

# Occurrence of sea lice, *Caligus undulatus* Shen and Li, 1959 (Copepoda: Siphonostomatoida: Caligidae) in plankton samples collected from Korea

Seong Yong Moon<sup>1,\*</sup> and Jong Sick Park<sup>2</sup>

<sup>1</sup>South Sea Fisheries Research Institute, National Institute of Fisheries Science, 22 Sepodangmeori-gil, Yeosu-si, Jeollanam-do 59780, Republic of Korea

<sup>2</sup>Ocean Fisheries Research and Development Co., Ssangbong-ro 82, Yeosu-si, Jeollanam-do 59677, Republic of Korea

\*Correspondent: msy7744@korea.kr

We have conducted faunistic study of sea lice collected from marine plankton samples of western and southern coasts of Korea. These specimens were identified as *Caligus undulatus* Shen and Li, 1959, belonging to family Caligidae and order Siphonostomatoida with worldwide distribution. The range extension of *C. undulatus* is reported in addition to the previously known distributional range from the Northwest Pacific (China, Japan, and Korea), India, Brazil, and Mexico. This species can be distinguished from all previous reports with characteristics such as overall body proportions of both sexes, structure details of mouth appendages, armature of legs, and some variation in body size. The distributional range of *C. undulatus* is now given with its northern and south hemisphere limit being 40° to 10°N in the Indo-Pacific and 30°S in the Southwest Atlantic. This is the first record of its female occurring in Korea.

Keywords: distribution range, Indo-Pacific, Korea, marine plankton, sea lice, Southwest Atlantic

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## INTRODUCTION

Sea lice are naturally occurring ectoparasitic copepods that escape from the host or result from host-switching by planktonic larvae. The genus *Caligus* Müller, 1785 is a well-known sea lice belonging to the order Siphonostomatoida, and includes more than 400 species that parasitize marine fish (Boxshall and Halsey, 2004; Ho and Lin, 2004a; Moon and Kim, 2012; Dojiri and Ho, 2013), having serious impact on cultured fishes around the world. Although the specific host is unknown for several species of *Caligus* Müller, 1785, their presence in marine plankton samples has been reported around the world (Gnanamuthu, 1948; Shen and Li, 1959; Heegaard, 1972; Kabata, 1972; Ho and Lin, 2004b; Venmathi Maran and Ohtsuka, 2008; Venmathi Maran *et al.*, 2012a; 2012b; Suárez-Morales *et al.*, 2012a; 2012b).

*Caligus undulatus* Shen and Li, 1959 was originally described from plankton samples of coastal waters of Tsingtao Harbor, China (Shen and Li, 1959). This species has been recorded from India (Pillai, 1966), Brazil (Montú, 1982), Japan and Korea (Venmathi Maran and Ohtsuka, 2008; Venmathi Maran *et al.*, 2012b), and Mex-

ico (Suárez-Morales *et al.*, 2012b). Venmathi Maran and Ohtsuka (2008) described *C. undulatus* from off Ube City, the Ariake Sea, Japan and near the mouth of the Seomjin River, Korea. However, there have been no records of the species from the western coast of Korea. Venmathi Maran and Ohtsuka (2008) have described *C. undulatus* in detail with fine illustrations. Herein, we briefly describe specimens collected from the western coast of Korea. Attention is paid to characteristics that differ from descriptions reported in previous studies (Shen and Li, 1959; Pillai, 1966; Venmathi Maran and Ohtsuka, 2008; Suárez-Morales *et al.*, 2012b).

We conducted faunistic studies on sea lice along the western and southern coasts of Korea from 2012 to 2013. Of materials collected from studied area, we found both sexes of *C. undulatus* among marine plankton samples from western and southern coasts of Korea. The present study provides detailed illustration and description of both female and male specimens of *C. undulatus*. This is the first record of its female occurring in Korea. We also discuss its distributional range in the northern and southern hemispheres.

