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Copepodid stages of *Conchyliurus quintus* Tanaka, 1961 (Poecilostomatoida, Clausidiidae) associated with bivalve mollusks

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Key words: Conchyliurus quintus, copepodid stages, development

Abstract

Copepodid stages of *Conchyliurus quintus* Tanaka, a poecilostomatoid copepod associated with bivalve mollusks, are described. Comparisons with other poecilostomes were made on the developmental changes of appendages. Some general patterns of poecilostomatoid leg development and characteristics in *C. quintus* are shown.

Introduction

Conchyliurus Bocquet & Stock, 1957 is currently composed of nine species that are found in association with marine bivalves in the shallow waters of India, eastern Atlantic and western Pacific. Their larval stages are unknown except for Gooding's (1963) record of the first copepodid of *C. solenis* Bocquet & Stock, 1957. *C. quintus* Tanaka, 1961 is a commonly found associate of bivalves in the Far East. It was redescribed and recorded from five species of commercial bivalves (Ho & Kim, 1991).

According to Izawa (1991) copepodid stages of poecilostomes are known for 44 species in 18 families. But the published records are often fragmentary, dealing with only some of the developmental stages. In 1992, the author found bivalves, *Nuttallia olivacea*, heavily infested with *C. quintus*, including all copepodid stages, in a lagoon of Korea. Thus, the copepodid stages are described here to narrow the gap in our knowledge on the ontogeny of *Conchyliurus*.

Material and methods

The copepodids were collected from a brackish lagoon (Lake Hwajinpo) on the east coast of Korea. More than three hundred bivalves, *Nuttallia olivacea* (Jay), were dug from the lake floor (depth of water 20–30 cm) on 11 May, 1992. The substrate consisted of fine sand or sandy silt. The salinity was 17 ppt at the time of collection. The bivalves were transported to the laboratory in a bucket with lake water. Alcohol was added to this bucket to make about 5% alcohol solution. After about 10 hours the hosts were removed and the remaining water and sediments were filtered by a plankton net of mesh size about 100 μm. This yielded 1 copepodid I, 4 copepodid II, 9 copepodid III, and numerous later stages including adults. Towing plankton net over the lake floor where the bivalves were collected yielded no specimen of *C. quintus*. One copepodid I resembling that of *C. quintus*, which was found together with numerous *Ostrincola koe* Tanaka after washing more than a thousand small bivalves, (*Cryptomya busoensis* Yokoyama), from Tongjin estuary, the west coast of Korea, on August 15th, 1992 was used for comparison. The specimens were fixed in a 5% formalin solution for one hour, then preserved in 70% alcohol. Dissections and measurements of the specimens were made in lactic acid. Drawings were made with the aid of a camera lucida.

Descriptions

Copepodid I (Fig. 1A–M)

Body (Fig. 1A, specimen from Lake Hwajinpo) 5-segmented. Length including caudal ramus 501 μm, and maximum width 158 μm. Cephalothorax 220 μm long. Second pedigerous somite 109 μm wide. First urosomite 78 μm wide, bearing rudimentary third legs,

