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Jianmei An [a], Jason D. Williams [b] & Haiyan Yu [c]

[a] School of Life Science, Shanxi Normal University, Linfen, 041004, China

[b] Department of Biology, Hofstra University, Hempstead, NY, 11549, USA

[c] Institute of Oceanology, Chinese Academy of Sciences, Qingdao, 266071, China

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Three abdominal parasitic isopods (Isopoda: Epicaridea: Bopyridae: Athelginae) on hermit crabs from China and Hong Kong

Jianmei An[a]*, Jason D. Williams[b] and Haiyan Yu[c]

[a]*School of Life Science, Shanxi Normal University, Linfen, 041004, China;* [b]*Department of Biology, Hofstra University, Hempstead, NY 11549, USA;* [c]*Institute of Oceanology, Chinese Academy of Sciences, Qingdao 266071, China*

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Three bopyrid isopods of the subfamily Athelginae parasitizing hermit crabs collected in Chinese waters are discussed and described in this paper. *Athelges takanoshimensis* Ishii, 1914 is recorded again from China on *Pagurus pectinatus* (Stimpson) and from Hong Kong on a new host, *Pagurus minutus* Hess. *Parathelges enoshimensis* Shiino, 1950 is recorded for the first time from China on a member of the genus *Spiropagurus*. *Pseudostegias setoensis* Shiino, 1933 is recorded again from Hong Kong but from a new host, *Clibanarius virescens* Hess, and for the first time from Hainan Province on a new host *Calcinus laevimanus* (Randall). A combination of light and scanning electron microscopy is used to investigate the morphology of these species and data on their prevalence with hermit crab hosts are provided.

Keywords: hermit crab; isopod; parasite

Introduction

Members of the bopyrid isopod subfamily Athelginae are ectoparasites found on the abdomen of hosts, nearly all being hermit crabs (one species is known from another anomuran host, a lithodid crab). There are eight athelgine genera with a total of 41 currently recognized described species (Boyko and Williams 2009; Markham 2010; McDermott et al. 2010). Examination of five species of hermit crabs collected in Chinese waters led to the finding of three athelgine species that are discussed and described herein. This paper represents one in a recent series on the bopyrid fauna of China and surrounding waters (e.g. An 2009; Williams and An 2009; An et al. 2009, 2010); a region that remains understudied in terms of these obligate parasites of crustacean hosts.

Materials and methods

Materials for this study came from the China/Vietnam Comprehensive Oceanographic Survey of Beibu Gulf, Gulf of Tonkin, (1959–1960, 1962), Chinese Academy of Sciences Nansha Islands Multi-disciplinary Investigation (1985, 1987–2000), and specimens collected by the second author (J.D.W.) in Hong Kong (2001–2004). Collections from Taihou Bay, China, made in June 2010 (57 specimens of *Diogenes paracristimanus*

*Corresponding author. Email: anjianmei@hotmail.com

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Wang and Dong) yielded no parasites. All materials examined have been deposited in the Institute of Oceanology, Chinese Academy of Sciences, Qingdao, China (IOCAS) and the National Museum of Natural History, Smithsonian Institution, Washington D.C., USA (USNM).

Animals preserved in 70% ethyl alcohol were viewed and drawn using a Zeiss Stemi SV Apo or an Olympus CX31 microscope. For scanning electron microscopy, specimens were prepared as described elsewhere (Williams and Madad 2010) and viewed with a Hitachi S-2460N scanning electron microscope. ADOBE PHOTOSHOP and ADOBE ILLUSTRATOR were used to create plates based respectively on digital images and drawing tube sketches of specimens.

Specimen number "CIEA" is an acronym of C(Crustacean); I(Isopoda); E(Epicaridea); A(Anomura).

Systematic account

Family **BOPYRIDAE** Rafinesque-Schmaltz, 1815
Subfamily **ATHELGINAE** Codreanu and Codreanu, 1956
Genus ***Athelges*** Gerstaeker, 1862
Type species ***Athelges fullodes*** Gerstaeker, 1862 by original designation

Athelges takanoshimensis Ishii, 1914
(Figure 1)

Abbreviated synonymy (see Markham 2009, for complete synonymy before 2009).
Athelges takanoshimensis Ishii, 1914: 519–530, pl. 7 (type locality Takanoshima, Tokyo Bay, Japan; infesting *Eupagurus geminatus* McLaughlin). Markham 2009: 229–233, fig.5.