## MATERIALS AND METHODS

Sea lice samples were collected from estuarine and coastal waters in western and southern Korea using a plankton net (mesh size = 200  $\mu\text{m}$ ; mouth diameter = 45 cm) towed obliquely from near the bottom to the surface (Fig. 1). Samples were preserved immediately in 5% buffered formalin/seawater solution. Individuals of caligid specimens were sorted out from these samples. Preserved copepods were cleared in a drop of 85% lactic acid for 2–4 hours and examined using an Olympus BX51 phase contrast microscope. Selected specimens were measured intact using an ocular micrometer. They were dissected and examined according to the wooden slide procedure (Humes and Gooding, 1964). Drawings were made using a Nikon Eclipse 80i microscope equipped with a drawing tube. The descriptive terminology follows Dojiri and Ho (2013). In the formula for the armature of legs 1–4 in description, Roman numerals indicate spines and Arabic numerals represent setae. Abbreviations “exp.” and “enp.” indicate exopod and endopod, respectively. These specimens are deposited at the National Institute of Biological Resources (NIBR), Incheon, Korea.

## SYSTEMATIC ACCOUNTS

Order Siphonostomatoida Thorell, 1859 대롱입요각목  
Family Caligidae Burmeister, 1835 물이과  
Genus *Caligus* Müller, 1785 물이속

### *Caligus undulatus* Shen and Li, 1959

Korean name: Tteo-dol-i-mul-i  
떠돌이물이 (신칭) (Figs. 2–4)

*Caligus undulatus* Shen and Li, 1959: 12, 16, pl. 1; Yamaguti, 1963: p. 61, pl. 80, fig. 3; Pillai, 1966: 123, fig. 1; Margolis *et al.*, 1975: p. 81; Montú, 1982: 329; Venmathi Maran and Ohtsuka, 2008: 206, figs. 3I–O, 4A–M; Suárez-Morales *et al.*, 2012b: 805, figs. 1, 2; Venmathi Maran *et al.*, 2012b: 212, fig. 8D, E.

**Material examined.** One female (left antenna dissected on glass slide, 1 vial) (NIBRIV0000282332), Gangjin Bay (34°49'31"N, 127°47'23"E), Jeollanam-do Province, southern Korea, 12 September, 2012, Jong Sick Park; four females and three males, the Mokpo Harbour (34°49'31"N, 127°47'23"E) (NIBRIV0000293068), Jeollanam-do Province, western Korea, 2 August, 2013, Seong Yong Moon.