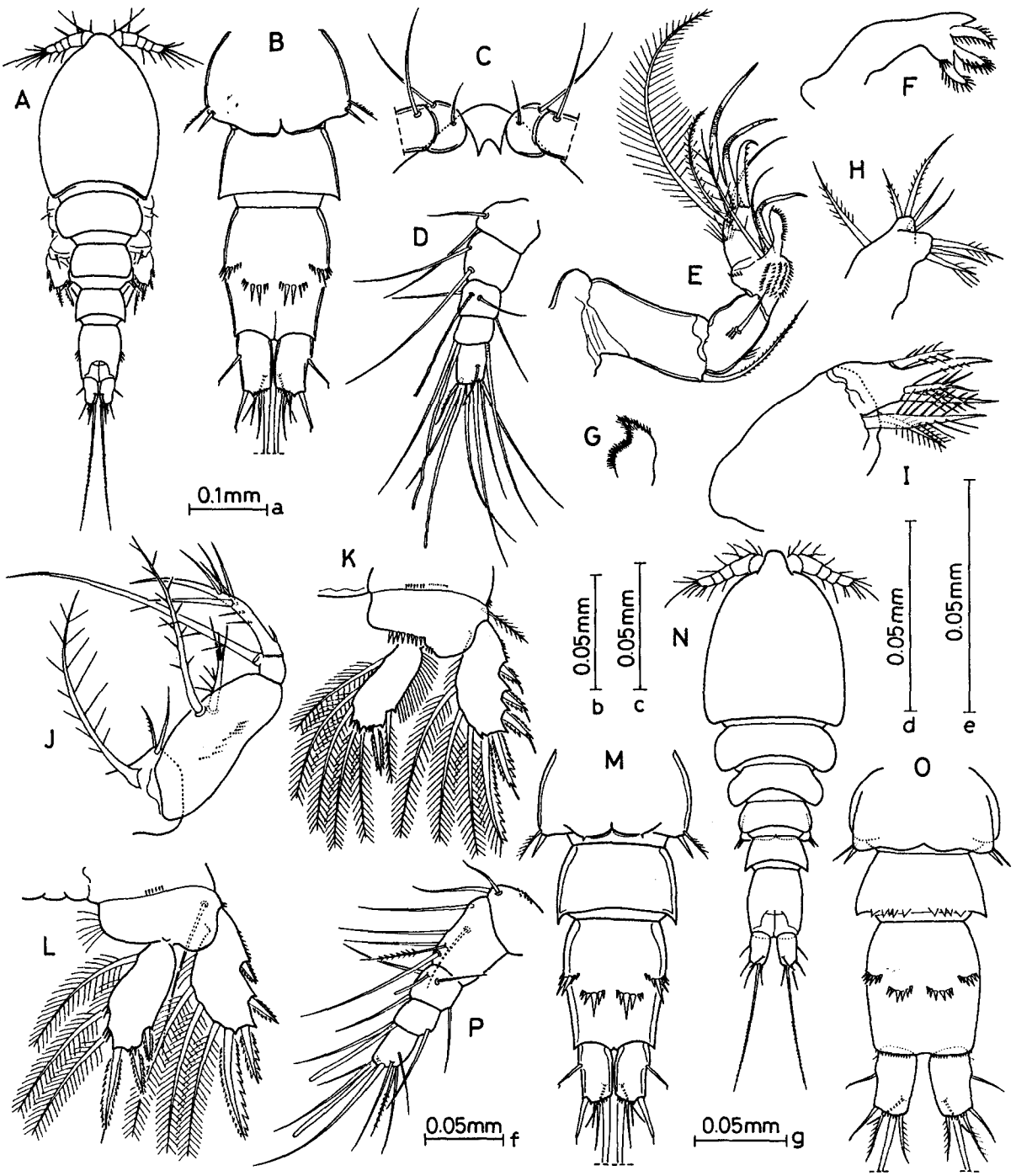

Fig. 1. *Conchyliurus quintus*. Copepodid I: A, habitus, dorsal; B, urosome, ventral; C, rostral area, ventral; D, antennule; E, antenna; F, mandible; G, paragnath; H, maxillule; I, maxilla; J, maxilliped; K, leg 1; L, leg 2. Copepodid I of *Conchyliurus* sp. from *Cryptomya busoensis*: M, urosome, ventral. Copepodid II: N, habitus, dorsal; O, urosome, ventral; P, antennule. Scales: A, N = a; B, M = g; C = c; D, K, L, P = b; E = d; F-J = e; O = f.

each represented by 2 spines (Fig. 1B). Second urosomite 65 μm wide, with pointed posterolateral corners. Anal somite 73 μm long and 56 μm wide, with 4 transverse rows of spinules on mid-ventral surface. Rostrum projecting ventrally, with bifurcate tip (Fig. 1C).

Antennule (Fig. 1D) 5-segmented and 77 μm long. Setal formula: 2, 2, 3 + 1 aesthete, 2 + 1 aesthete, and 7 + 1 aesthete. All setae, except for one on terminal segment, naked. Antenna (Fig. 1E) 4-segmented with formula for armature: 1, 1, 4, and 6. First segment longest. The third with 5 longitudinal rows of spinules on inner surface and a transverse row of spinules on inner distal margin.

Labrum straight posteriorly, with 2 transverse posterior rows of spinules and 5 groups of spinules. Mandible (Fig. 1F) with 4 elements, anteriormost of which is a smooth, hook-like process. Paragnath (Fig. 1G) nearly bilobate, with tapering distal lobe. Maxillule (Fig. 1H) bilobate, with 3 and 5 setae as in adult on inner and outer lobes respectively. Maxilla (Fig. 1I) 2-segmented. First segment with 2 inner distal setae. Second segment distally with 4 elements, one of which distinctly thicker, process-like. Maxilliped (Fig. 1J) well developed and 4-segmented, with setal formula: 3, 2, 1, and 1.