Material examined

Infesting *Pagurus pectinatus* (Stimpson). Bohai Sea, Stn 1098, 38°40′ N, 121°15′ E, 51.5 m, 17 July 1959, Chen coll., 1 ♀, CIEA109801, 1 ♂, CIEA109802. Yellow Sea, Stn 2023, 38°40′ N, 121°55′ E, 49 m, 13 July 1959, Jiang coll., 1 ♀, CIEA202301, 1 ♂, CIEA202302. Yellow Sea, Stn 2006, 38°45′ N, 121°45′ E, 51 m, 21 October 1959, Huang coll., 1 ♀, CIEA200601, 1 ♂, CIEA200602. Bohai Sea, Stn 1035, 39°00′ N, 120° 50′ E, 52.5 m, 17 July 1959, Jiang coll., 1 ♀, CIEA103501, 1 ♂, CIEA103502. Yellow Sea, Stn 2023, 38°40′ N, 121°55′ E, 50 m, 21 October 1959, Jiang coll., 1 ♀, CIEA202303, 1 ♂, CIEA202304. Yellow Sea, Stn 2023, 38°40′ N, 121°55′ E, 50 m, 21 October 1959, Jiang coll., 1 ♀, CIEA202305.

Infesting *Pagurus minutus* Hess. Hong Kong, Discovery Bay, Lantau Island, 22°18′0.74″ N, 114°1′0.84″E, 9 June 2001, J. Williams coll., 10 ♀, 10 ♂, USNM1155301.

Remarks

This species has been reported several times from Hong Kong (Markham 1982, 1990; 1992), Zhejiang (Wei 1991), Taiwan (Boyko 2004), Korea (Kim and Kwon 1988b), Singapore (Markham 2009) and Japan (Ishii 1914; Shiino 1934, 1936) and the present specimens closely match those described previously (Figure 1). However,