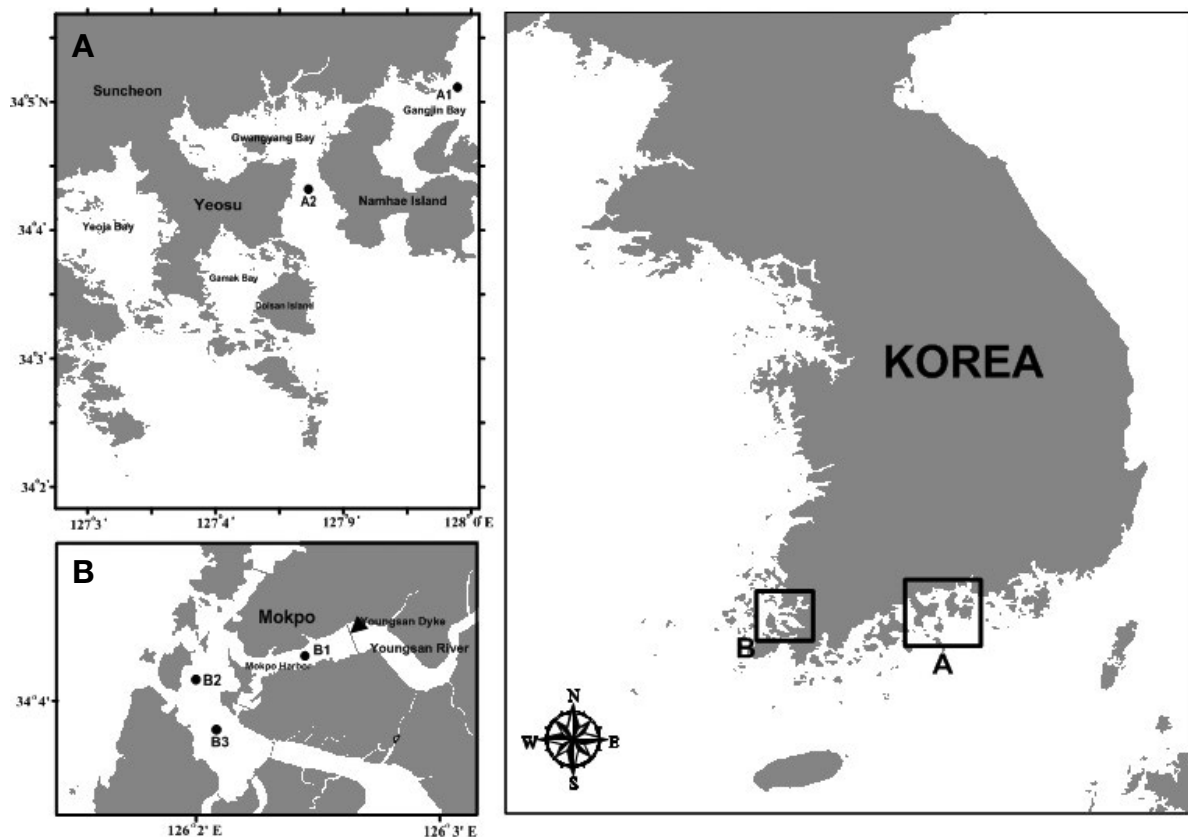


Fig. 1. Map showing the sampling sites along the southern coast of Korea. A. Gwangyang Bay and Gangjin Bay. B. Mokpo Harbor.

**Description.** Female. Body (Fig. 2A) 3.08–4.46 mm (mean  $3.52 \pm 0.54$  mm) in length excluding caudal setae. Cephalothoracic shield slightly ovoid, 1.38 times longer than width ( $2.16 \times 1.56$  mm); lateral zone with smoothly curved ventral rib; posterior sinus deep; posterolateral pit present. Fourth pedigerous somite indistinctly articulated from genital complex. Genital complex (Fig. 2A) with trapezoidal-shaped and/or a peculiar irregular undulation, gradually broadened distally,  $1.17 \times 1.11$  mm, with rounded and slightly projected posterolateral corners. Abdomen (Figs. 2A, 3A) indistinctly separated from genital complex and 2-segmented; first segment wider than length ( $0.22 \times 0.35$  mm); distal segment 1.75 times longer than width ( $0.56 \times 0.32$  mm). Caudal ramus (Fig. 2B) 1.92 times longer than width ( $0.23 \times 0.12$  mm), with 6 plumose setae (seta I lacking); inner margin convex, with setules on distal half. Antennule (Fig. 2C) 411  $\mu$ m long and 2-segmented; proximal segment 73% length of antennule, with 25 pinnate and 2 naked setae; distal segment with 12 naked setae and 2 aesthetascs. Antenna (Fig. 2D) 3-segmented; proximal segment with proximal process; second segment nearly quadrangular, with 1 adhesion pad on ventromedial margin; distal segment forming long, distally strongly bent claw bearing 2 small setae. Post-antennal process (Fig. 2E) long and narrow, proximally bearing 2 papillae, each tipped with 2 setules; another papilla located posterior to post-antennal process also tipped with 2 setules. Mandible (Fig. 2F) with 12 teeth distally. Maxillule (Fig. 2G) consisting of anterior papilla bearing 3 unequal setae and tapering posterior process. Maxilla (Fig. 2H, I) 2-segmented; proximal segment (lacertus) large and unarmed; slender distal segment (brachium) with membrane (flabellum) at about 60% region of inner margin; calamus about twice as long as canna. Maxilliped (Fig. 2J) 3-segmented; proximal segment (corpus) with broader proximal half and narrower distal half; second segment (shaft) 1 seta distally; distal segment forming long, curved claw. Sternal furca (Fig. 2K) with slender, long tines bearing membrane on lateral sides. Armature formula of legs 1–4 as follows (Roman numerals: number of spines; Arabic numerals: number of setae):

	Exopod	Endopod
Leg 1	I-0; III, I, 3	vestigial
Leg 2	I-1; I-1; II, I, 5	0-1; 0-2; 6
Leg 3	I-0; I-1; III, 4	0-1; 6
Leg 4	I-0; I, III	lacking

Leg 1 (Fig. 3B, C) intercoxal sclerite naked and elongate. Coxa with simple outer seta. Basis with pinnate outer and inner setae. Exopod 2-segmented; first segment with 1 small outer distal naked seta and row of setules on inner margin; second segment with 3 apical spines, middle and inner apical spines with accessory process, inner distal seta naked and shorter than mid-terminal setae; en-

dopod small, knob-like.