Legs 1 and 2 (Fig. 1K, L) with unimerous rami. Lateral 4 spines on leg 1 exopod and a terminal spine on leg 2 endopod with flagellum. Basis of leg 1 with denticles near base of endopod. Formula for armature of legs 1 and 2 as follows:

- P1: Prp 0–0; 1–0 Exp IV, I, 3
  Enp 1, I, 5
- P2: Prp 0–0; 1–0 Exp IV, 3
  Enp III, 3

Caudal ramus 34 μm long and 19 μm wide, with small spinules on disteroventral border and 6 elements, of which 2 spines with a flagellum.

Specimen from *Cryptomya busoensis* 487 μm long and 152 μm in maximum width. It differs from specimen from *Nuttallia olivacea* in following points: Cuticle thicker than the latter, first urosomite with 1 small process on posteroventral lobes of rudimentary third legs, second urosomite with more acutely pointed posterolateral corners (Fig. 1M).

Copepodid II (Fig. 1N–P and 2A–H)

Body (Fig. 1N) 6-segmented, 590 (570–595) μm long and 177 (171–179) μm wide in a mean of 4 specimens, with 2 pedigerous somites and 3 urosomites. Cephalothorax 223 μm long. Second and third pedigerous somites 151 μm and 119 μm wide respectively. First urosomite 90 μm wide, with rudimentary fourth legs represented by ventrolateral flap with 2 elements (Fig. 1O). Second urosomite 81 μm wide, with pointed posterolateral corners and several thick denticles on posteroventral border. Anal somite 90 × 70 μm, with 4 groups of spinules on mid-ventral surface and fine spinules on posteroventral margin (Fig. 1O). Rostrum projected anteriorly.

Antennule (Fig. 1P) 5-segmented, 95 μm long. Setal formula: 2, 6, 4 + 1 aesthete, 2 + 1 aesthete, and 7 + 1 aesthete. First segment with minute spinules on anterior margin. All seta naked, except two on second and terminal segments. Antenna (Fig. 2A) with formula for armature: 1, 1, 4, and 6. Two elements on inner distal margin of fourth segment much reduced.

Labrum (Fig. 2B) adult form, with row of spinules on posterolateral margins and 2 rosette-like elements on posteroventral surface as in adult. Mandible (Fig. 2C) as in adult with 3 distal pinnate elements. Maxilla (Fig. 2D) transformed to adult form; first segment unarmed; second segment forming a strong claw accompanied by 2 medial spines and 1 lateral seta; claw and one spine bifurcate. Maxilliped (Fig. 2E) transformed to an anchoring device of adult form. First 2 segments weakly separated from each other. Second segment with 1 short inner distal seta and fine spinules on outer distal surface. Third segment forming a stout claw.

Leg 1 (Fig. 2F) and leg 2 (Fig. 2G) with 2-segmented rami. Distal margin of basis of both legs armed with spinules. Leg 3 (Fig. 2H) with unimerous rami. Formula of legs 1–3 as follows:

- P1:0–1; 1–I Exp I–0; III, I, 4
  Enp 0–1; II, 4
- P2: 0–1; 1–0 Exp I–0; II, I, 4
  Enp 0–1; III, 3
- P3: 0–0; 1–0 Exp II, 1, I, 3
  Enp IV, 2

Caudal ramus 45 × 25 μm, with fine spinules on posteroventral border and 6 elements.

Copepodid III (Fig. 2I–P)

Body (Fig. 2I) 7-segmented, with 3 pedigerous somites and 3-segmented urosome. Length of body 650 μm (620–700 μm) and maximum width 225 μm (215–