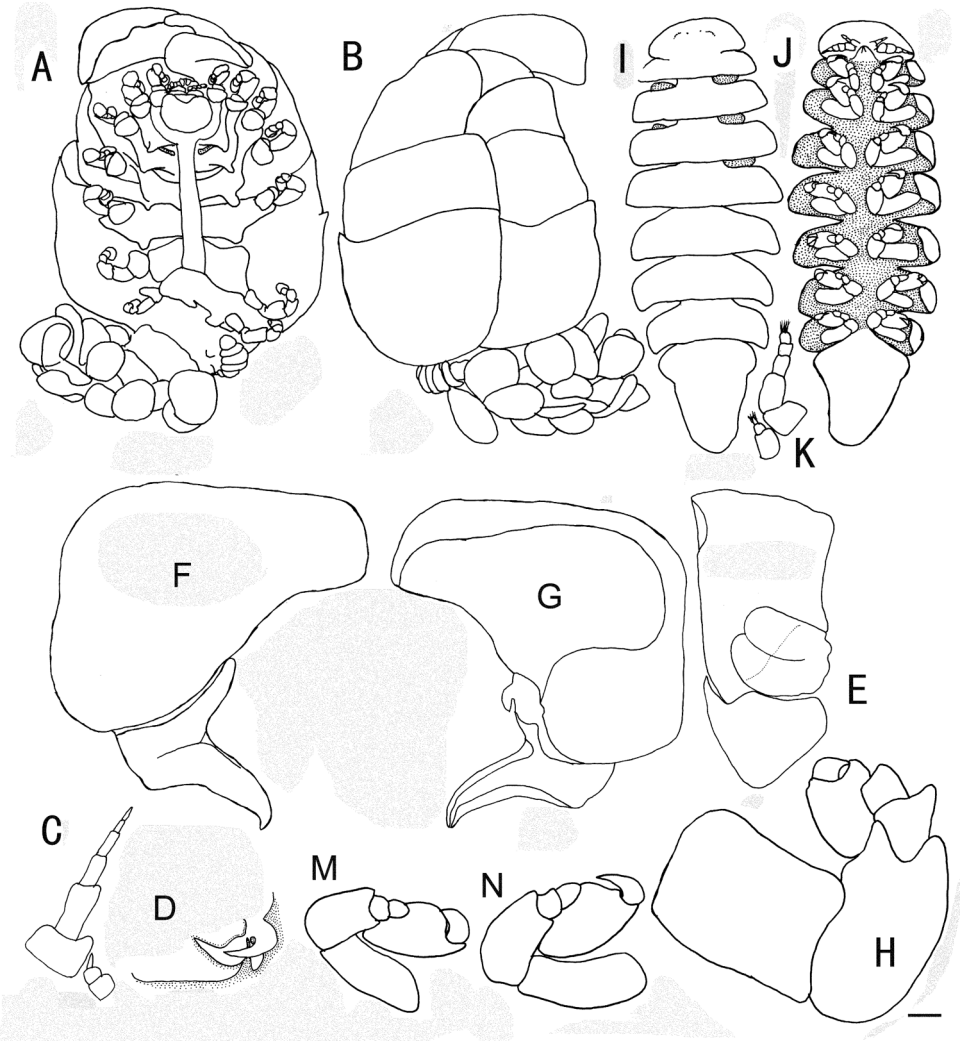

Figure 1. *Athelges takanoshimensis* Ishii, 1914. (A–H) Female (CIEA109801): (A) dorsal view; (B) ventral view; (C) left antennule and antennae; (D) left side of barbula; (E) left maxilliped, external view; (F) left oostegite 1, external view; (G) left oostegite 1, internal view; (H) right pereopod 5. (I–M) Male (CIEA109802): (I) Dorsal view; (J) ventral view; (K) left antennule and antennae; (L) left pereopod 3; (M) left pereopod 7. Scale bars: 1 mm for A, B; 0.08 mm for C, K, M, L; 0.38 mm for D; 0.33 mm for E; 0.50 mm for F, G; 0.14 mm for H; 0.28 mm for I, J.

the maxilliped of the specimens from China lacks a palp (Figure 1E) and in this character more closely resembles Markham's (1982) description based on Hong Kong specimens.

Prevalence

In total, 5.5% (87 of 1571) of hermit crabs collected from Hong Kong between 2001 and 2004 were parasitized by *A. takanoshimensis*. In this region, the parasite

was only recorded from *Pagurus minutus*. The reproduction and ecology of *A. takanoshimensis* from Hong Kong is the subject of a separate paper (Williams, in preparation).

Range and hosts

Japan: on *Pagurus dubius* (Ortmann) (Saito et al. 2000), *Pagurus maculosus* Komai and Imafuku (Nagasawa et al. 1996), *Pagurus japonicus* (Stimpson) (Shiino 1934), *Pagurus pectinatus* (Stimpson) (Shiino 1937) and *Pagurus samuelis* (Stimpson) (Ishii 1914) (*P. samuelis* is a synonym of *Eupagurus geminatus*); Zhejiang, China: on *Pagurus* sp. (Wei 1991); Bohai Sea, China: on *Pagurus pectinatus* (herein); Hong Kong: on *Clibanarius* sp., *Diogenes edwardsii* (De Haan), *Diogenes* sp., *Pagurus* aff. *geminatus* McLaughlin, *Pagurus trigonocheirus* (Stimpson) (Markham 1982) and *Pagurus minutus* (herein); Korea: on *Pagurus brachiomastus* (Thallwitz), *Pagurus dubius*, *Pagurus filholi* (de Man), *Pagurus middendorffii* Brandt, and *Pagurus pectinatus* (Kim and Kwon 1988b); Taiwan: on *Pagurodofleinia doederleini* (Doflein) (Boyko 2004); Singapore: on *Diogenes pallescens* Whitelegge (Markham 2009).

Genus ***Parathelges*** Bonnier, 1900
Type species ***Athelgue aniculi*** Whitelegge, 1897 by monotypy

Parathelges enoshimensis Shiino, 1950
(Figure 2)

Parathelges enoshimensis Shiino, 1950: 162–164, fig. 5. Codreanu 1961: 137 (list). Markham 1972: 58 (list), 76 (key). Kim and Kwon 1988a: 213–215, fig. 8. Kim and Kwon 1988b: 215. Kazmi and Markham 1999: 884. Markham 2003: 74 (list). McDermott et al. 2010: 11 (table). Markham 2010: 183.

Material examined

Infesting *Spiropagurus* sp. South Sea, Stn 6142, 18°00′ N, 111°00′ E, 96 m, 8 April 1960, Yongliang Wang coll., 1 ♀, CIEA614201, 1 ♂, CIEA614202.

Description of female (CIEA614201)

Length (not including pleopods and uropods) 13.2 mm, maximal width 7.24 mm, head length 1.49 mm, head width 1.69 mm. All body regions and segments distinct. No pigmentation (Figure 2A).

Head pentagonal, anterior edge straight, posterior edge rounded, with short frontal lamina. Without eyes. Antennule and antennae of three and six articles, respectively, all articles without setae (Figure 2C). Maxilliped lacking palp, with long and sharp plectron (Figure 2D). Barbula with three small falcate projections on each side, flat middle region (Figure 2E).