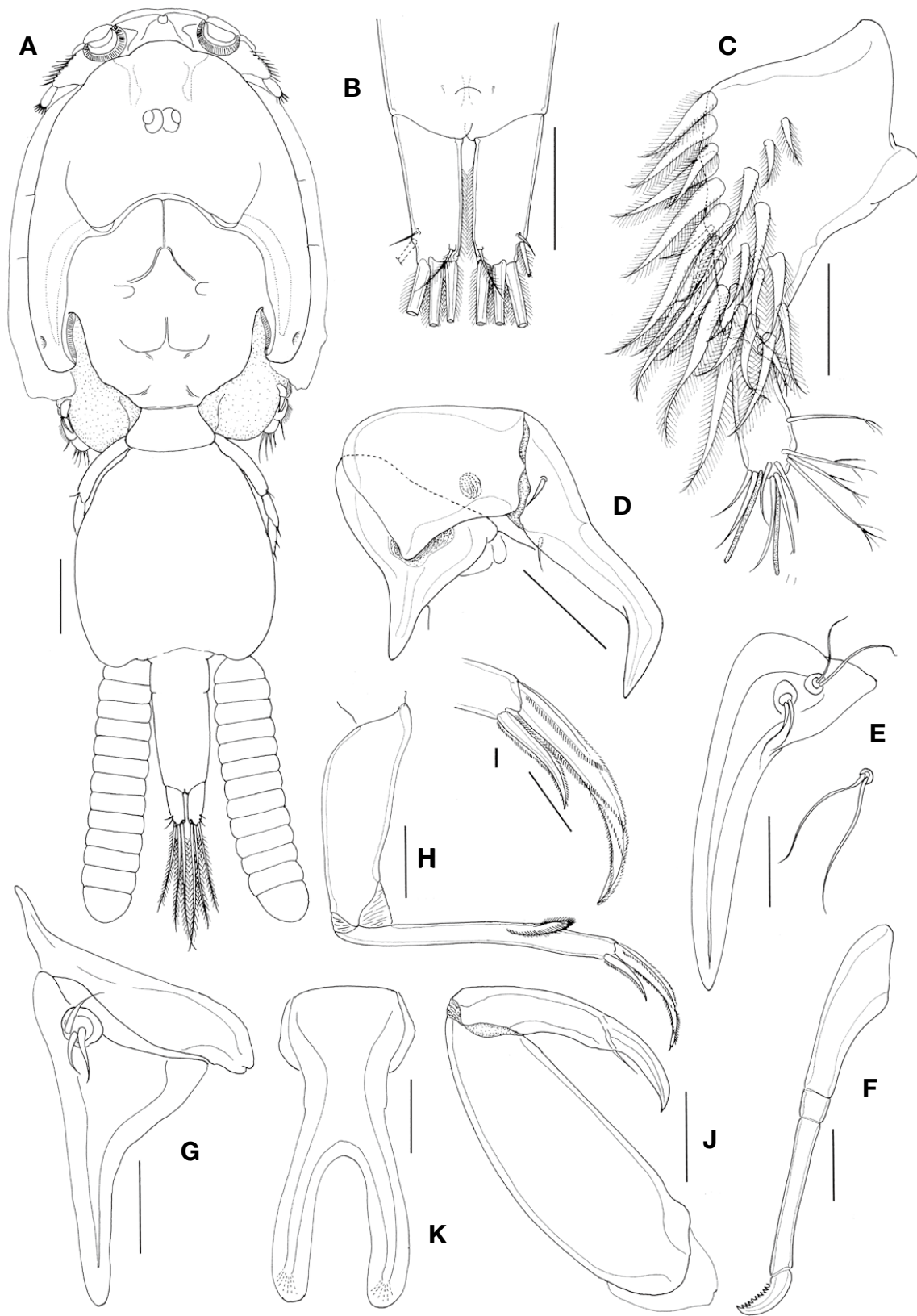
Leg 2 (Fig. 3D) intercoxal sclerite subquadrate, with hyaline membrane along distal margin. Coxa with large seta on inner posterior margin and one setule on anterior surface. Basis with small outer seta and one inner setule and membrane on inner part of posterior margin; outer side of basis and first exopodal segment with broad membrane. Exopod 3-segmented, with large hyaline membrane covering dorsal surface of ramus; first segment with 1 inner plumose seta, row of setules along inner margin and pectinate membrane at base of outer serrate spine; second segment with 1 inner plumose seta, short row of setules along proximomedial margin, 1 outer serrate spine on anterior surface; distal segment with 5 inner plumose setae, one serrated spine, and 2 outer small spines on mediolateral margin. Endopod 3-segmented; first segment with 1 long inner plumose seta, row of setules along most of outer margin; second segment with 2 inner plumose setae and row of large setules along most of outer margin; distal segment with spinules at base of 6 plumose setae and row of setules along proximolateral and proximomedial margins.