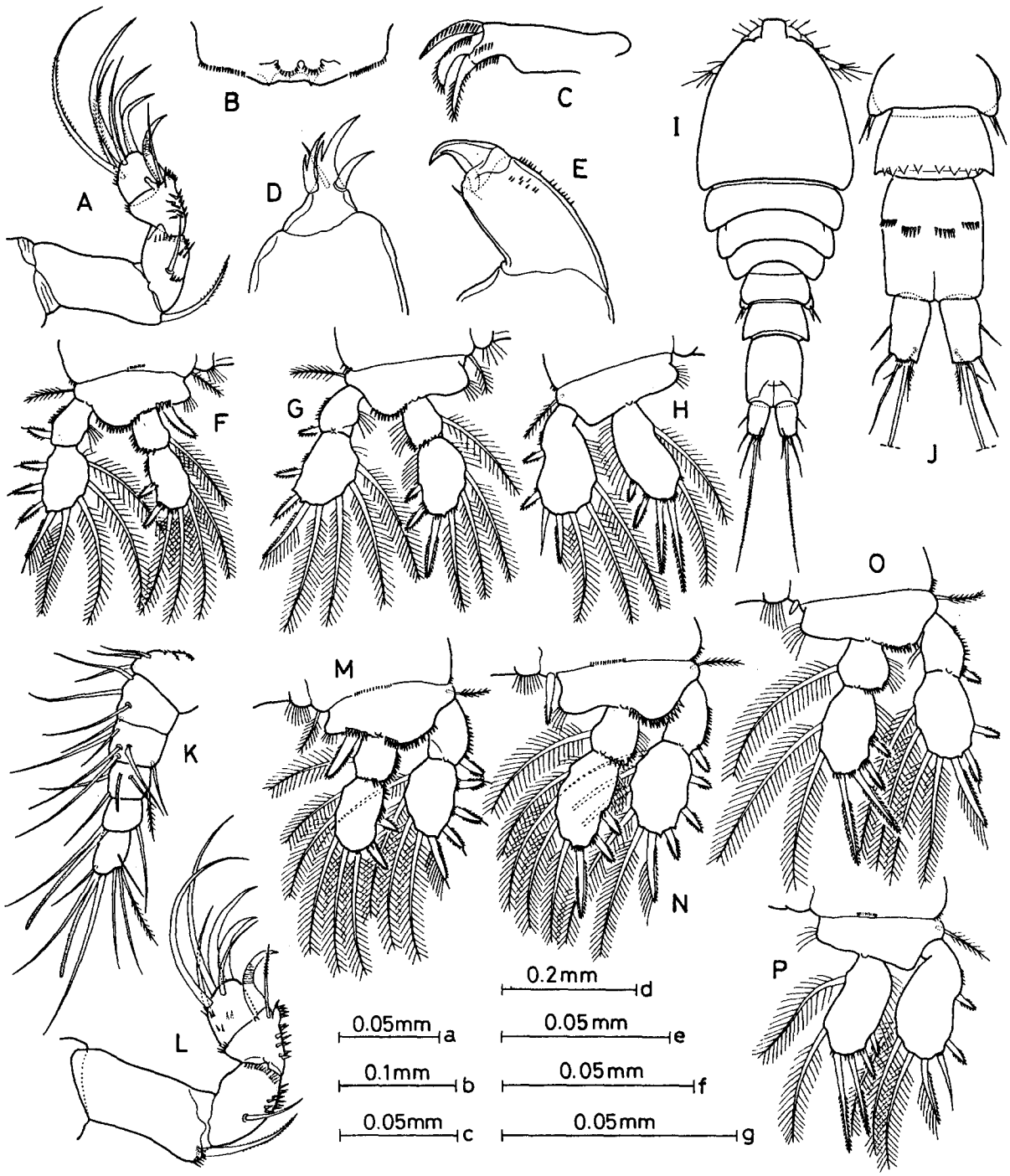

Fig. 2. Conchyliurus quintus. Copepodid II: A, antenna; B, labrum; C, mandible; D, maxilla; E, maxilliped; F, leg 1; G, leg 2; H, leg 3. Copepodid III: I, habitus, dorsal; J, urosome, ventral; K, antennule; L, antenna; M, leg 1; N, leg 2; O, leg 3; P, leg 4. Scales: A, B, L = e; C, D = g; E = f; F-H = c; I = d; J = b; K, M-P = a.

236 μm), based on 6 specimens. Cephalothorax 258 μm long, with almost quadrangular rostrum. First urosomite with rudimentary fifth leg represented by posterolateral lobes bearing 2 elements. Second urosomite with pointed posterolateral corners and several thick spinules on posteroventral margin (Fig. 2J). Anal somite 106 × 84 μm, with 4 groups of spinules on ventral surface. Caudal ramus 56 × 32 μm, with fine spinules and 6 elements as in previous stage.