Pereon almost completely segmented dorsally, with mid-dorsal ridge. Pereon broadest across pereomere 4. Pereomere 1 bisected by head, pereopod 1 anterior to head; pereomere 2 surrounding head, pereopod 2 beside head. Posterolateral flaps on pereomeres 2–7. Pereomere 5 markedly longer than others. Oostegites almost enclosing highly vaulted brood pouch (Figure 2B). Oostegite 1 (Figure 2F, G) greatly extended,

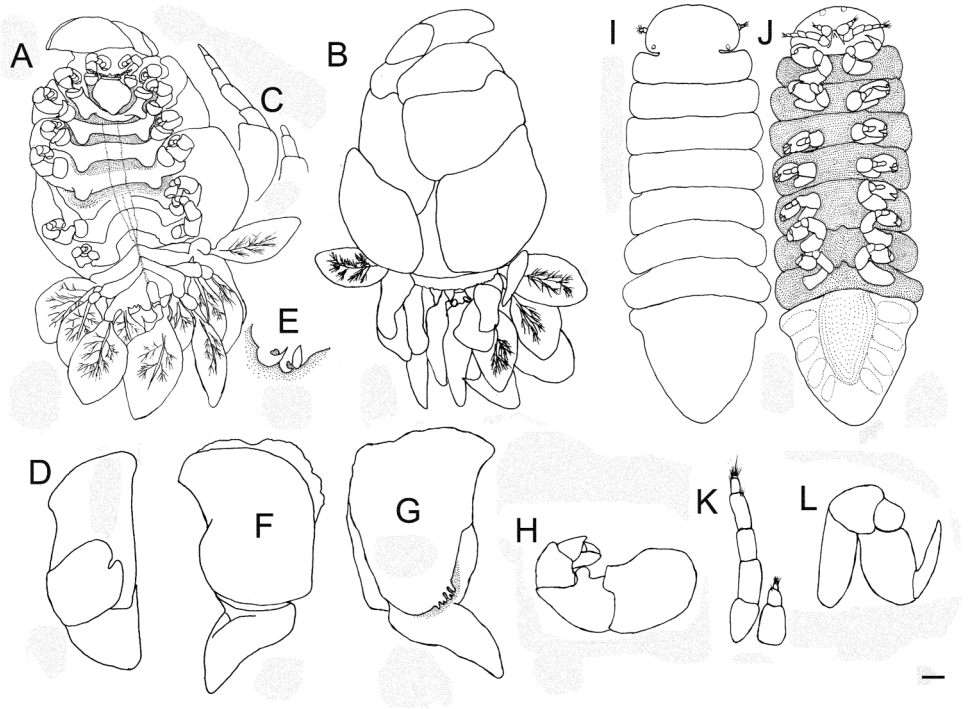

Figure 2. *Parathelges enoshimensis* Shiino, 1950. (A–H) Female (CIEA614201): (A) dorsal view; (B) ventral view; (C) right antennule and antennae; (D) right maxilliped, external view; (E) right side of barbula; (F) right oostegite 1, external view; (G) right oostegite 1, internal view; (H) right pereopod 5. (I–L) Male (CIEA614202): (I) dorsal view; (J) ventral view; (K) right antennule and antennae; (L) left pereopod 1. Scale bars: 1 mm for A, B; 0.12 mm for C, E; 0.27 mm for D, H; 0.43 mm for F, G; 0.17 mm for I, J; 0.10 mm for K, L.

anterior article twice as long as posterior articles, digitate internal ridge, posterior article tapering to rounded point. Pereopods small, bent; ischium with rounded projection (Figure 2H).

Pleon of five pleomeres, first four bearing pedunculate biramous foliate pleopods, all of similar structure, with venation on the surface (Figure 2A). Pleomere 5 short, terminating in pair of small uniramous uropods.

Description of male (CIEA614202)

Length 5 mm, maximal width across pereomere 7, 2.16 mm, head length 0.56 mm, head width 1.39 mm, pleonal length 1.56 mm (Figure 2I, J).

Head oval, nearly three times as broad as long (Figure 2I), fused with pereomere 1. Colourless eyes near posterior margin. Antennule and antennae of three and five articles respectively, distal articles setose (Figure 2K).

Pereomeres distinctly segmented, almost equally wide, with truncate margins. Last two pereomeres with small midventral projections (Figure 2J). Pereopod 1 with meri and carpi fused, pereopods 1 and 2 with much longer dactyli than posterior pereopods (Figure 2L).

Pleomeres fused, pleomere 1 indicated by lateral enlargement. Middle region of pleon distinctly concave. Four pairs of low, oval tuberculate structures (remnant pleopods) on pleon (Figure 2J).

Remarks

Parathelges enoshimensis has been reported from Japan (Shiino 1950) and Korea (Kim and Kwon 1988a, b). The present specimens conform well to Shiino's syntypes except in some minor characters that have been shown to be variable in bopyrids (e.g. venation of pleopods, lack of pigment in males). *Parathelges enoshimensis* is very similar to *Parathelges weberi* Nierstrasz and Brender à Brandis, 1923 and further investigations may show that the species are conspecific. Markham (2010) considered *Parathelges weberi* and *Parathelges whiteleggei* Nierstrasz and Brender à Brandis, 1931 to be junior synonyms of *Parathelges aniculi* (Whitelegge, 1897). However, this species complex is in need of further study because specimens from the Philippines call into question the identity of *Parathelges weberi*, which appears to be distinct from *Parathelges aniculi* (Williams and Boyko in preparation).