Leg 3 (Fig. 3E) protopod broad membrane on outer and inner margins and with 1 outer naked and 1 inner plumose seta, velum between rami, corrugated patched on dorsolateral surface, 2 marginal membranes, 2 long setules along posterior margin; exopod 3-segmented; first segment (Fig. 3F) with 1 outer long setule and spinulate spine, with hyaline membrane at base; second segment with 1 inner plumose seta and 1 outer seta; distal segment with 4 plumose setae, 3 naked spines, setules along the outer margin. Endopod 2-segmented; first segment with 1 inner long plumose seta; second segment with 6 plumose setae and setules along outer margin.

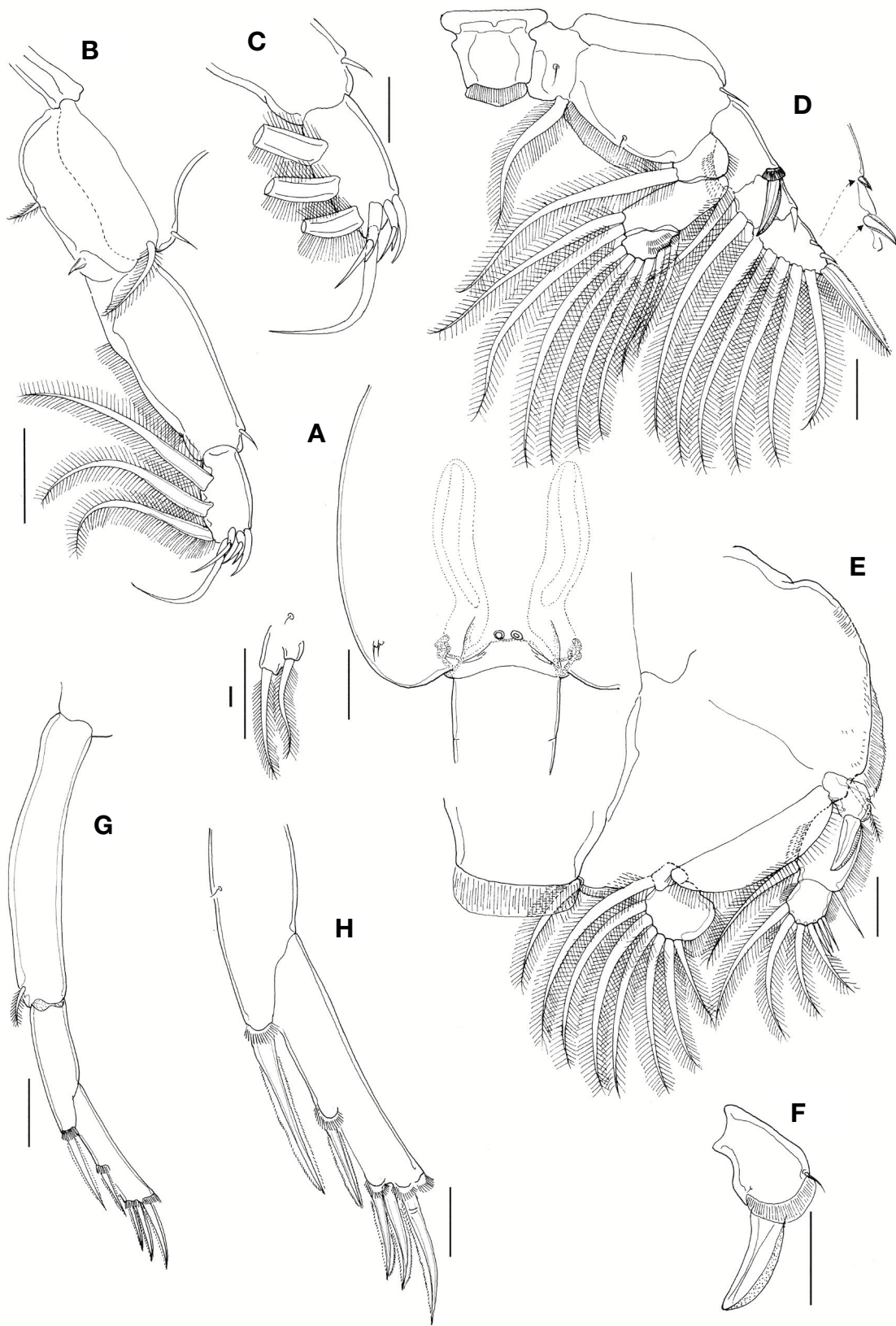
Leg 4 (Fig. 3G, H) uniramous, composed of protopod and 2-segment exopod; protopod with 1 distolateral pinnate seta; first exopodal segment with pectinate membrane at base of outer spinulate spine; second exopodal segment with 3 unequal apical spinulate spines and pectinate membrane at base of innermost spine.

