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J.H. Wi^a & H.Y. Soh^a

^a Faculty of Marine Technology, Chonnam National University, Yeosu, Korea

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Two *Farranula* (Copepoda: Cyclopoida: Corycaeidae) species from Korean waters

Jin Hee Wi and Ho Young Soh*

Faculty of Marine Technology, Chonnam National University, Yeosu, Korea

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Identification for *Farranula* species has hitherto been carried out with reference to several fragmentary figures and incomplete descriptions of species from the temperate and tropical oceans. As a result, many identification errors such as mixing of characters of different species and confusing two species have occurred in many taxonomic and ecological studies. It is apparent that morphological details such as mouthparts, relative lengths of endopodal spines of swimming legs, ornamentation on surface of genital somite and length : width proportions are needed to verify taxonomic status. In this study, distinct morphological characters differentiating the genus *Farranula* from other genera within Corycaeidae are discussed on the basis of detailed redescriptions of *Farranula concinna* and *Farranula gibbula* from southern waters off Jeju Island, Korea (East China Sea). This is the first record of *F. concinna* from Korean Waters.

Keywords: taxonomy; Corycaeidae; *Farranula*; East China Sea; microcopepod

Introduction

The genus *Corycaeus* was first established by Dana in 1846. Subsequently, Dana (1852) provided figures showing the general shape of *Corycaeus*, but did not mention a type species. Farran (1911) designated the species characterized by a posteriorly directed ventral cephalothoracic process as a new genus, *Corycella*, and designated *Corycella gibbulus* (Giesbrecht, 1891), as the type species of the genus. However, in a revision of the Corycaeidae conducted by Dahl (1912), the family was treated as comprising only a single genus, *Corycaeus* and seven subgenera. Wilson (1932, 1950) recognized that the generic name *Corycella* Farran, 1911 was preoccupied by *Corycella* Légar, 1893, a genus of Protozoa and suggested the replacement name of *Farranula*. *Farranula* species were accorded full generic status in the generic level treatment of the whole family Corycaeidae by Boxshall and Halsey (2004).

Currently, the genus *Farranula* includes seven species: *Farranula carinata* (Giesbrecht, 1891), *F. concinna* (Dana, 1849), *F. curta* (Farran, 1911), *F. gibbula*, *F. gracilis* (Dana, 1849), *F. longicaudis* (Dana, 1849) and *F. rostrata* (Claus, 1863). The genus is widely distributed, having been described from temperate and tropical Atlantic, the Mediterranean Sea (Wilson 1942) the Indian and Pacific Oceans (Giesbrecht 1893[“1892”]; Farran 1911; M. Dahl 1912; Tanaka 1957, 1960), the North Pacific Ocean (Motoda 1963), and the East China Sea and Yellow Sea (Chen et al. 1974; Zheng et al. 1982; Kang et al. 1990), and Japanese waters (Itoh 1997).

*Corresponding author. Email: hysoh@chonnam.ac.kr

Most morphological identifications for *Farranula* species have been performed based mainly on general appearance, such as proportions of prosome and urosome, distance between eyes, lateral and dorsal shape of genital double-somite (Farran 1911; Tanaka 1957; Motoda 1963), but males have been separated only by their sizes without specific taxonomic information. This has sometimes caused taxonomic confusion in identifying closely related species that share similar morphological characteristics (Dahl 1912; Chen et al. 1974; Kang et al. 1990). Currently, to clarify the ambiguity often apparent in species identifications from different zoogeographical provinces and to resolve the taxonomic confusion that exists for many small cyclopoids, minute morphological characters, such as the mouthpart armature, the surface ornamentation of the genital double-somite, the lengths of the exopodal spines, and the proportional lengths of each body segment have been considered (Böttger-Schnack 1999, 2005; Böttger-Schnack and Schnack 2009; Böttger-Schnack and Machida 2010). Their value for accurate species identification has been confirmed by molecular techniques (Böttger-Schnack and Machida 2010).

To overcome these taxonomic limitations and the confusion in species identification within the genus *Farranula*, which often leads to an underestimation of the species diversity, two *Farranula* species, *Farranula gibbula* and *Farranula concinna*, found in waters off Jeju Island of Korea (in the East China Sea) in 2009 have been examined morphologically and redescribed in detail. In addition, comparisons of the relative lengths and widths of each body segment of seven *Farranula* species given in Table 1, provide diagnostic criteria that can be used to differentiate between species within the genus. The results are compared with previous records of *Farranula* species from other areas of the world's oceans.

Material and methods

Zooplankton was taken from off Jeju Island, Korea (the East China Sea) on 27 June 2009 (Figure 1). A conical net (mesh size 100 μm , mouth diameter 45 cm) was towed vertically from near bottom (total depth 111 m) to the surface at one station. Vertical profiles of temperature and salinity (T-S) were recorded using a Conductivity/Temperature/Depth (CTD) profiler (Sea-bird, Electronics, Inc., Bellevue, WA, USA) at each station. The specimens were fixed in 99.8% ethanol (not denaturated). *Farranula* species were sorted out from zooplankton samples. Each specimen was dissected under a dissecting microscope (Nikon, JP/E200) in CMC-10 aqueous mounting medium (Masters Co., Wood Dale, IL, USA), mounted on slides, and sealed with high-quality nail-varnish. Drawings were made using a stereo-microscope (Nikon AFX-II) equipped with a drawing tube. Scale bars were given in μm . Total body length and the ratio of prosome to urosome (including caudal rami) were measured in lateral aspect, and telescoping of body somites was not considered. However, measurements of the relative lengths of different urosomites were adjusted for the telescoping effect. Zoogeographical distributions of *Farranula* species were determined from the web site of Razouls et al. (2005–2011; <http://copepodes.obs-banyuls.fr>). The descriptive terminology follows Huys and Boxshall (1991). Abbreviations used in the text and figures are as follows: ae, aesthetasc; CR, caudal rami; P1–P6, first to sixth thoracopods; exp, exopod; enp, endopod; exp(enp)-1(-2,-3) is used to denote the proximal (middle, distal) segment of a ramus. All voucher specimens were deposited in the National Institute of Biological Resources (NIBR),

Table 1. Length and width proportions of body segments of seven *Farranula* species, including *Farranula concinna* and *Farranula gibbula* from Korean water.

| Character/species (F/M) | <i>F. gibbula</i> | | <i>F. concinna</i> | | <i>F. carinata</i> | | <i>F. curta</i> | | <i>F. rostrata</i> | | <i>F. gracilis</i> | | <i>F. longicaudis</i> | |
|--|-------------------|---------------|--------------------|---------------|--------------------|--------|-----------------|--------|--------------------|-------|--------------------|--------|-----------------------|---|
| | F | M | F | M | F | M | F | M | F | M | F | M | F | M |
| Length ratio of prosomal segments | <u>2.7:1</u> | 3.4:1* | 3.3:1* | <u>3.5:1</u> | 4.6:1 | 3.4:1† | 2.7:1† | 4.6:1 | 2.6:1† | 2.4:1 | 2.6:1† | 3.2:1† | 3.4:1* | |
| | <u>3.4:1</u> | <u>3.5:1</u> | <u>2.1:1†</u> | 3.1:1¶ | <u>3.9:1†</u> | 3.5:1† | | 4.6:1 | 3.4:1† | | | | 3.5:1§ | |
| | 3.3:1 | 4:1¶ | <u>3.2:1</u> | <u>3.2:1</u> | <u>3.8:1**</u> | | | | 3.3:1§ | | | | | |
| Ratio of length to maximum width of prosome | 2.4:1 | 2.2:1* | 2.3:1* | <u>1.5:1</u> | 2.4:1† | 2.4:1† | 2.4:1† | 2.4:1 | 1.8:1† | 2.4:1 | 2.3:1† | 2.3:1† | 2.4:1* | |
| | 2.5:1 | 2.2:1¶ | 2:1† | 2.5:1 | 2.4:1* | 2.2:1† | 2.2:1† | 2.2:1 | 2.4:1† | 2.2:1 | 2.4:1† | | 2.3:1§ | |
| Length ratio of prosome to genital double-somite/somite | 2.9:1 | 1.6:1* | 2.7:1* | <u>2.2:1</u> | 3.5:1 | 1.8:1† | 2.4:1† | 2.4:1 | 2.1:1† | 3:1 | 1.8:1† | 3.1:1* | | |
| | <u>3:1</u> | <u>1.6:1</u> | 2.9:1† | 2:1¶ | 3.9:1* | 2:1† | | 2.5:1 | 2.4:1† | | | 3.4:1§ | | |
| | 3.2:1 | 1.5:1¶ | <u>3:1</u> | <u>3.2:1</u> | 3.7:1** | | | 1.5:1§ | | | | | | |
| Ratio of length to maximum width of genital double-somite/somite | 2.1:1 | 2.4:1* | <u>3:1*</u> | 2.4:1 | 2:1 | 2.8:1† | 2:1† | 2.1:1 | 2.9:1* | 2.1:1 | 3:1† | 2.6:1* | | |
| | 1.9:1 | <u>2.5:1</u> | 2.5:1† | <u>2.6:1¶</u> | 1.8:1* | | | 3:1 | 2.4:1† | | | 2.4:1§ | | |
| | <u>2.1:1</u> | <u>2.3:1¶</u> | 2.6:1 | 2.6:1 | 2.2:1** | 2.6:1† | | 2.8:1 | 2.6:1† | | | | | |
| Length ratio of double-somite/somite to caudal ramus | 2.6:1* | 2.7:1* | 2.6:1* | <u>2.5:1</u> | 2.2:1 | 2.2:1† | 2.5:1† | 4:1 | <u>5.1:1*</u> | 2.7:1 | 2.4:1† | 1.4:1* | | |
| | <u>1.8:1</u> | <u>2.5:1</u> | 2.3:1* | 2.3:1¶ | 1.9:1* | | | 5.3:1 | <u>4.4:1†</u> | | | 1.4:1§ | | |
| | <u>2.3:1</u> | 2.3:1¶ | <u>2.6:1</u> | 2:1** | | | | 5.5:1 | 3.2:1† | | | | | |
| Dorsal projection on prosome | 2.3:1 | | 2.5:1 | 2:1 | 2:1 | 2:1 | | 3.3:1§ | | | | | | |
| | P | A | A | A | A | A | A | A | A | A | A | P | | |

*Griesbrecht 1893 ("1892"); †Dahl 1912; ‡Zheng et al. 1982; ¶Present study; **, Motoda 1963.