Range and hosts

Japan on *Pagurus* sp. (Shiino 1950); South Sea, China on *Spiropagurus* sp. (herein); Korea on *Pagurus dubius* (Ortmann) and *Pagurus filholi* (de Man) (Kim and Kwon 1988a).

Genus ***Pseudostegias*** Shiino, 1933
Type species ***Pseudostegias setoensis*** Shiino, 1933 by monotypy

Pseudostegias setoensis Shiino, 1933
(Figures 3–5)

Abbreviated synonymy (see Markham 2010, for complete synonymy before 2010.)
Pseudostegias setoensis Shiino, 1933: 290–293, fig. 16 [type locality Seto, Japan; infesting *Clibanarius bimaculatus* (De Haan, 1849)]. McDermott et al. 2010: 11 (table). Markham 2010: 183–185, 153 (table); figs. 34, 35.

?Non *Pseudostegias setoensis* Markham 1994: 247–249, fig. 17.

Material examined

Infesting *Calcinus laevimanus* (Randall). Hainan, Maozhou, 18°13′ N, 109°24′ E, 19 March 1992, 1 ♀, CIEA920301, 1 ♂, CIEA920302.

Infesting *Clibanarius virescens* Hess. Hong Kong, Siu Kau Yi Chai (Island near Peng Chau), 22°17′16.70″ N, 114°3′28.65″ E, 3 June 2004, J. Williams coll., 3 ♀, 3 ♂, USNM1155302.

Description of female

Length of reference female (CIEA920301) (not including pleopods and uropods) 9.33 mm, body roughly rectangular, dextral. No pigmentation (Figure 3A, B).