Leg 5 (Fig. 3I) represented by 1 seta on knob and 1 seta on papilla at posterolateral margin of genital complex.

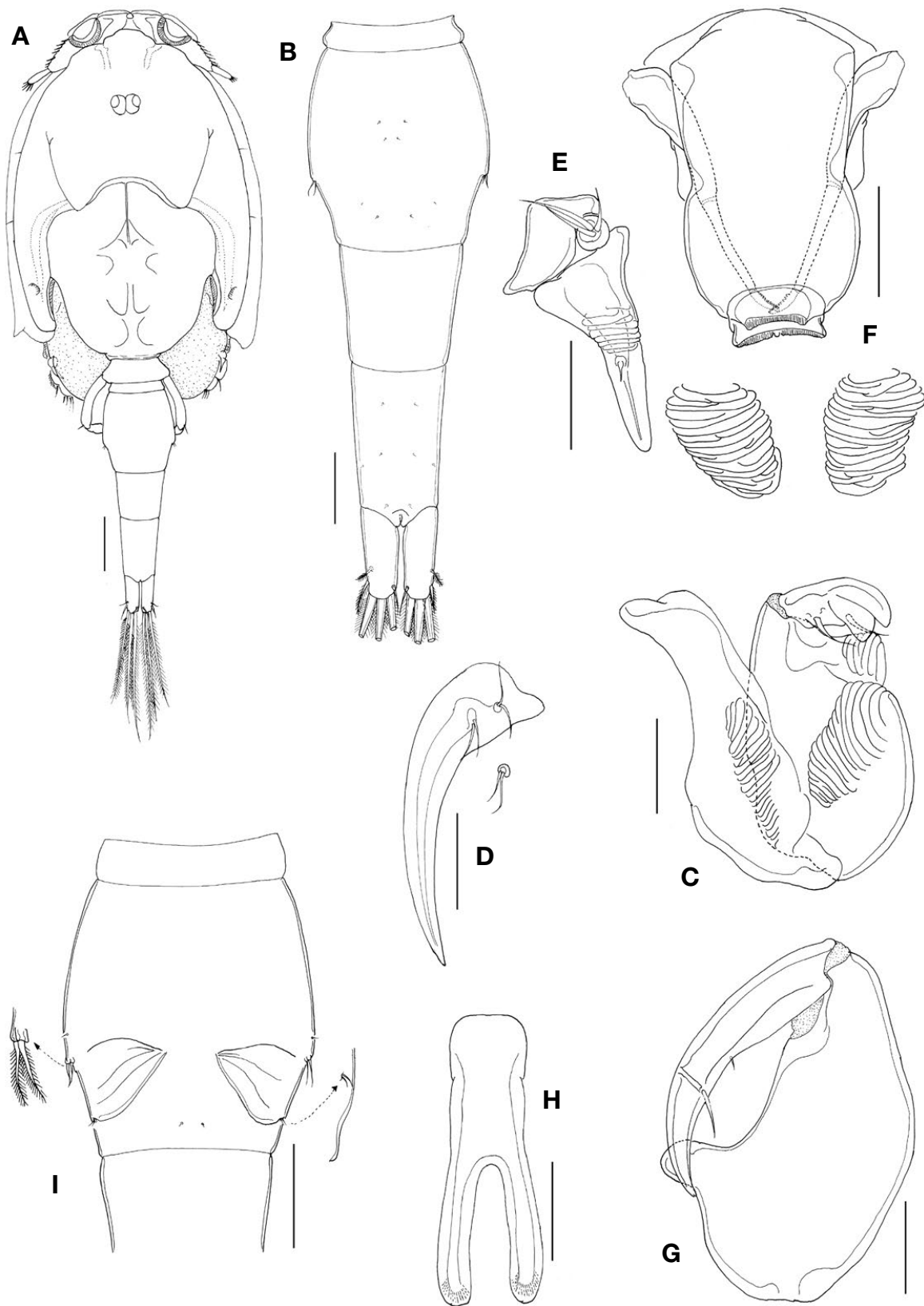
Male. Body (Fig. 4A) 2.91–4.61 mm (mean  $3.72 \pm 0.65$ ) in length (excluding caudal setae). Cephalothoracic shield 1.48 times longer than width ( $2.68 \times 1.81$  mm). Free fourth pedigerous somite wider than length ( $516 \times 258$   $\mu$ m). Genital complex trapezoidal, slightly longer than width ( $623 \times 561$   $\mu$ m). Abdomen (Fig. 4B) 2-segmented; proximal segment slightly longer than width ( $397 \times 382$   $\mu$ m); distal segment 1.65 times longer than width ( $467 \times 283$   $\mu$ m). Caudal ramus (Fig. 4B) 2.91 times longer than width ( $308 \times 106$   $\mu$ m), armed as in female. Antennule as in female. Antenna (Fig. 4C) 3-segmented, comprising coxa, basis, and 1-segmented endopod incorporating dis-