Grey-shaded blocks represent doubtful data that require re-examination.

P, present; A, absent.

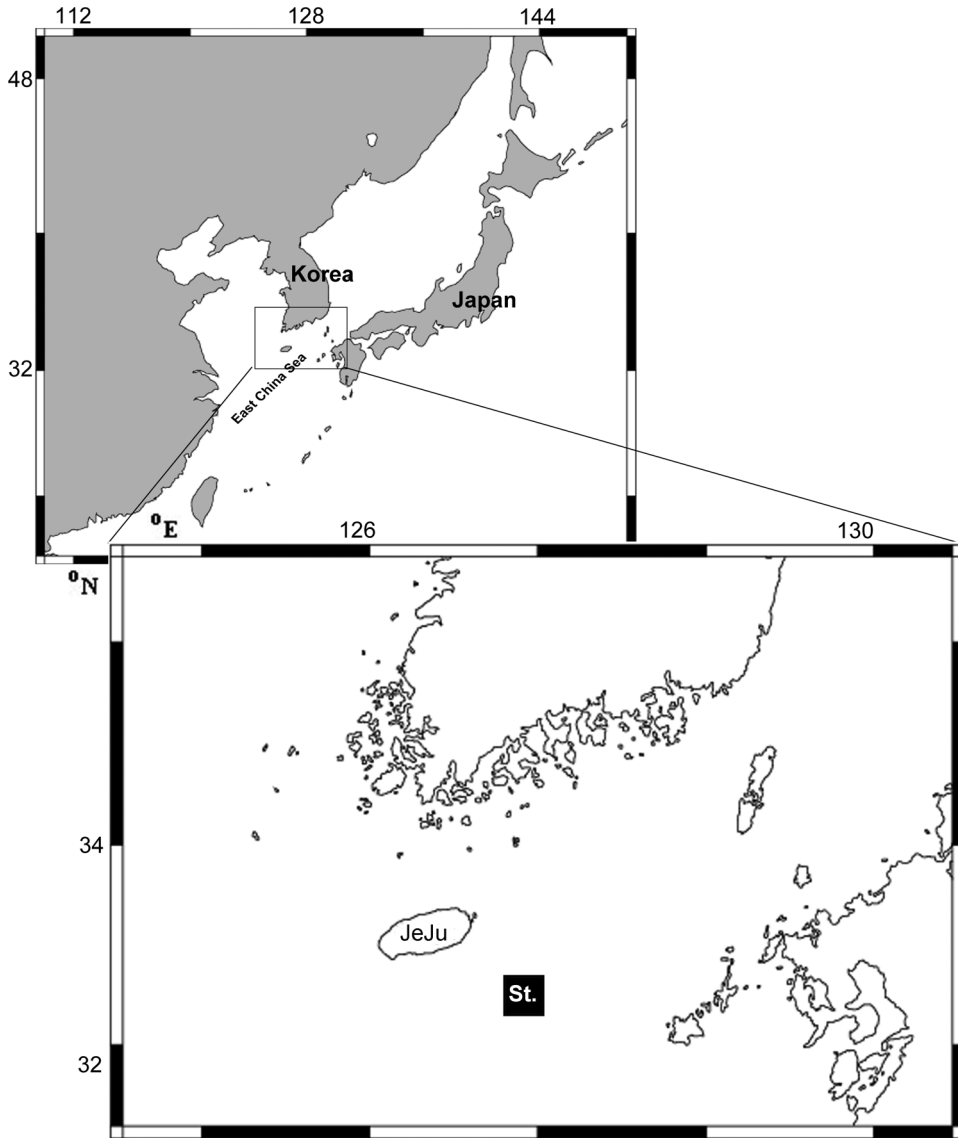


Figure 1. Location of sampling station west of Jeju Island (the East China Sea), Korea.

Incheon, Korea. Corycaeidae was established by Wilhelm Giesbrecht in his comprehensive monograph on the pelagic copepods of the Gulf of Naples (Giesbrecht, 1893 ["1892"]). Following the arguments given by Holthuis and Vervoort (2006), the actual date of publication of Giesbrecht's monograph appears to be different (1893) from the date specified in the work (1892). According to Article 22A.2.3. of the International Code of Zoological Nomenclature, it is recommended to cite both dates with the actual date cited first, followed by the imprint date for information and enclosed in parentheses or other brackets and quotation marks.

Descriptions

Order **CYCLOPOIDA** Burmeister, 1835

Family **CORYCAEIDAE** Dana, 1852

Farranula concinna (Dana, 1849)

(Figures 2–6)

Corycaeus concinnus: Giesbrecht 1893[“1892”], p. 661, 675, fig. f.

Corycella concinna: Farran 1911, p. 286, rem.; Farran 1936, p.139

Corycaeus concinnus: Mori 1937, p.138, figsf, m

Corycaeus (Corycella) concinnus: M. Dahl 1912, p.121, figs f, m; Tanaka 1957, p. 96, figs f, m, rem, 1960, p. 88, figs f, m, rem.; Chen et al. 1974, p.66, figs f, m; Zheng et al. 1982, p.150, fig. F.

Farranula concinna Wilson, 1942, p. 186, fig. 33.

Material examined

In all, 72 ♀♀ and 19 ♂♂ were collected from off Jeju Island, Korea (in the East China Sea) (32°00' N, 126°5' E) on 17 June 2009, of which 5 ♀♀ and 5 ♂♂ were dissected and examined in detail; 2 ♀♀ and 2 ♂♂ have been deposited in the National Institute of Biological Resources (NIBR), Incheon, Korea (NIBRIV0000245151).

Description of female

Body cylindrical, tapering posteriorly. Total body length in lateral view 930 μm (average: 885 μm, $n = 4$), measured from anterior margin of prosome to posterior margin of caudal rami. Urosome distinctly narrower than prosome.

Prosome two-segmented (Figure 2A,B), frontal part rounded, with two large separate cuticular lenses: cephalosome completely fused with first pedigerous somite, second to fourth pedigerous somites forming single compound segment with suture line between second and third pedigerous somites; prosome about 1.8 times as long as urosome including caudal rami, 2.5 times as long as urosome excluding caudal rami; third pedigerous somite dorsally covering fourth pedigerous somite, forming inverted triangular shape; fourth pedigerous somite with extended and pointed posterolateral corners, secretory pore on inner pleural area (Figure 2A).

Urosome (Figure 2A–C) two-segmented: first urosomite bearing P5 ventrolaterally (Figure 2D); genital double-somite and anal somite combined. Proportional lengths (%) of urosomites and caudal rami 7.8 : 62.8 : 29.4. Genital double-somite (Figure 2A–C) rounded in anterior two-fifths and remaining part almost rectangular, length 2.5 times greater than maximum width; rounded hump-like projection arising from anteroventral margin (visible in lateral view), ornamented with patch of spinules, posteroventral margin fringed with minute spinules from one-third distance from posterior margin almost to distal end, in lateral view; posterior margin finely serrated ventrolaterally (Figure 2C); dorsoposterior surface with two adhering spermatophores

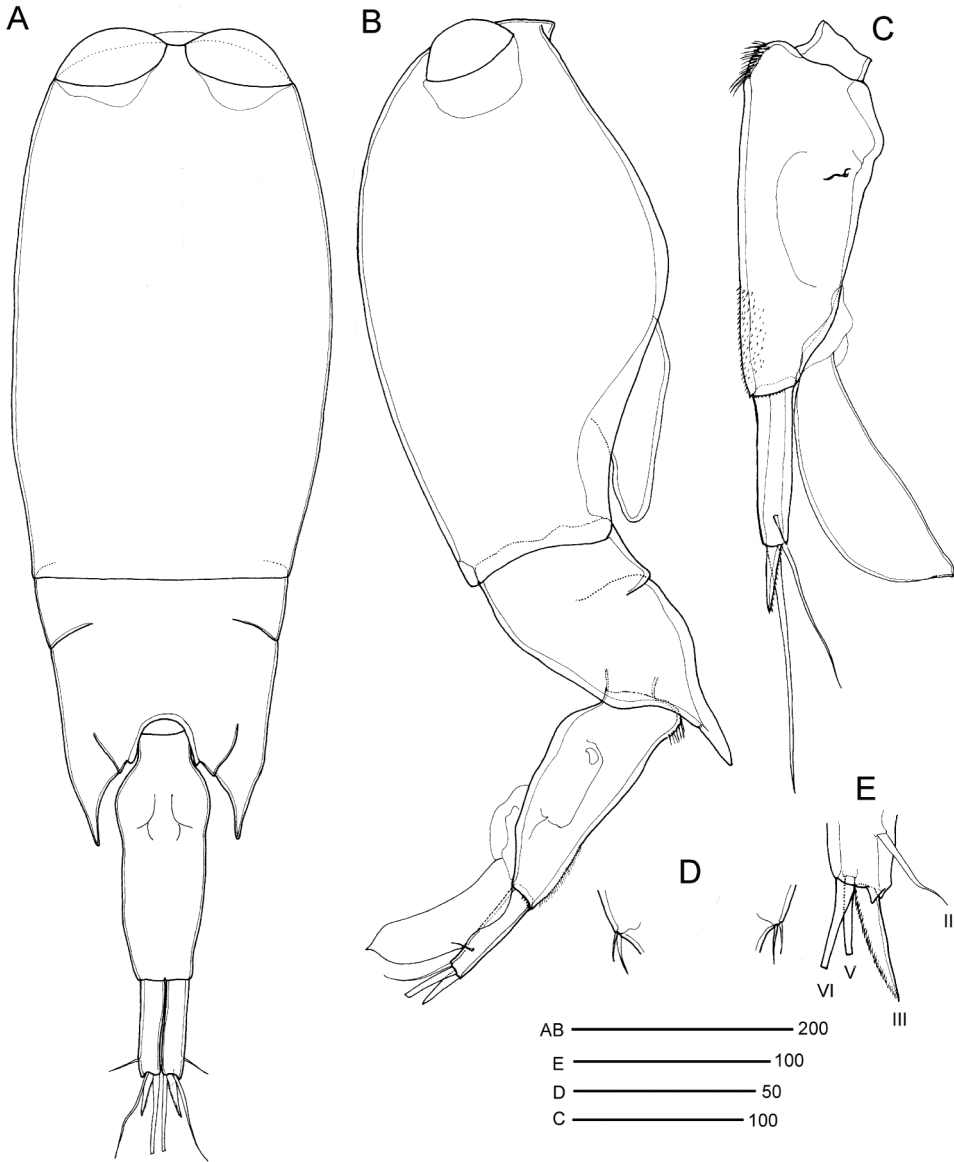


Figure 2. *Farranula concinna*. Female: (A) habitus, dorsal view; (B) habitus, lateral view; (C) urosome, lateral view; (D) P5; (E) caudal setae, left.