Antennule (Fig. 2K) 6-segmented and 119 μm long. Second and third segments weakly demarcated from each other. Setal formula: 3, 4, 6, 4 + 1 aesthete, 2 + 1 aesthete, and 7 + 1 aesthete. Antenna (Fig. 2L) with same formula for armature as in preceding stage, but outermost element of third segment further reduced to small knob.

Oral appendages as in adult, showing no further changes from previous stage.

Leg 1 (Fig. 2M), leg 2 (Fig. 2N) and leg 3 (Fig. 2O) with 2-segmented rami. Leg 4 (Fig. 2P) with unimerous rami. Formula of legs 1–4 as follows:

- P1: 0–1; 1–I Exp I–0; III, I, 4
  Enp 0–1; II, 5
- P2: 0–I; 1–0 Exp I–0; III, I, 5
  Enp 0–1; III, 4
- P3: 0–I; 1–0 Exp 1–0; II, I, 4
  Enp 0–1; IV, 2
- P4: 0–0; 1–0 Exp II, 1, I, 3
  Enp IV, 2

Copepodid IV (Fig. 3A–H)

Body (Fig. 3A) slender, 8-segmented, with 3 pedigerous somites and 4-segmented urosome. Length 1.03 mm (0.99–1.97 mm), and maximum width 263 μm (243–275 μm), based on 7 specimens. Second and third urosomites with pointed posterolateral corners (Fig. 3B), 105 × 112 μm and 72 × 95 μm respectively. Anal somite 128 × 90 μm. Caudal ramus 72 × 37 μm.

Antennule (Fig. 3C) 138 μm long, and distinctly 6-segmented. Setal formula: 4, 8, 7, 4 + 1 aesthete, 2 + 1 aesthete, and 7 + 1 aesthete. Antenna (Fig. 3D) with 2 spines and a lobe on inner distal margin of third segment.

Leg 1, and legs 2–4 (Fig 3E-G) with 2-segmented rami. Armature of leg 1 as in copepodid III. Formula for armature of legs 1–4 as follows:

- P1: 0–1; 1–I Exp I–0; III, I, 4
  Enp 0–1; II, 5
- P2: 0–I; 1–0 Exp I–0; III, I, 5
  Enp 0–1; III, 5
- P3: 0–I; 1–0 Exp I–0; III, I, 5
  Enp 0–1; IV, 3
- P4: 0–I; 1–0 Exp I–0; III, I, 5
  Enp 0–1; IV, 2

Leg 5 (Fig. 3H) 1-segmented, accompanied by a seta dorsally near the base, 60 × 28 μm, with a pointed distal corner and 3 spines and 1 plumose seta.

Copepodid V (Fig. 3I–M)

Female

Body (Fig. 3I) 9-segmented, with 3 pedigerous somites and 5 urosomites. Length 1.36 mm (1.25–1.46 mm), and maximum width 323 μm (306–335 μm), based on 10 specimens. Cephalothorax 370 μm long, as wide as first pedigerous somite. Genital somite 178×160 μm, with pointed posterolateral corners (Fig. 4J) bearing 1 or no ventral spinule. Third and fourth urosomites 95×126 and 91×113 μm respectively. Anal somite 153×105 μm, with armature as in adult. Caudal ramus 98×43 μm.

Appendages including maxilliped (Fig. 3K) as in adult, but leg 5, which is somewhat narrower than the previous stage, with subterminal spine bearing a flagellum.

Male

Length 1.20 mm (1.17–1.22 mm), and maximum width 295 μm (267–325 μm), based on 10 specimens. Genital somite 145×140 μm, smaller than that of female, with more acute posterolateral corners bearing 1 or 2 spinules ventrally (Fig. 3L). Maxilliped (Fig. 3M) with shorter terminal claw carrying 2 spinules and a tiny nodule on inner side of claw in the middle.

Discussion

A copepodid I obtained from *Cryptomya busoensis*, which bears relatively thick exoskeleton and resembles *Conchyliurus quintus* and Itoh & Nishida's (1991) type 7 "*Saphirella*" which also resembles *C. quintus* in the shape of mandible and rostum, is considerd here to represent the copepoid I of a *Conchyliurus* species.