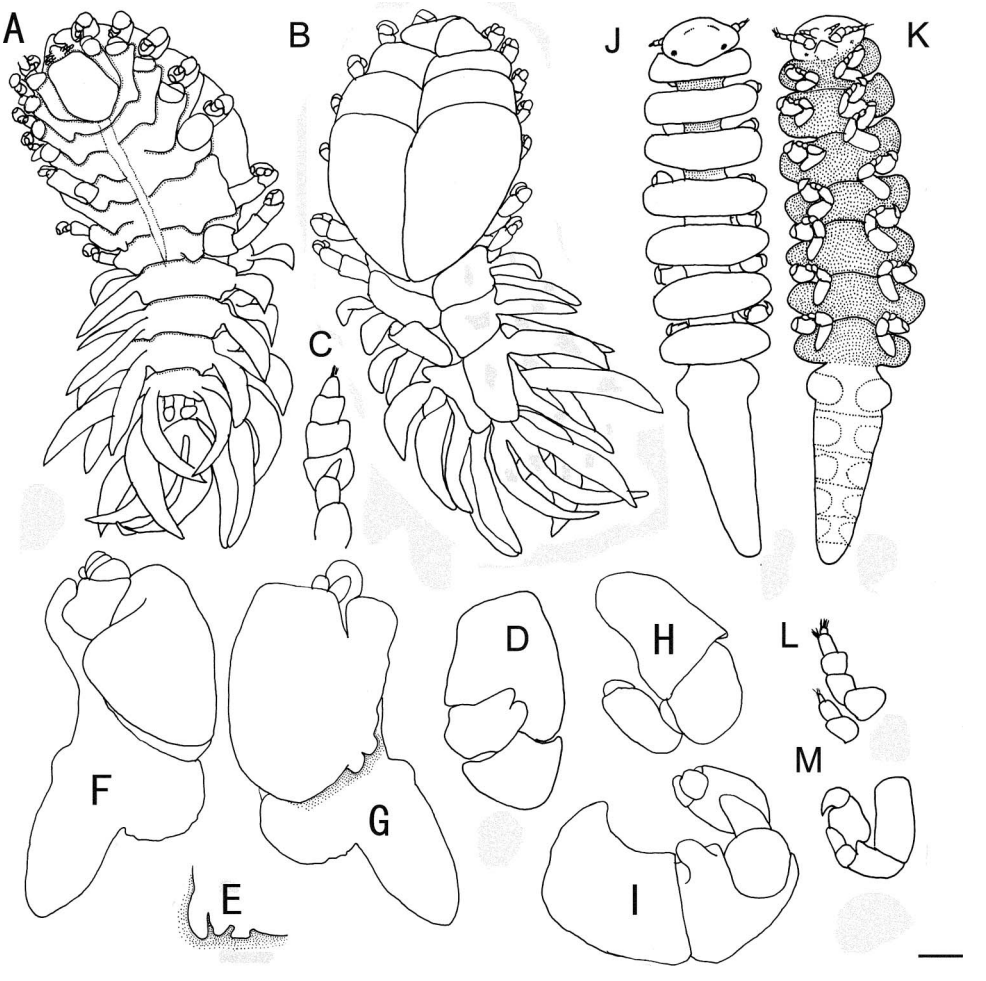

Figure 3. *Pseudostegias setoensis* Shiino, 1933. (A–I) Female (CIEA920301): (A) dorsal view; (B) ventral view; (C) right antennule and antennae; (D) right maxilliped, external view; (E) right side of barbula; (F) right oostegite 1, external view; (G) right oostegite 1, internal view; (H) right pereopod 1; (I) right pereopod 6. (J–M) Male (CIEA920302): (J) dorsal view; (K) ventral view; (L) right antennule and antennae; (M) left pereopod 5. Scale bars: 1 mm for A, B; 0.17 mm for C, H, I; 0.35 mm for D; 0.40 mm for E, F, G; 0.30 mm for J, K; 0.12 mm for L, M.

Head pentagonal, longer than wide, eyes absent (Figure 3A). Antennule and antennae of three and four articles, respectively; antennae with a tuft of terminal setae (Figure 3C). Maxilliped without palp, with plectron short and blunt (Figure 3D). Barbula with three short and blunt projections on each side, flat middle region (Figure 3E).

Pereon with mid-dorsal ridge, broadest across pereomere 6. Pereomeres 1 and 2 surrounding head, pereomers 3, 4 fused medially, and pereomeres 2–7 produced into pair of posterolateral points. Oostegites completely enclosing highly vaulted brood pouch (Figure 3B). Oostegite 1 (Figure 3F, G) more than twice as long as wide,

extending beyond head, bearing round anterior edge and sharp posterolateral point, internal ridge with two blunt tuberculate structures. Fifth oostegites largest, covering half of pereon ventrally (Figure 3B). First five pereopods (Figure 3H, I) of nearly same size, pereopods 6 and 7 much longer.

Pleon of six pleomeres, first four pleomeres bearing biramous pleopods and lanceolate lateral plates (Figure 3A, B). Lateral plates progressively longer in posterior pleomeres and extending laterally. Pleomere 5 with pair of globose lateral plates (Figure 3A) and biramous pleopods. Pleomere 6 with pair of uniramous uropods. Lateral plates, exopodites of pleopods and uropods lanceolate, endopodites of first three pleopods much larger, covering pleonal surface and creating posterior extension of the brood chamber, within which male often resides (Figure 3A, B).

Description of male

Length of reference male (CIEA920302) 3.30 mm, maximal width across pereomere 5, 0.92 mm, head length 0.31 mm, head width 0.68 mm, pleonal length 1.32 mm.

Male attached inside brood chamber. Body elongate, sides nearly parallel except for anteriorly rounded head and posterior end with tapering pleon (Figure 3J).

Head roughly oval, wider than long, and distinctly separated from pereomere 1. Small dark eyes near posterolateral regions (Figure 3J). Antennule of three articles, with tuft setae on terminal article; antennae of five articles, with tuft of setae on distal end of last two articles (Figure 3L).

Pereomeres nearly subequal, with truncate margins. Large gap between adjacent pereomeres. All pereopods of similar structure and proportions (Figure 3M).

Pleon fused into single piece, pleomere 1 indicated by anterior enlargement, pleomeres indicated by low, rounded structures on ventral sides of pleon (reduced pleopods). uropods lacking.

Remarks

The genus *Pseudostegias* contains seven described species. The new specimens from China (Figure 3) and Hong Kong (Figures 4, 5) are similar to recent descriptions of *Pseudostegias setoensis* (e.g. Markham 2010). However, they are also very similar to *Pseudostegias dulcilacuum* Markham, 1982. The two species are reportedly distinguished by barbula digitation, posterolateral projection of oostegite 1, and morphology of the pleonal appendages (Markham 2010). Unfortunately, these features are quite variable in the reports of both species. We believe it is likely that *Pseudostegias dulcilacuum* is a junior synonym of *Pseudostegias setoensis* but further research, ideally incorporating morphological and molecular data, is required to determine the extent of variation in the species. The crenulate or digitate posterior margins of the pereomeres found in the present specimens are similar to those reported in the original description of *Pseudostegias dulcilacuum* (Markham, 1982), although the digitation appears more pronounced in some of the new specimens. The two larger digitiform lateral projections under the fifth oostegites in *Pseudostegias setoensis* from Hong Kong (Figure 4B) have not been recorded before and their function is unknown. These could be of taxonomic importance in *Pseudostegias* and should be considered in future studies.