(Figure 2B); genital area located dorsolaterally, paired genital apertures approximately one-third distance from anterior margin of dorsal surface, hidden behind opercula. Caudal rami (Figure 2A,C,E) cylindrical, about two-fifths length of genital double-somite, 3.3 times longer than width at base. Each ramus with triangular process located near insertion armed with four setae: slender anterolateral seta II, outer posterolateral seta III short and robust, spiniform and serrated along medial margin, inner terminal seta IV longest and dorsal seta V almost equal in length to seta III (Figure 2E).

Antennule (Figure 3A) short, six-segmented. Armature formula 1-[2], 2-[8], 3-[2+ae], 4-[3+a], 5-[2+ae], 6-[5+(1+ae)]. Proportional lengths (%) of segments measured along posterior non-setiferous margin 21.8 : 10.2 : 14.2 : 29.5 : 11.5 : 12.8.

Antenna four-segmented (Figure 3B,C), with coxa and basis fused and bearing three endopodal segments. Coxobasis 2.4 times longer than wide, with strong bipinnate seta at inner distal margin. Endopod three-segmented, unequal in length; first endopodal segment robust, much longer than the rest of endopodal segments, about 2.7 times as long as wide, bearing bipinnate seta on inner proximal margin, slightly shorter than coxobasal seta; inner distal margin roughly serrated from two-thirds of margin, with long, curved spinous process at three-quarters of serrated part outer lateral margin ornamented row of denticles; naked seta on distolateral margin (indicated by arrow in Figure 3C); second endopodal segment short, bearing three elements: curved stout spine arising from outer distal margin, with lateral branch; slender, pinnate spine located near its base and reaching almost middle of distal spine; and short curved spine arising from inner margin. Third endopodal segment cylindrical, as long as wide and armed with curved terminal claw plus two elements, short spine arising from inner margin and strong seta on outer margin of segment, extending to two-thirds of terminal claw.

Mandible (Figure 3D,E) with two elements on gnathobase: one spine and one blade. Spine broad and robust, with two naked slender setae on medial area and two basal setae. Blade forming spinuous processes, surrounded by patch of spinules around base.

Maxillule (Figure 3F) reduced, bearing four articulated spinous elements: innermost one A at some distance from other elements and distal margin serrated, element B longest and stout, and distal margin with spinous process, element C short and serrated, and element D short and naked.

Maxilla (Figure 3G) two-segmented, allobasis shorter than syncoxa: syncoxa unarmed; allobasis produced distally into strong spine, carrying two naked setae proximally, inner margin bearing three spines of different lengths: two naked spines and longest, unipinnate innermost spine with slender naked seta at base of spine.

Maxilliped (Figure 3H) three-segmented: syncoxa unarmed; basis robust and expanded, with two elements along margin: proximal one short, located at base of distal one, distal one with two to four spinules along inner margin, located at two-thirds distance of inner margin, three times shorter than basis; endopodal segment drawn out into long curved claw, unornamented and slightly shorter than basis, accessory armature consisting of slender long, unipinnate seta on inner proximal margin, and short unipectinate spine laterally on outer proximal margin of claw.

Swimming legs 1–3 (Figure 4A–C) comprising coxa, basis and three-segmented rami. Intercoxal sclerites well developed; basis of P1 and P3 with naked outer seta, whereas that of P2 with vestigial coxal seta (indicated by arrows in Figure 4B), basis of P1 to P3 with round process between insertions of endopod and exopod; exopods distinctly longer than endopods.

Exopods of P1 to P3: inner margin of proximal segments with long setules, first segments of P1 and P3 without spine, and relative length ratio of terminal spine to distal outer spine of P1 to P3 different: P1 smallest (about 2 : 1), in P2 2.6 : 1, and P3 largest (3.8 : 1); terminal spines longer than distal segments: in P1 1.3 times longer, in P2 about 1.7 times longer, and in P3 2.4 times longer.

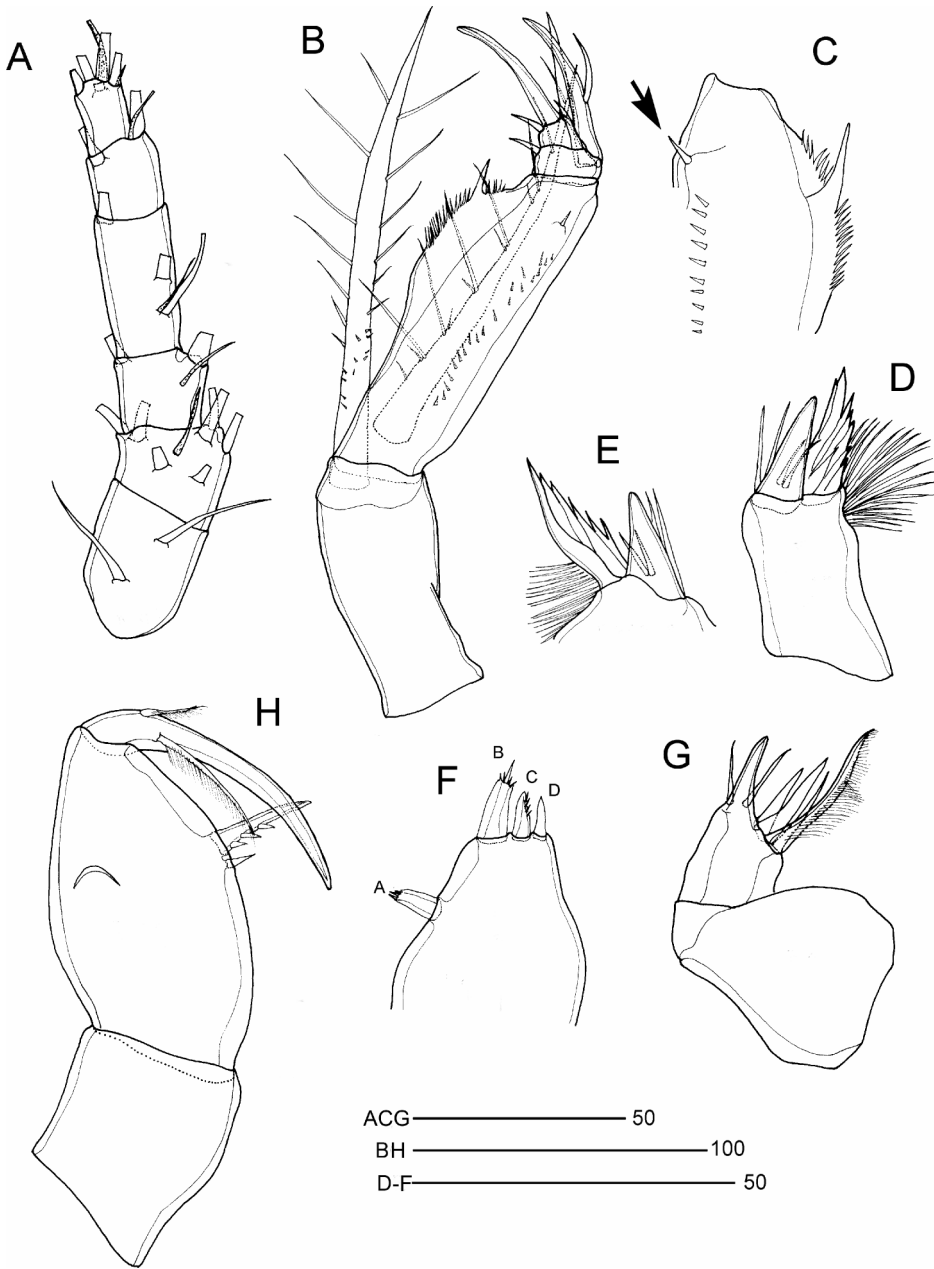


Figure 3. *Farranula concinna*. Female: (A) antennule; (B) antenna, posterior; (C) distal margin of antenna, anterior, arrow indicating naked seta on distal outer margin; (D) mandible, left side; (E) mandible, right side; (F) maxillule, individual elements designated using capital letters; (G) maxilla; (H) maxilliped.