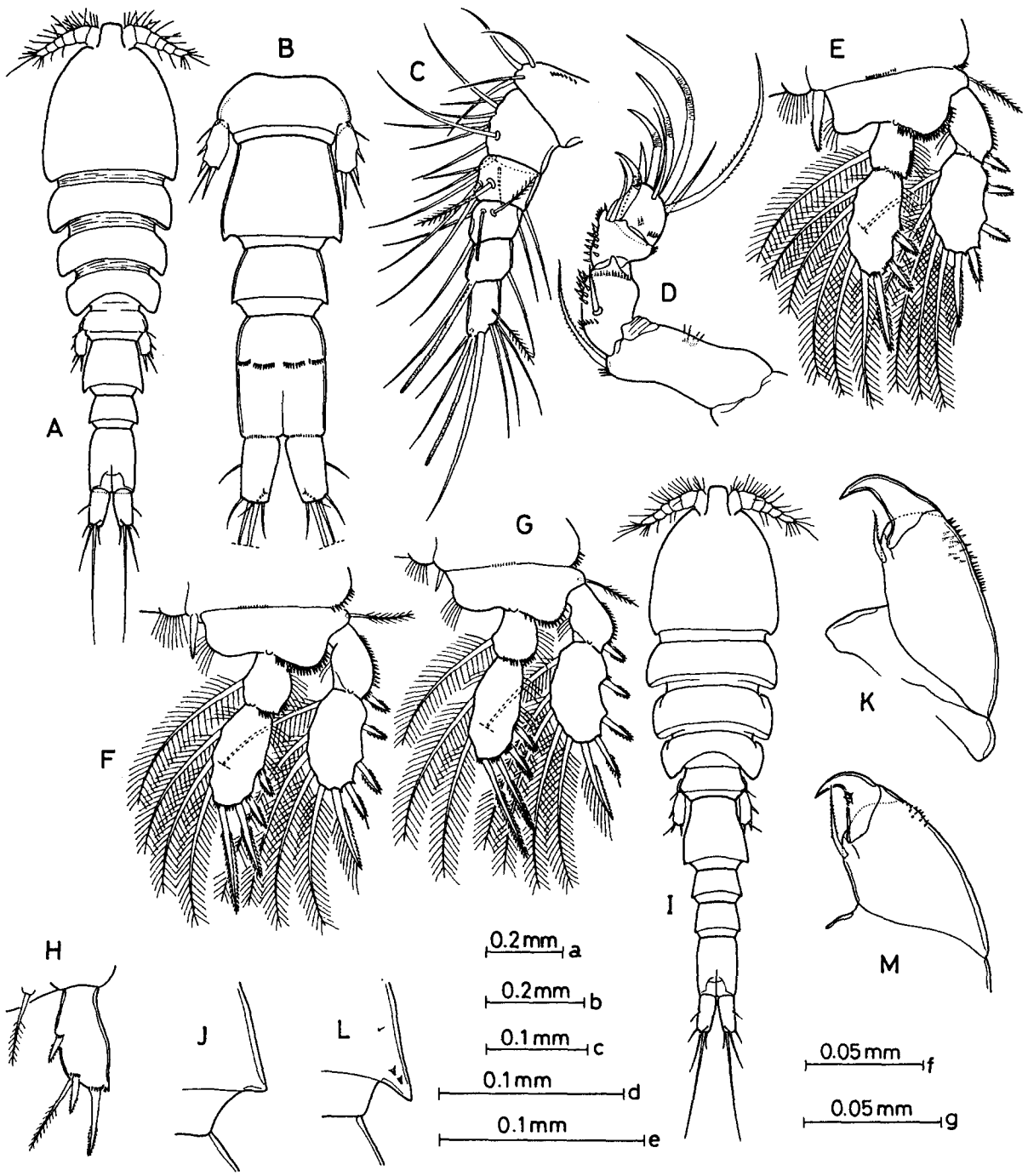

Fig. 3. Conchyliurus quintus. Copepodid IV: A, habitus, dorsal; B, urosome, ventral; C, antennule; D, antenna; E, leg 2; F, leg 3; G, leg 4; H, leg 5. Copepodid V: I, habitus, dorsal; J, posterolateral corner of female genital complex, ventral; K, maxilliped, female; L, posterolateral corner of male genital complex, vental; M, maxilliped, male. Scales: A = b; B = c; C = e; D = g; E-H, J, L = d; I = a; K, M = f.