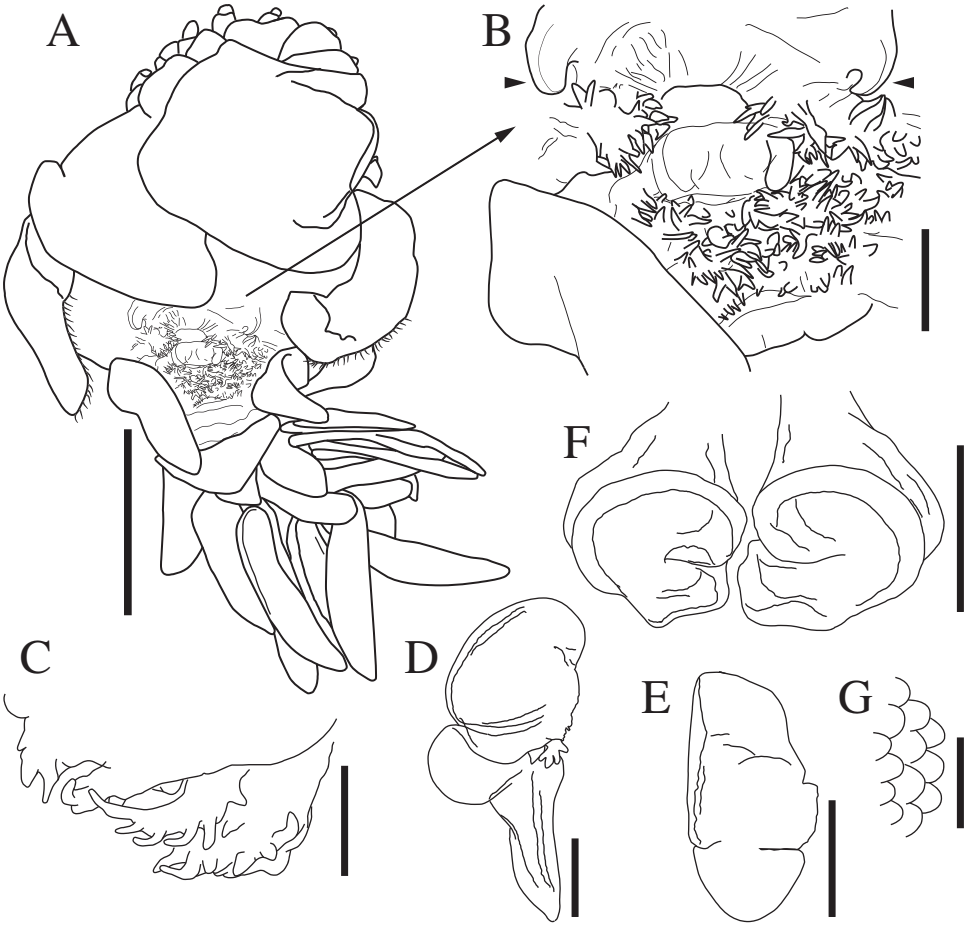

Figure 4. *Pseudostegias setoensis* Shiino, 1933. (A–G) Female (USNM1155302): (A) ventral view; (B) ventral view of posterior region within brood chamber, with digitiform extensions (horizontal arrowheads) above crenulate margins of pereomeres; (C) left side of barbula; (D) right oostegite 1, internal view; (E) right maxilliped, external view; (F) fifth set of lateral plates; (G) scales on lateral plates. Scale bars: 5 mm for A; 1 mm for B, D, E; 500 μm for C, F; 25 μm for G.

The record of *Pseudostegias setoensis* from the Chesterfield Islands and New Caledonia by Markham (1994) probably respresents a distinct species (as suggested by Williams and Boyko 1999). Unlike all other reports of *Pseudostegias setoensis* that come from shallow-water hermit crabs (members of the genera *Calcinus*, *Clibanarius*, *Diogenes)*, the specimens from the Chesterfield Islands were found on hosts from deeper waters (400 m) (*Strigopagurus boreonotus* Forest). In addition, the specimens from this locality are distinguished by a broader body shape of the females, more foliose female pleonal appendages, and different head morphology of males (Markham 1994).