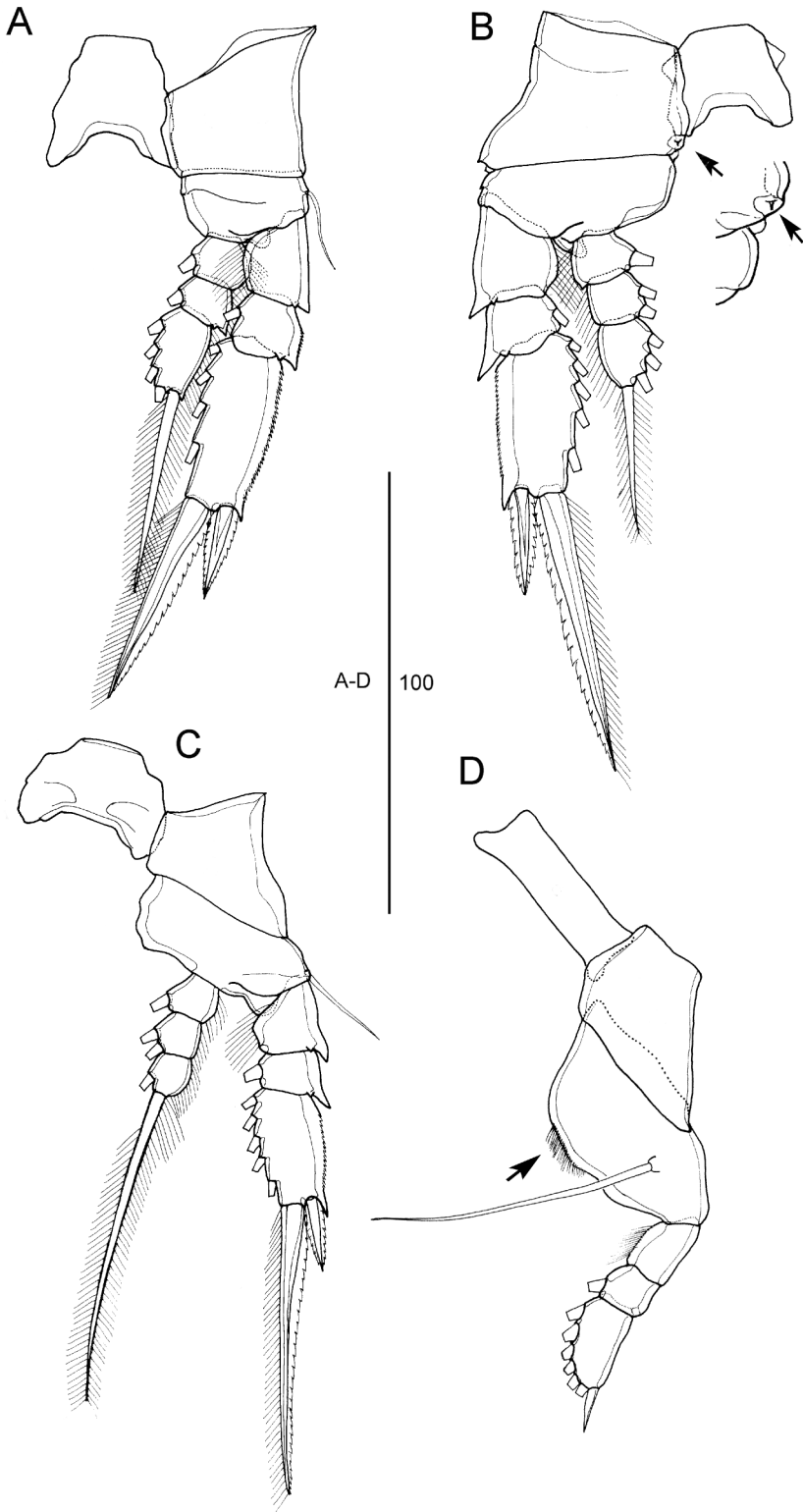


Figure 4. *Farranula concinna*. Female: (A) P1; (B) P2; (C) P3; (D) P4, arrow indicating row of spinules along inner margin of basis.

Table 2. Armature formula of P1 to P4 in *Farranula concinna*.

| Leg | Coxa | Basis | Exopod | Endopod |
|-----|------|-------|-------------------|-------------------|
| P1 | 0-0 | 1-0 | 0-0; 0-1; I, I, 4 | 0-1; 0-1; 0, 2, 3 |
| P2 | 0-1 | 0-0 | 0-0; 0-1; I, I, 5 | 0-1; 0-2; 0, 1, 3 |
| P3 | 0-0 | 1-0 | 0-0; 0-1; I, I, 5 | 0-1; 0-2; 0, 1, 1 |
| P4 | 0-0 | 1-0 | 0-0; 0-1; I, 6 | Absent |

Roman numerals indicate spines, Arabic numerals indicate setae.

Endopods of P1 to P3: outer margins of segments with fringe of long setules; relative lengths of distal segments of P1–P3 different, relatively: P1 longest, and P3 shortest; each segment of P3 equal in length; outer margins of segments fringed with setules in P1 to P3; terminal seta of distal segment shortest in P2 and longest in P3; relative length ratio of distal segments to terminal setae of P1–P3 different: in P1 1 : 2.6, and in P2, 1 : 2.2, and in P3 1 : 7.8.

P4 (Figure 4D): with transversely extended intercoxal sclerite narrow, coxa unarmed, and basis with outer basal seta arising from posterior surface, fringed with row of setules along inner margin; exopod well developed, three-segmented, bearing spinules along inner margin of first segment; proportional length ratio of each segment, 37.5 : 21.9 : 40.6; distal segment about 1.8 times as long as terminal spine. Endopod absent. Armature formula of P1 to P4 as shown in Table 2.

P5 (Figure 2D) consisting of two unequal simple setae, located ventrolaterally. P6 (Figure 2A–C) represented by operculum closing off each genital aperture.

Male

Total body length in lateral view 845 μm (average: 820 μm , $n = 7$), measured from anterior margin of prosome to posterior margin of urosome. Urosome distinctly narrower than prosome (Figure 5A,B).

Prosome two-segmented, cephalosome fused with first pedigerous somite, and second to fourth pedigerous somites fused into compound segment, prosomal length about 1.8 times as long as urosome including caudal rami, 2.5 times urosome length excluding caudal rami (Figure 5A,B). Suture line present between second and third pedigerous somites dorsolaterally on surface; paired epimeral extensions of third pedigerous somite largely covering fourth pedigerous somite, forming inverted triangle-shape on each side; fourth pedigerous somite with extended and pointed posterolateral corners, reaching midway along genital somite. Frontal part of prosome rounded, with two large contiguous cuticular lenses (Figure 5A).

Genital somite (Figure 5A,B) with four secretory pores on dorsomedial surface; posterior part between sharply narrowing region (indicated by arrows in Figure 5A) and rear margin about 2.1 times shorter than rest of genital somite, and 1.2 times as long as caudal ramus.

Caudal rami seven times longer than wide at base (Figure 5A,B), about 2.3 times shorter than urosome. Armature of rami similar to that of female, except for longer caudal seta III.

Antennule (not figured) with segmentation and armature similar to that of female.

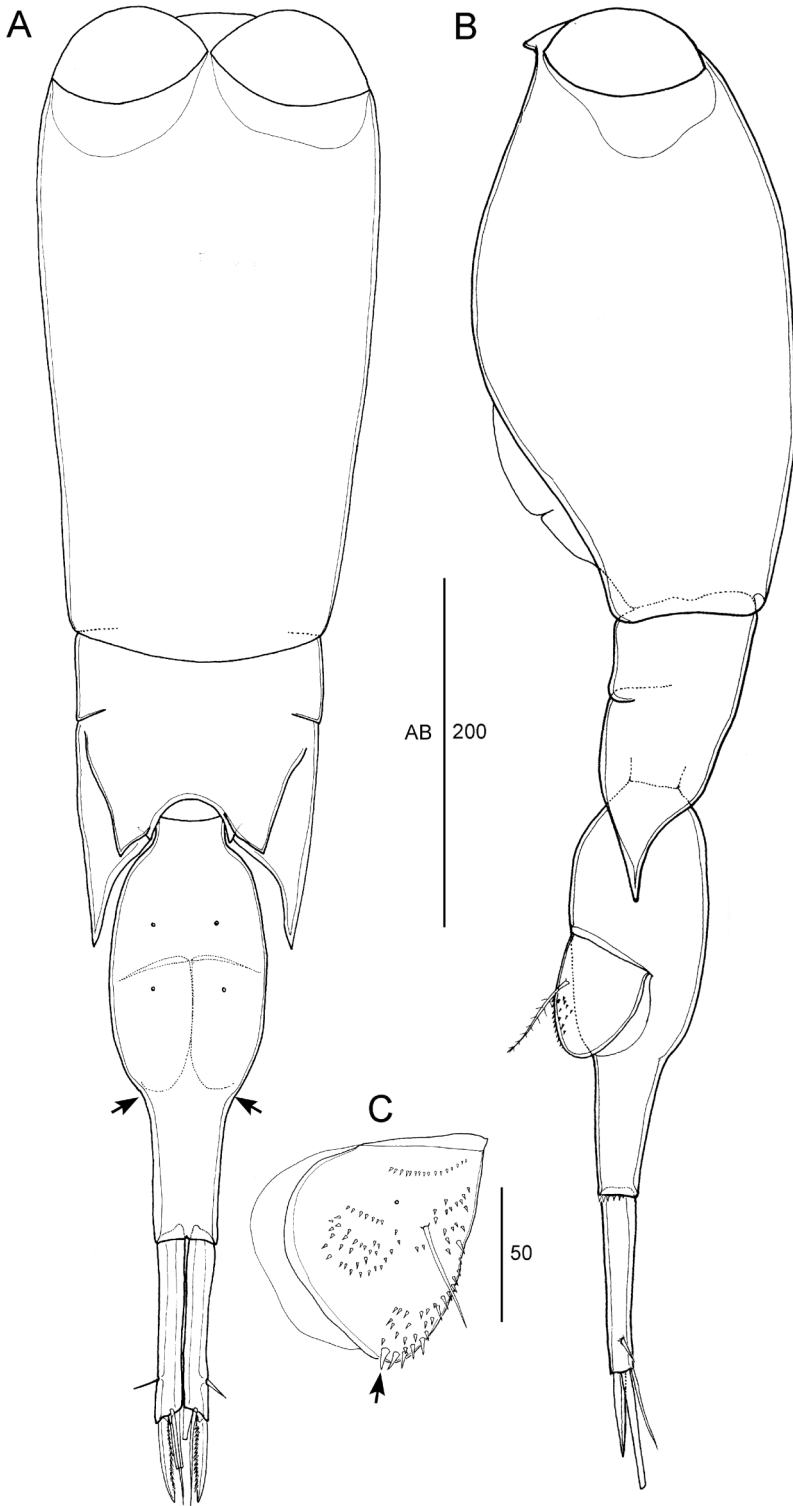


Figure 5. *Farranula concinna*. Male: (A) habitus, dorsal view; (B) habitus, lateral view, arrows indicating sharply narrowing part; (C) genital flap, large denticles indicated by arrow.

Antenna (Figure 6A) sexually dimorphic, four-segmented, with coxa and basis fused and endopod three-segmented. Coxobasis 2.2 times as long as wide, with long, bipinnate strong seta on inner distal margin, reaching to tip of first endopodal segment, fringed with patch of spinules along inner margin. First endopodal segment about 2.5 times as long as maximum width, bearing bipinnate seta on ventral proximal margin, almost as long as coxobasal seta, outer lateral margin ornamented with row of denticles. Second endopodal segment short, bearing three elements: curved stout spine arising from outer distal margin, with lateral branch, short, plumose spine located near base, and short curved spine arising from inner distal margin. Third endopodal segment drawn out into long claw, extending to two thirds of coxobasis and armed with four elements: short spine arising from proximal inner margin, long naked seta and two slender, naked setae inserted on outer proximal margin.