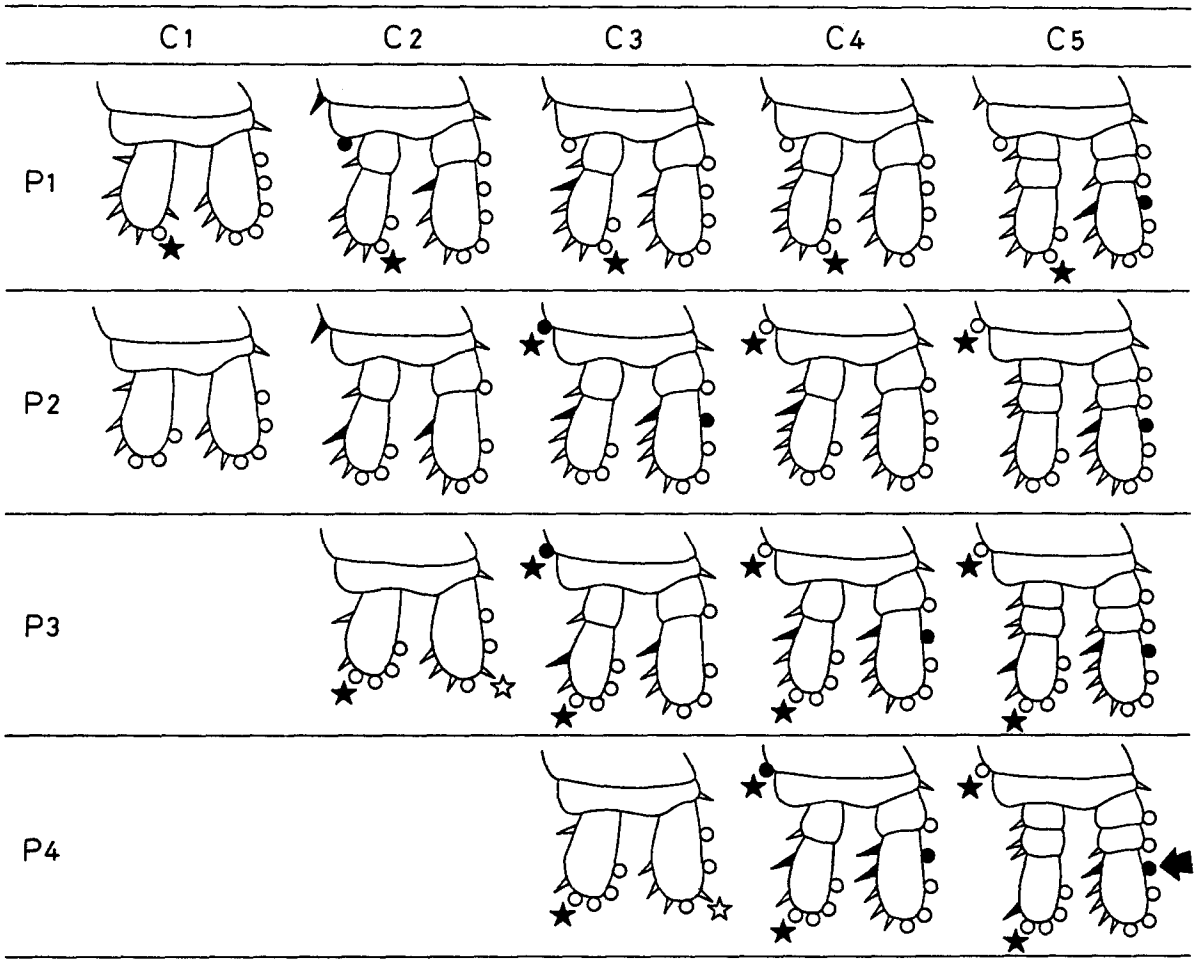

Fig. 4. Symbolized leg development in *Conchyliurus quintus*. C1–5: Copepodid stages I-V; P1–4: legs 1–4; circles and spines indicate spines and setae, respectively, and black ones indicate newly added elements; black and open asterisks represent setae and spines, respectively, in general poecilostomatoid leg armature; arrow indicates an element usually lacking in other primitive poecilostomes.

