales: A–H, J = 1.0 mm; D', H', H'', I = 0.5 mm.

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