Maxilliped (Figure 6B) sexually dimorphic, four-segmented, comprising syncoxa, basis and two-segmented subchela. Syncoxa without surface ornamentation, unarmed. Basis robust, oval-shaped, particularly swollen in proximal half, inner margin with spiniform seta ornamented with two to four short spinules along inner margin, with slender spinules between proximal third and seta of basis. Subchela comprising unarmed proximal endopodal segment and distal endopodal segment drawn out into long curved claw, with accessory armature consisted of minute, unipinnate spine on outer proximal margin and long, unipinnate spine delimited basally to inner proximal corner of claw.

Swimming legs 1–3 (Figure 6C–E) segmentation and armature similar to female, except relative length ratio of terminal spine to outer distal spine larger (4.3 times) than that of female (3.8 times).

P4 (Figure 6F) similar to that of female, except length ratio of distal segment to terminal spine (1.9 : 1) larger than that of female (1.1 : 1).

P5 similar to that of female.

P6 (Figure 5B,C) represented by genital flap closing off each genital aperture, armed with long seta; surface ornamented with unique pattern of denticles and two small secretory pores: anterior part with curved line of denticles, outer part fringed with minute denticles and distal margin with comparatively large denticles (indicated by arrow in Figure 5C).

Remarks

This species is consistent with the typical morphology of the genus *Farranula* as characterized by the ventral cephalothoracic process in the female and leg 4 lacking an endopod in both sexes, which distinguishes *Farranula* from the genus *Corycaeus* (Farran, 1911). The morphological features, such as the combination of proportional lengths of urosomites and caudal ramus, the shape of the genital somite, and the location of the spermatophore attached distally on the genital somite, show this species to be *F. concinna*. Earlier records of *F. concinna* have typically been limited to simple and ambiguous descriptions based on habitus, genital double-somite, antenna and/or maxilliped, with P4. In this study, mouthparts including mandible, maxillule, maxilla, and all legs are newly described and revealed as important morphological characteristics: in female 1) anteroventral protrusion of genital double-somite bearing patches of setules, 2) posteroventral margin of genital double-somite fringed with spinules from one-third distance along posterior margin to almost distal end in lateral view, 3) second element of the maxillule (Figure 3F) robust and longest, with spinous process on top

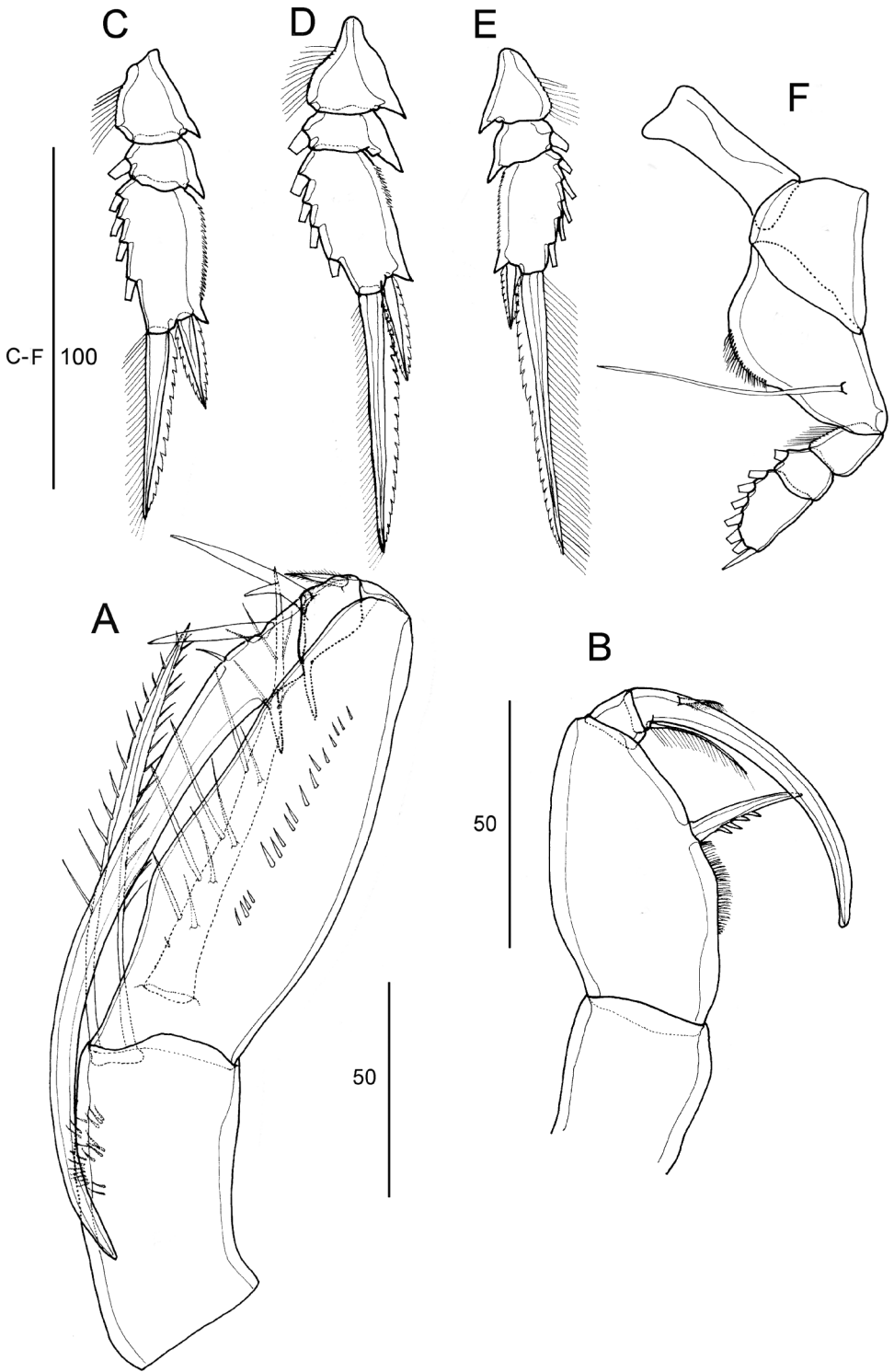


Figure 6. *Farranula concinna*. Male: (A) antenna; (B) maxilliped; (C) P1, exopod; (D) P2, exopod; (E) P3, exopod; (F) P4.

of it, and remaining elements about equal in length, 4) allobasis of maxilla drawn out distally into strong spine plus three spines of different lengths, 5) basis of P4 fringed with row of spinules along inner margin (arrowed in Figure 4D); in male 6) maxilliped four-segmented, ornamented with row of spinules between seta and about middle of proximal inner margin, 7) relative lengths of spines of P1 to P3 exp-3 different from those of female: in P2-3 exp-3, relative length ratio of terminal spine to distal spine larger than that of female, and that in P1 smaller than in female, 8) distance between sharply narrowing part and distal margin 1.2 times almost same or slightly longer than length of caudal ramus.

Farranula gibbula (Giesbrecht, 1891)
(Figures 7–11)

Corycaeus gibbulus Giesbrecht, 1891, p. 481; Giesbrecht 1893 [“1892”], p. 675, pl. 51, figures 22, 23; Mori 1937 (1964), p. 137, pl. 76, figs 12–16, pl. 77, figs 1–4.

Corycaeus pellucidus: Wolfenden 1906, p. 1027, figs F.

Corycaeus brevis: Farran 1911, p. 285, pl. 10, figs 16, pl. 11, fig. 7.

Corycaeus (Corycaella) gibbulus: M. Dahl 1912, p. 115, pl. 15, figs 14, 9, 10, 25, 35, 36; Tanaka 1957, p. 96, pl. 10, figs 611; 1960, p. 89, 90, pl. 38, fig. 12; Chen al. 1974, p. 65, figures F,M; Zheng et al. 1982, p. 148, fig. F

Farranula gibbula: Motoda 1963, p. 252–255, fig. 27.

Material examined

In all, 109 ♀♀ and 55 ♂♂ collected from the East China Sea (to the west of Jeju island of Korea) (32°00' N, 126°5' E) on 17 June 2009, of which 5 ♀♀ and 5 ♂♂ were dissected and examined in detail and 2 ♀♀ and 2 ♂♂ are deposited in the National Institute of Biological Resources (NIBR), Incheon, Korea (NIBRIV0000245152).

Description of female

Body cylindrical, tapering posteriorly. Total body length in lateral view 1025 μm (average: 1012 μm, $n = 4$ individuals), measured from anterior margin of prosome to posterior margin of caudal rami. Urosome distinctly narrower than prosome (Figure 7A,B).

Prosome length about 2.4 times longer than urosome including caudal rami, 3.6 times urosome length, excluding caudal rami. Second prosomal somite with dorso-posterior projection on third pedigerous somite in lateral view, with extended and pointed posterolateral corners and small protrusions on inner distal part in dorsal view, fourth pedigerous somite with secretory pores on each inner and outer pleural area (arrowed in Figure 7B).