The specimens from China (Figure 3) and Hong Kong (Figures 4, 5) are similar in most characters. However, female specimens from Hong Kong had digitate projections

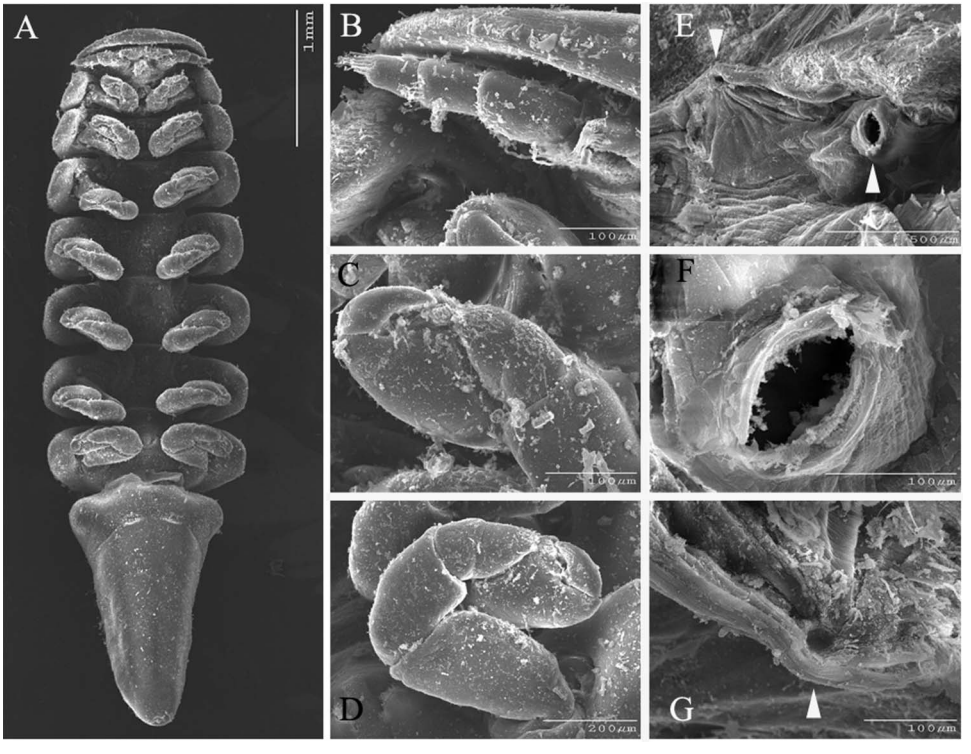

Figure 5. *Pseudostegias setoensis* Shiino, 1933 (USNM1155302), scanning electron micrographs. Male (A–D), damage to body of host (E–G): (A) ventral view; (B) right antennae; (C) right pereopod 1; (D) left pereopod 7; (E) abdomen of host showing hole left by mouthparts of female (upward facing arrowhead) and attachment site of left pereopod 1 (downward facing arrowhead); (F) close-up of hole left by mouthparts of female; (G) close-up of attachment site of left pereopod 1, showing where dactyl and propodus were positioned (arrowhead). Scale bars: 1 mm for A; 100 µm for B, C, F, G; 200 µm for D; 500 µm for E.

on the barbula (Figure 4C), posterior margins of pleomeres with crenulate margin or highly digitate in ventral respect (Figure 4A, B), with two distinct lateral digitiform projections under the fifth oostegites (Figure 4B), the fifth lateral plates kidney shaped (Figure 4F). Male specimens almost similar.

Prevalence and impact on host

In total, 7.5% (three of 40) of *Clibanarius virescens* Hess collected from Hong Kong were parasitized by *Pseudostegias setoensis* in 2004. None of the 1000+ *Pagurus minutus* from this region examined were found with *Pseudostegias setoensis*, indicating that the parasite has some degree of host specificity. To date, the species has only been documented from diogenid hermit crabs.

One host specimen of *Clibanarius virescens* collected in Hong Kong showed evidence of the damage caused by *Pseudostegias setoensis* (Figure 5E, F). A hole in the host exoskeleton left by the mouthparts of the female isopod was oval in shape

(approximately 100 μm in length and 50 μm in width) and positioned on the abdomen near the pleopods of the host. The exoskeleton of the hosts also displayed points where the dactyl and propodus of the pereopods were used to attach (Figure 5E, G).

Range and hosts

Japan on *Clibanarius bimaculatus* (De Haan) (Shiino 1933); Hainan, China on *Calcinus laevimanus* (Randall) (herein); Hong Kong on *Clibanarius bimaculatus*, *Clibanarius ransoni* Forest (Markham 1982) and *Clibanarius virescens* (herein); Thailand on *Clibanarius padavensis* de Man (Markham 1985); Taiwan on *Clibanarius striolatus* Dana (Shiino 1958); Australia on *Diogenes pallescens* Whitelegge (Markham 2010); ?Chesterfield Islands and New Caledonia on *Strigopagurus boreonotus* Forest (Markham 1994; see discussion above).

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