**Fig. 2.** *Caligus undulatus*, adult female from Gangjin Bay, Korea. A. habitus dorsal. B. caudal ramus, dorsal. C. antennules. D. antenna. E. post-antennal process. F. mandible. G. maxillule. H. maxilla. I. tip of maxilla. J. maxilliped. K. sternal furca. Scale bars: A = 400  $\mu$ m; B = 200  $\mu$ m; C, H, J, K = 100  $\mu$ m; D-G, I = 50  $\mu$ m.



**Fig. 3.** *Caligus undulatus*, adult female from Gangjin Bay, Korea. A. genital complex and abdomen, ventral. B. leg 1. C. tip of second exopodal segment of leg 1. D. leg 2. E. leg 3. F. first exopodal segment of leg 3. G, H. leg 4. I. leg 5. Scale bars: A = 200  $\mu$ m; B–E, G = 100  $\mu$ m; F, H, I = 50  $\mu$ m.



**Fig. 4.** *Caligus undulatus*, adult male from Mokpo Harbour, Korea. A. habitus, dorsal. B. urosome, dorsal. C. antenna. D. postantennal process. E. maxillule. F. post oral pad. G. maxilliped. H. sternal furca. I. genital segment and legs 5 and 6, ventral. Scale bars: A = 400  $\mu$ m; B, I = 200  $\mu$ m; C-H = 100  $\mu$ m.

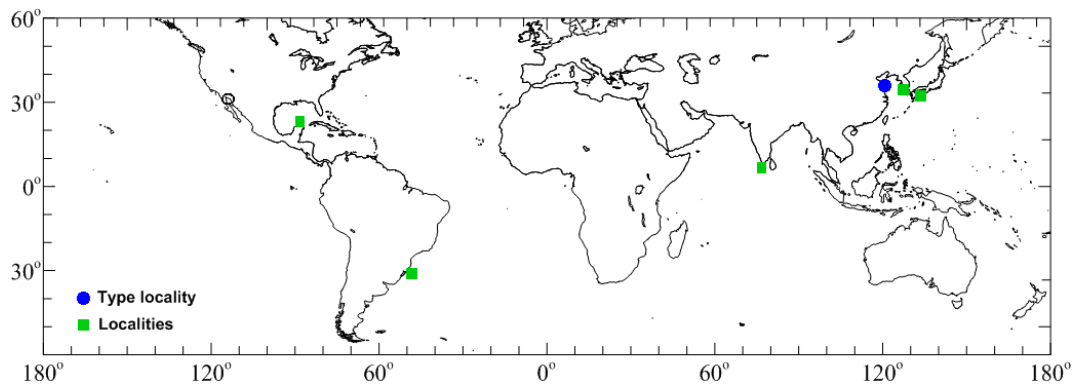


Fig. 5. Schematic illustration of latitudinal distributions of *Caligus undulatus*.

tal claw as in female; proximal segment (coxa) with two weak adhesion pads; second segment (basis) with two adhesion pads; distal segment (endopod) blunt, with two inner proximal setae, distally forming bifurcated structure, and round processes. Post-antennal process (Fig. 4D) long and more acutely pointed at tip than female. Mandible and maxilla as in female. Maxillule (Fig. 4E) with corrugate surface and one stout hyaline structure on dentiform process. Pair of post oral pads (Fig. 4F) present just below oral cone. Maxilliped (Fig. 4G) as in female, except proximal segment (corpus) with well protruded quadrilateral knob at midlength; distal segment (claw) long, acutely pointed, with one minute seta on distal half and one long setae located posteriorly along 2/3 of claw. Tines of sternal furca (Fig. 4H) noticeably longer than female. Legs 1–4 as in female. Leg 5 (Fig. 4I) vestigial, situated mid-laterally on genital complex and bearing two pinnate setae. Leg 6 (Fig. 4I) forming genital operculum, with two unequal minute setae on distolateral corner.