Proportional lengths (%) of urosomites and caudal rami are 6.6 : 59 : 34.4. Genital double-somite (Figure 7A,B) irregular, showing folds in dorsal view, 2.3 times longer than maximum width in middle of somite, round hump-like projection arising

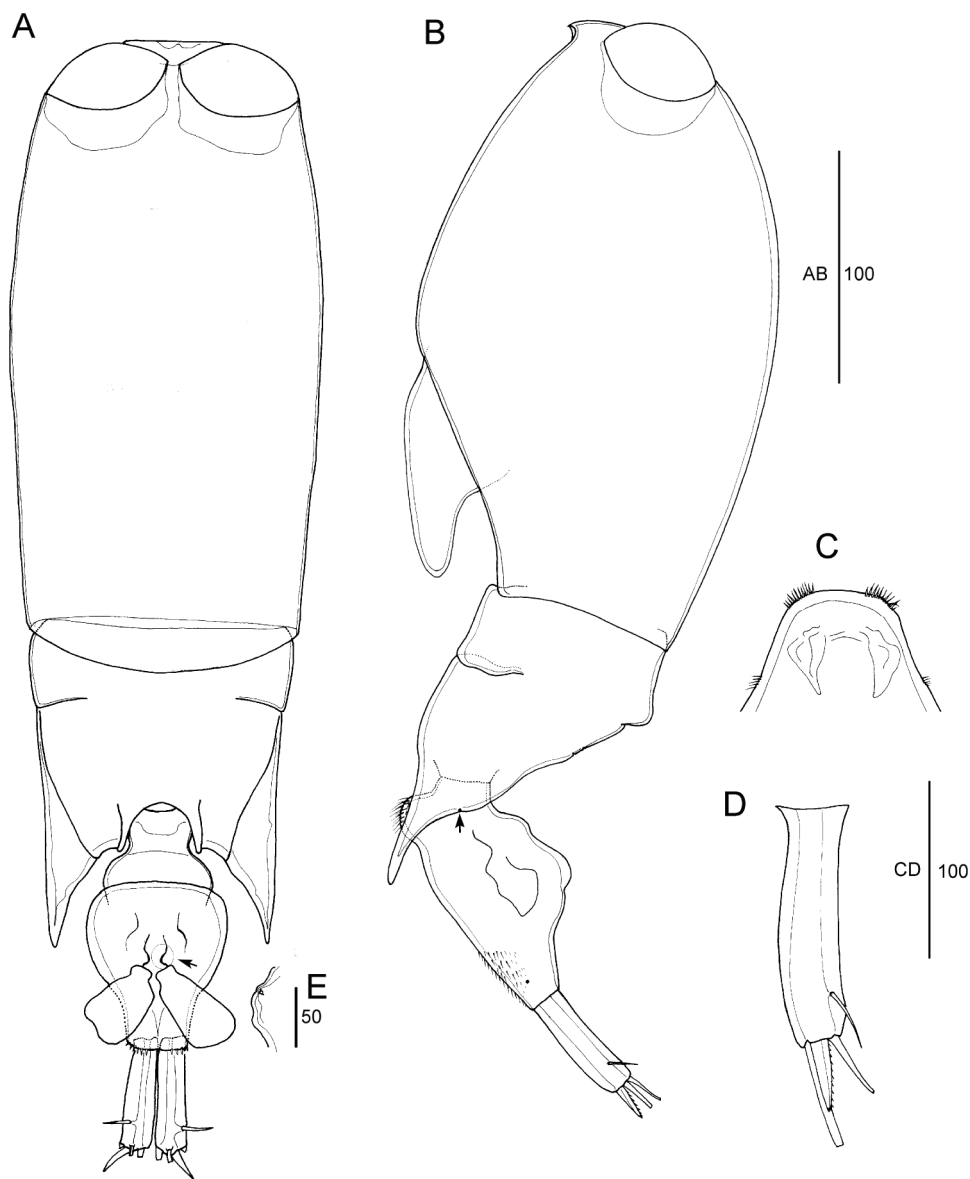


Figure 7. *Farranula gibbula*. Female: (A) habitus, dorsal view; (B) habitus, lateral view; (C) anterior part of anteroventral projection, ventral view; (D) caudal ramus, lateral view; (E) P6.

from anteroventral margin (visible in lateral view), bearing patch of spinules laterally (Figure 7B,C), posteroventral and lateral margins fringed with minute spinules and denticles; posterior margin finely serrated ventrally, dorsoposterior surface often with two attached spermatophores.

Caudal rami (Figure 7A,B,D) about 2.3 times shorter than genital double-somite, 3.5 times longer than maximum width. Caudal setation similar to that of *F. concinna*.

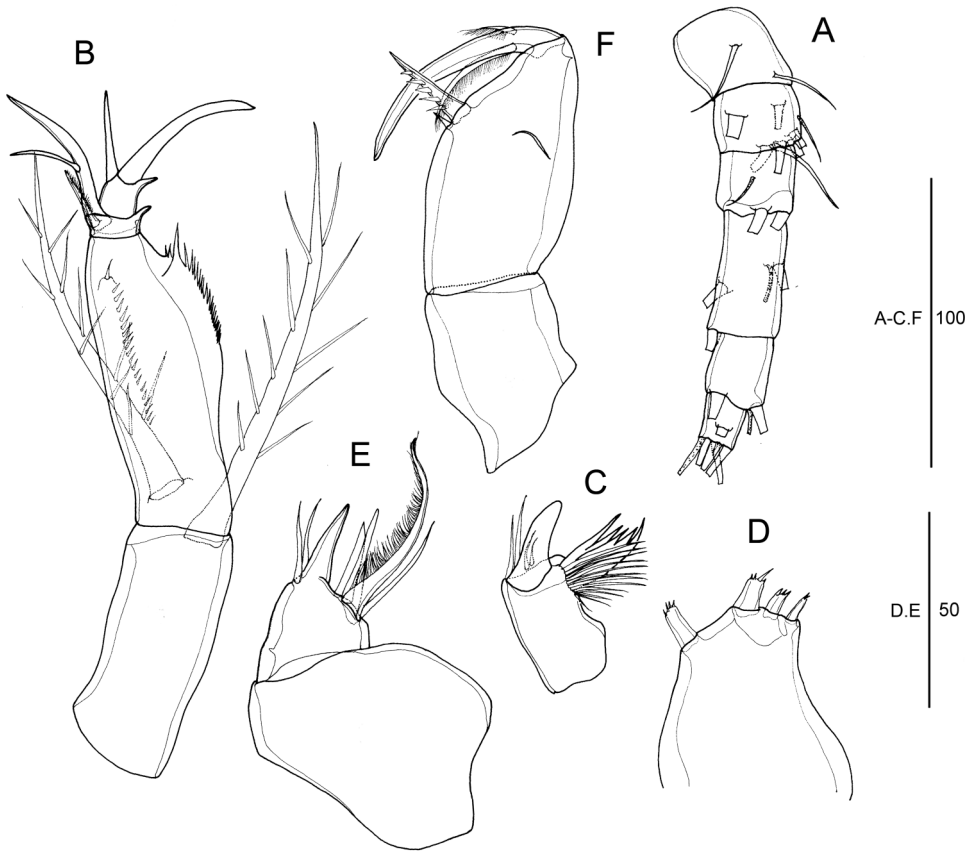


Figure 8. *Farranula gibbula*. Female: (A) antennule; (B) antenna; (C) mandible; (D) maxillule; (E) maxilla; (F) maxilliped.

Antennule (Figure 8A) similar to that of *F. concinna*. Proportional lengths (%) of segments measured along posterior non-setiferous margin 17.6 : 13.5 : 13.5 : 28.4 : 14.9 : 12.1.

Antenna (Figure 8B) similar to that of *F. concinna* but outer spine of third endopodal segment relatively shorter than that of *F. concinna*.

Mandible (Figure 8C) similar to that of *F. concinna*.

Maxillule (Figure 8D) similar to that of *F. concinna*, except innermost element (A) longest. In *F. concinna* second inner element longest

Maxilla (Figure 8E) and maxilliped (Figure 8F) similar to *F. concinna*.

Swimming legs 1–3 biramous (Figure 9A–C), with armature and ornamentation as in *F. concinna*.

Exopods of P1 to P3: length ratios of terminal spines to distal spines, in P1 and P2 2.6 : 1, and P3 largest (2.8 : 1), terminal spines longer than distal segments, in P1 1.2 times longer, in P2 about 1.4 times longer, and in P3 2.1 times longer.

Endopods of P1 to P3: proportional lengths of distal segments to terminal setae of P1 to P3 different, in P1 1 : 2.1, and in P2, 1 : 1.9, and in P3 1 : 7.5.

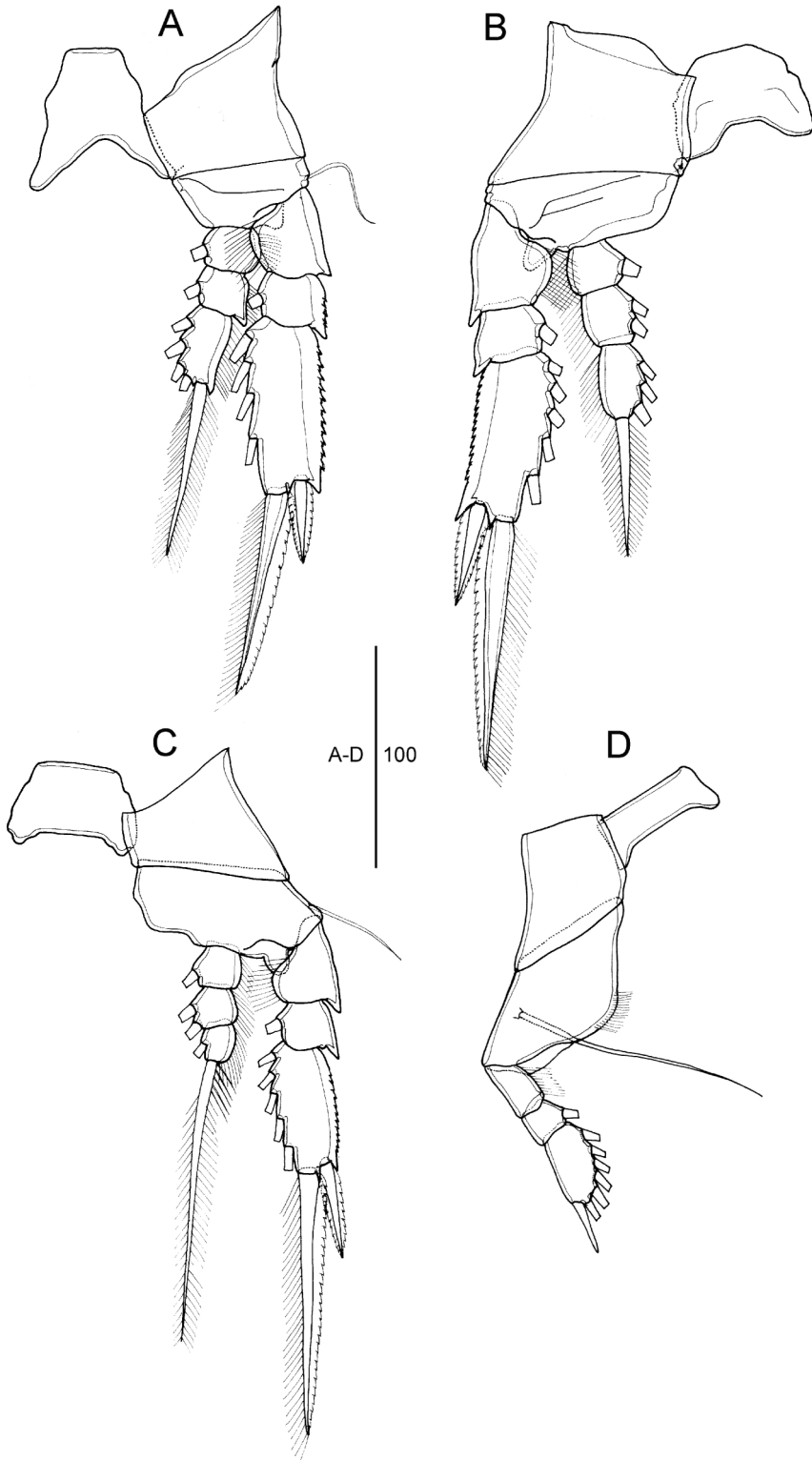


Figure 9. *Farranula gibbula*. Female: (A) P1; (B) P2; (C) P3; (D) P4.