**Host.** Unknown.

**Distribution.** Korea (Seomjin River Estuary, Gwangyang Bay, Gangjin Bay and Mokpo Harbour); China (Tsingtao Harbour); Japan (off Ube city, the Ariake Sea, Takamatsu Port); India (Palk Bay); Brazil (south Brazilian coast); Mexico (Laguna Chelem, Yucatan). All previous reports on *C. undulatus* were based on specimens from plankton samples.

**Remarks.** The original illustration of sea lice *C. undulatus* by Shen and Li (1959) showed a peculiar irregular undulation of genital complex in female (Shen and Li, 1959: fig. 1). However, our specimen was trapezoidal-shaped and/or a peculiar irregular undulation of genital complex in female which gradually broadened distally. The shape of genital complex might have been variable during breeding season because all other reports agree with our illustrations (see Pillai, 1966; Venmathi Maran and Ohtsuka, 2008; Suárez-Morales *et al.*, 2012b; Venmathi Maran *et al.*, 2012b).

Body sizes of female specimens in the present study ranged from 3.08–4.46 mm, similar to previous reports (Shen and Li, 1959; Venmathi Maran and Ohtsuka, 2008). Males in the present study were a little smaller and/or much larger (ranged 2.91–4.61 mm) than those reported from China (3.08 mm in Shen and Li, 1959), India (3.50 mm in Pillai, 1966), Japan and Korea (3.50–3.52 mm in Venmathi Maran and Ohtsuka 2008), and Mexico (2.82 mm in Suárez-Morales *et al.*, 2012b). Nevertheless, our specimens shared characters of *C. undulatus*, including proportional length of the cephalothoracic shield, genital complex, abdomen, postantennal process, sternal furca, and maxilliped with well protruded quadrilateral knob at midlength in male. We consider that specimens from Korea are *C. undulatus* with some variation in body size. These facts allow both specimens collected from three different times to be conspecific to each other. They are identified as *C. undulatus*. Small and large males (2.91–4.05 mm) of *C. undulatus* co-occurred in the Mokpo Harbor, southwestern coasts of Korea.

The latitudinal distribution of *C. undulatus* is shown in Fig. 5. The species was originally recorded from Tsingtao Harbor, China (40°N) by Shen and Li (1959). Our record extends the known latitudinal distribution of *C. undulatus* southward into the tropical zone of South India (10°N) (Pillai, 1966) from the Northwest Pacific between 32 to 35°N (Venmathi Maran and Ohtsuka, 2008; Venmathi Maran *et al.*, 2012b), the previous northern border of its known distributional range. It also represents a modest southwards range extending from the two localities that it was recorded, Mexico (21°N) and Brazil (30°S) in the Atlantic Ocean (Montú, 1982; Suárez-Morales *et al.*, 2012b), although it has not been reported as a parasite yet. One of the first recorded *C. undulatus* in the Northwestern Tropical Atlantic and in Mexican waters was reported by Suárez-Morales *et al.* (2012b). How this species has reached the Americas remains unclear. However, it was probably introduced by aquaculture ac-

tivities as other Asian fish parasites (Suárez-Morales *et al.*, 2010). This species has been reported from various countries. Its host might be a highly migratory fish (Ho and Lin, 2004b; Venmathi Maran and Ohtsuka, 2008). Adults of pelagic caligids have been observed in four genera [*Caligus* Müller, 1785, *Lepeophtheirus* Nordmann, 1832, *Metacaligus* Thomsen, 1949 (Caligidae), and *Pandarus* Leach, 1816 (Pandaridae Milne Edwards, 1840)] (Suárez-Morales *et al.*, 1998; Ho and Lin, 2004b; Venmathi Maran and Ohtsuka, 2008; Venmathi Maran *et al.*, 2012a; Suárez-Morales *et al.*, 2012a; 2012b). Since it is the second record from Korean waters, a detailed parasitological survey of its fish hosts in Korea is necessary to understand host(s) of this particular caligid.

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