P4 (Figure 9D) similar to that of *F. concinna*, but proportional lengths of endopodal segments 35.7 : 21.4 : 42.9 and length ratio of distal segment to terminal spine 1.3 : 1.

P5 similar to that of *F. concinna* (not figured)

P6 (Figure 7E) represented by operculum closing off each genital aperture.

Male

Total body length in lateral view 863 μm (average: 833.5 μm , $n = 7$ individuals), measured from anterior margin of prosome to posterior margin of caudal rami. Urosome distinctly narrower than prosome (Figure 10A,B).

Prosome (Figure 10A,B) two-segmented, prosome length about 1.2 times longer than urosome including caudal rami, about 1.7 times longer than urosome excluding caudal rami; pleural areas extending quarter of length of urosome. Two large separate cuticular lenses located very close to each other on frontal margin.

Caudal rami 7.1 times longer than wide at base (Figure 10A,B), longer than in female (3.5 times), about 2.5 times shorter as long as genital somite. Armature of rami similar to that of female, but caudal seta III longer than that of female.

Antenna (Figure 11A) similar to that of *F. concinna*, but third endopodal segment with shorter and more robust spine on proximal inner margin and third endopodal segment longer, expanding to 80% of syncoxa, greater than in *F. concinna* (expanding to 67% of syncoxa).

Maxilliped (Figure 11B) similar to that of *F. concinna*, except for basis bearing coarse setules between proximal third and medial seta, as compared with that of *F. concinna*. Distal endopodal segment (claw) relatively longer than in *F. concinna*.

Swimming legs 1–3 (Figure 11C–E) similar in segmentation and armature to female, except proportional length of terminal spine to outer distal spine in P3, relatively longer (3.7 times) than in female (2.8 times).

P4 (Figure 11F) similar to that of female, but length ratio of distal segment to terminal spine smaller (2 : 1) than in female (1.3 : 1).

P6 (Figure 10B,C) with long plumose seta and ornamented with many denticles: proximal area with rows of denticles; inner distal area with large denticles; middle part of outer surface covered with patch of minute denticles.

Remarks

Females of *F. gibbula* from Korean waters closely match Giesbrecht's (1893["1892"]): figs 22, 23) original description, and are characterized by a dorsoposterior projection on the second prosomal somite and uniquely shaped genital double-somite in both dorsal and lateral profile. In addition, the species is distinguished from other *Farranula* species by the following morphological characters: in the female 1) the outer spine of the third endopodal segment of the antenna is relatively shorter than that of *F. concinna*, 2) the innermost element A of the maxillule is longest, whereas in *F. concinna* it is shorter than the adjacent element B, 3) the ratio of the length of the distal spine on inner margin of basis of the maxilliped to length of the segment itself is smaller (2.6 : 1) than that of *F. concinna* (3 : 1), 4) the genital double-somite is ornamented with minute spinules and denticles on posteroventral and lateral margins; in the male 5) the pleural areas of the second prosomal somite extended over 25% of the length of the urosome, 6) caudal seta IV is longer than that of female, 7) the basis

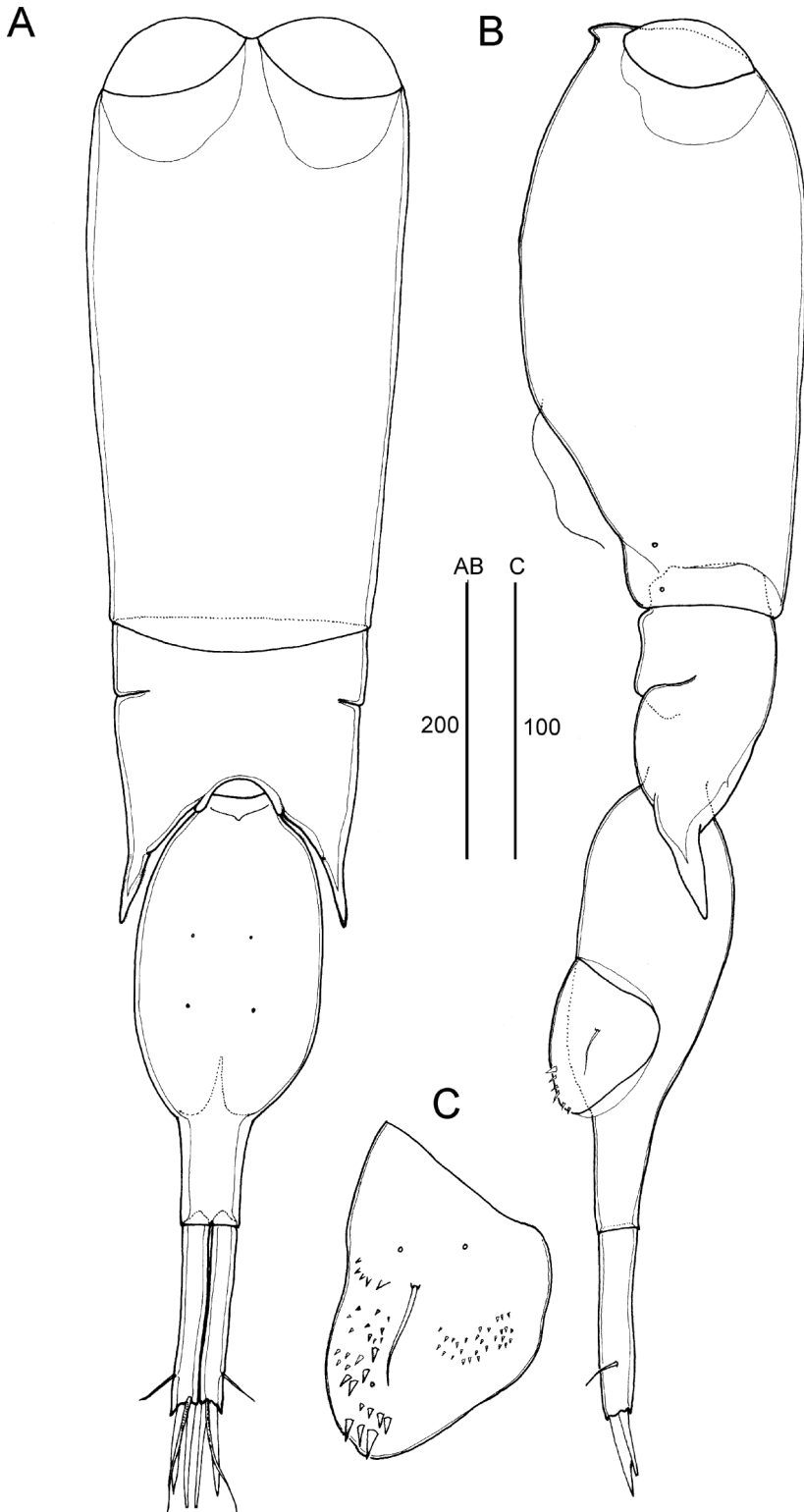


Figure 10. *Farranula gibbula*. Male: (A) habitus, dorsal view; (B) habitus, lateral view; (C) genital flap.

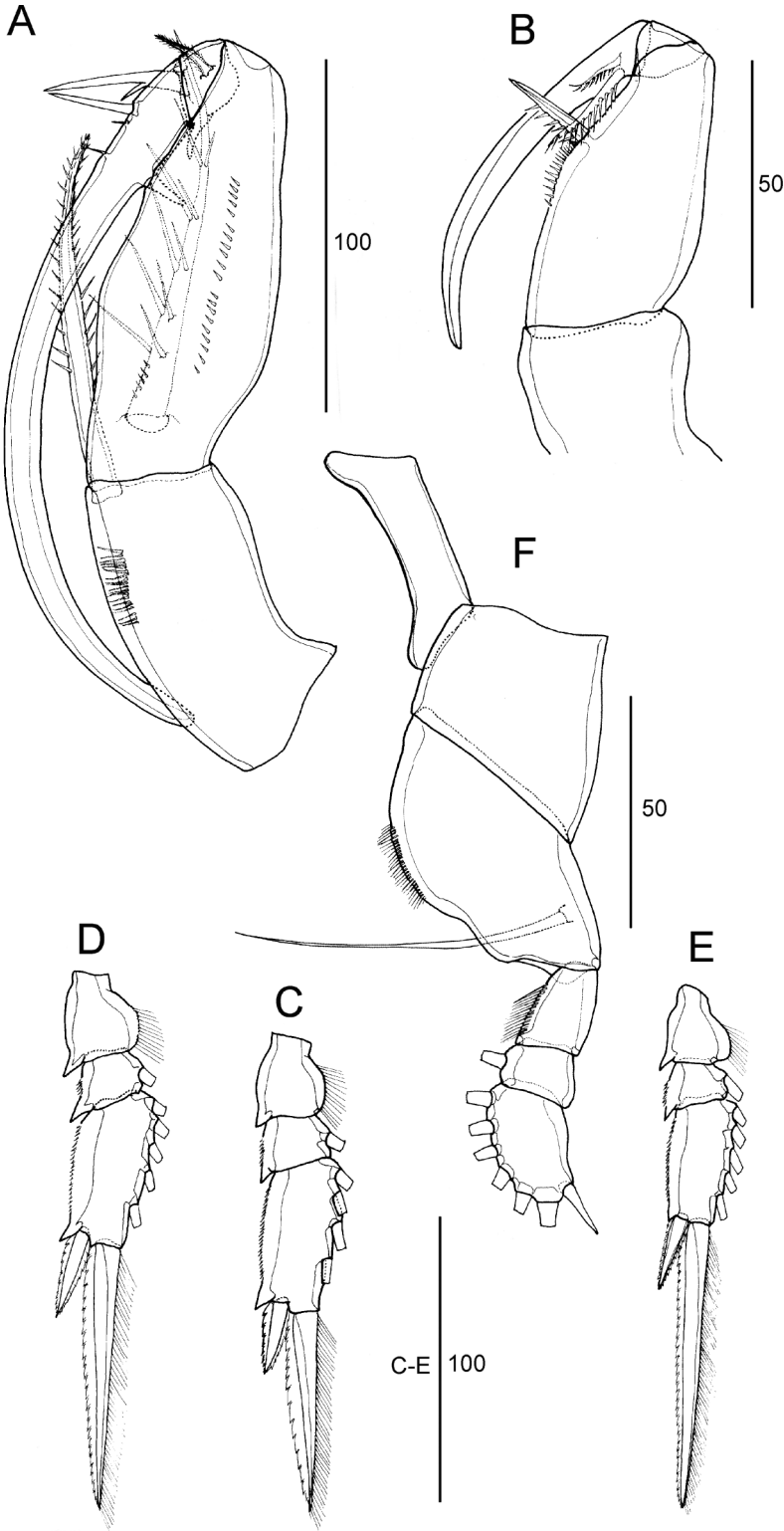


Figure 11. *Farranula gibbula*. Male: (A) antenna; (B) maxilliped; (C) P1, exopod; (D) P2, exopod; (E) P3, exopod; (F) P4.

of maxilliped bears coarser setules on the margin proximal to the inner seta on the basis, 8) the length ratio of the terminal spine to the outer distal spine on the distal exopodal segment of P 3, is larger than that of female, 9) length ratio of the distal segment to the terminal spine of P4 exp-3, is smaller than that of female, and 10) the genital flap is ornamented with a unique pattern of denticles,

Discussion

Taxonomy

The genus *Farranula* can easily be distinguished from other genera by conspicuous morphological features in both sexes: 1) the prosome consists of two segments, 2) the genital double-somite/somite and anal somite are combined, 3) leg 4 is uniramous, lacking the endopod, 4) P1 to P3 exopodal spines are lacking, except for the distal and terminal spines on the distal exopodal segment; and in females, 5) with a posteriorly directed ventral process on the cephalothorax. Additional morphological characters, which have not been noted or described by previous researchers include: 1) P1 and P3 of *Farranula* species lack coxal setae, which are present on those legs of other Corycaeidae; 2) coxa of P2 has a vestigial coxal seta, and a minute process on inner margin; and 3) the basis of P4 is fringed with spinules along inner median margin.

The genus includes seven species, two of which were found in Korean waters. Most *Farranula* species have not been described in detail, and there have been difficulties with identification partly because of their small size (more or less 1000 μm) and very similar morphology. So published figures of *Farranula* species often contain mistakes or are incomplete. For example, Motoda (1963) provided descriptions of three *Farranula* species, including habitus, antenna and P4, from Hawaiian waters, but these contain many errors: the lack of ornamentation on the surface of the first endopodal segment and coxobasis of the antenna; dorsal habitus of *F. carinata* (Motoda 1963: fig. 21a) probably represents *F. curta*, judging by shape of genital double-somite and degree of expansion of the pleural areas of second prosomal somite; incorrect setal formula for P4 in all three species. The dorsal habitus of female *F. rostrata* described by Chen et al. (1974: pl. 22, figs 1, 2) is also considered as *F. curta*, because of the shape of the genital double-somite and the relatively longer caudal ramus as compared with *F. rostrata*.

Distinguishing males of *Farranula* species is particularly difficult because of their similar appearance in different species and because of the lack of specific criteria for identification. Farran (1911) mentioned that he could not match the males thought to represent *F. gibbula*, *F. concinna* and *F. carinata* to their respective females, and the descriptions by both Dana (1852) and Dahl (1912) of *F. gracilis* males from the Atlantic Ocean did not demonstrate any specific difference between the males of this genus. Identification of *F. concinna* and *F. carinata* males are particularly difficult without examination of morphological details of dissected appendages, because of similarities in proportions of body segments and caudal rami (Table 1). Therefore, reliable information for the identification and separation of species, such as details of mouthparts, overall comparison of lengths and widths on respective segments, and shape and size of ornamentation on each armature element, is required, and these details have been proven to be important in correct identification of other planktonic cyclopoids such as the Oncaeidae, by Böttger-Schnack and Machida (2010).

In the present study, morphological characters of *F. concinna* and *F. gibbula* redescribed from Korean waters show that *Farranula* species can be identified by the following features: pattern of ornamentation on the surface of genital double-somite in females; pattern of ornamentation of the genital flap in males; relative length ratio and shape of each element on the maxillule; ornamentation on inner margin of the basis and the length of the terminal claw of the maxilliped; and relative length of each exopodal spine on the swimming legs. In addition, comprehensive comparisons of proportions of all seven *Farranula* species (Table 1) also provide important characters: *F. rostrata* presents the largest length ratio of genital double-somite/somite to caudal ramus in both sexes; *F. carinata* and *F. curta* females show very similar proportional lengths and shape, these two species can be readily identified by the difference of the length ratio of each prosomal somite; and *F. longicaudis* has the smallest length ratio of genital somite to caudal ramus in the female. Comprehensive comparison of such morphological characteristics presents important taxonomic information valuable for accurate identification of species belonging to *Farranula*.

Comparisons with other records for *F. concinna* and *F. gibbula*

Farranula concinna was first recorded by Dana (1849) as *Corycaeus concinnus* from the South Pacific without figures in 1849, and later with figures in 1852 (fig. 7a,á,b). Subsequently, Giesbrecht (1893 ["1892"]) provided a redescription of the female from the Gulf of Naples, including habitus (taf. 51, figs 21, 24). These are in close agreement with Korean *F. concinna*. However, these authors did not show the anteroventral protuberance and its patch of spinules (Dahl 1912, taf. 51, figs 21, 24). Dahl (1912) recorded six *Farranula* species (as the subgenus *Corycella*) from the Indo-Pacific and Atlantic Oceans, and the Mediterranean Sea, and partially described morphological characteristics for some limbs (e.g. antenna, legs and maxilliped), although the illustrations were limited to *F. rostrata* (as *Corycella gracilis*). In her drawings of *F. concinna* females (Dahl 1912, taf. XV. fig. 5), including habitus and genital double-somite, lateral caudal seta II was shorter than in the present account – lateral caudal seta II is the same length as seta III (Figure 2E). Tanaka (1957) illustrated both sexes of *F. concinna* (as subgenus *Corycella concinnus*) from Japanese waters. He did not provide a text description and all appendages except for the female antenna were lacking in the figures. In the antenna that was illustrated, Tanaka (1957) did not show any row of denticles on the lateral surface of the first endopodal segment, or the distal spine on the second endopodal segment. In addition, the segmentation between the second and third endopodal segments is incomplete (Pl. 10, fig. 14). Motoda (1963) described habitus, antenna and P4 of *F. concinna* females from Hawaiian waters, but the distance between the two lenses on the frontal margin of the prosome is too great and the P4 has no terminal spine (Motoda 1963: fig. 29d). In addition, the long curved spine on the second endopodal segment of the antenna has no laterally branched spine (fig. 29c) and the first endopodal segment and inner medial margin of the basis of P4 lack setules. Chen et al. (1974) reported both sexes of *F. concinna* from the East China Sea, in which some details and armature elements are lacking: in the female, the first endopodal segment of the antenna lacks ornamentation and the third endopodal segment lacks an inner distal spine; the inner margin of basis and inner margin of first exopodal segment of P4 lack setules; the ratio of terminal to outer distal spine in the P2 is smaller (2.2 : 1) than in Korean *F. concinna* (2.6 : 1); in male, the armature and

ornamentation of the antenna are incomplete, and the figures of dorsal habitus and lateral view of genital somite are more similar to *F. gibbula* than to *F. concinna*, in proportional lengths of the anterior part of genital somite to the posterior narrow part.

Dahl (1912) illustrated *F. gibbula* using Indian Ocean material, however, in her figures the ratio of genital double-somite to caudal ramus of female is much larger than those of Korean *F. gibbula* and of females reported by other authors (Giesbrecht 1893 [“1892”]; Farran 1911; Tanaka 1957, 1960; Motoda 1963; Chen et al. 1974; Zheng et al. 1982). Descriptions of *F. gibbula* have been limited only to the antenna, P2 and P4 distal exopodal spine of both sexes. In Mori’s figure (Mori 1937), the endopodal segments of the male antenna were shown fused into one segment, and there were errors in setation and ornamentation. Similar descriptive mistakes for male antenna of *F. gibbula* can be seen in figures by Tanaka (1957) and Motoda (1963). Motoda (1963) gave an erroneous description of *F. gibbula* P4 (fig. 27h) missing one seta on the inner margin. Chen et al. (1974) showed the antennae of both sexes inaccurately: again making errors in segmentation, armature and ornamentation. Zheng et al. (1982) provided detailed descriptions for lateral habitus, antenna, distal exopodal spines of P2 and P4 of female of *F. gibbula* from the East China Sea and Yellow Sea. However, the outer seta on P4 was shown as much shorter than in Korean *F. gibbula*, and the spine on the outer lateral margin of antenna as figured was not found in the present study. There are some differences between *F. gibbula* males described by Kang et al. (1990) from Korean waters and males of the present study, and it appears that the male in Kang’s figure (pl. 4, fig. M) is probably identical to *F. concinna* male: as judged by the length ratio of the first to second prosomal segments of the former (2.8 : 1) and the latter specimens (4.0 : 1). The length ratio of the broad anterior part to the narrow posterior part of the genital somite also differed, i.e. 2.1 : 1 and 2.8 : 1, respectively. In the *F. concinna* males examined in this study these ratios are 3 : 1 and 1.9 : 1, which are closer to those of Kang’s specimen.

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