Complete copepodid development is known for three species of clausidiids: *Leptinogaster major* (Williams) studied by Humes (1986), *Hemicyclops ctenidis* Ho & Kim studied by Kim & Ho (1992), and the present *Conchyliurus quintus*. None of these clausidiids have the exopod on the antenna during the copepodid development. The presence of antennal exopod is common in copepodid I of many poecilostomatoids such as *Ergasilus sieboldi* Nordmann (Ergasilidae; see Abdelhalim *et al.*, 1991), *Taeniacanthus lagocephali* Pearse (see Izawa, 1986a) and *Taeniatrotos pleuronichthydis* (Yamaguti) (Taeniacanthidae; see Izawa, 1986b), *Philoblenna arabici* Izawa (Philoblennidae; see Izawa, 1986b), *Neanthessius renicolis* Izawa and *Panaietis yamagutii* Izawa (both are Anthessiidae; see Izawa, 1986b), *Pseudacanthocanthopsis apogonis* Yamaguti & Yamasu and *Praecidochondria setoensis* Izawa (both are Chondracanthidae; see Izawa, 1986b), *Sabellacheres illgi* (Gastrodelphyidae; see Dudley, 1964), *Pseudomyicola spinosus* (Raffaele & Monticelli) (Myicolidae; see Do *et al.*, 1984), *Sarcotaces pacificus* Komai (Sarcotacidae; see Izawa, 1973), and *Colobomatus pupa* Izawa (Philichthyidae; see Izawa, 1975). It is interesting to point out that although the clausidiids possess relatively primitive antennae, there is no exopod in copepodid I antennae.

The female maxillipeds vary with the genera of Clausidiidae. All clausidiid copepodid I have a functional, *Saphirella*-type maxillipeds. In *Hemicyclops* this appendage does not change greatly during the female development (Kim & Ho, 1992). Howev-

er, in *Leptinogaster*, it is remarkedly reduced in the adult female (Humes, 1986). In *Conchyliurus* it is transformed into a prehensile appendage in copepodid II, without further change in later development. The *Saphirella*-type maxilliped is also found in copepodid I of *Taeniacanthus lagocephali* (see Izawa, 1986a) (Taeniacanthidae; but not in *Taeniatrotos pleuronichthydis*, according to Izawa, 1986b), *Lichomolgus canui* Sars (Lichomolgidae; see Costanzo, 1969), and *Modiolicola insignis* Aurivillius (Sabelliphilidae; see Costanzo, 1984; but not in *Herrmannella rostrata* Canu as reported by Costanzo & Calafiore, 1985), and *Philoblenna arabici* Izawa (Philoblennidae; see Izawa, 1986b).

The leg development in Copepoda has recently been analyzed by Ferrari (1988) for phylogenetic implication. As in most poecilostomatoids, the leg development in *Conchyliurus quintus* is completed at copepodid V. In this stage legs 1–4 have a simultaneous addition of one outer spine and one inner seta on the third exopod segments (Fig. 4). The addition of one pair of elements on the third exopod segment of legs 1–3 and only one inner seta on the third exopod segment of leg 4 is universal in Poecilostomatoida. However, addition of one outer spine (indicated with arrow in Fig. 4) on the third exopod segment of leg 4 in copepodid V varies among Poecilostomatoida. According to Huys & Boxshall (1991, p. 353), the addition of this spine (to become III, I, 5) is an apomorphic trait. Besides adding this spine on the exopods, *C. quintus* has more spines on the coxae and endopods. In Poecilostomatoida, the inner coxal element of legs 2–4 and the distalmost element on the endopod of legs 1, 3 and 4 are usually setae, but they are replaced by spines in *C. quintus* (indicated by black asterisks in Fig. 4). Such condition of more spines in copepodids is also found on the endopods of legs 1, 3 and 4 in *Pseudomyicola spinosus* (see Do *et al.*, 1984) and *Panaietis yamagutii* (see Izawa, 1986b), on the endopods of legs 2 and 3 in *Lubbockia carinata* Heron & Damkaer (see Heron & Damkaer, 1978) and *Ostrincola koe* Tanaka (see Ko, 1969), on the endopod of leg 1 in *Ergasilus sieboldi* (see Abdelhalim *et al.*, 1991) and *Neoergasilus japonicus* (Harada) (see Urawa *et al.*, 1980), and on the endopod of leg 2 in *Modiolicola insignis* (see Costanzo, 1984). With very few exceptions, this replacement is seen as early as when the leg first appears in the development. Some further general patterns found in the poecilostomatoid leg development characteristics in *C. quintus* are as follows:

(1) Formulae of the initial unimerous leg 1 are: Exopod, IV, I, 3 and endopod, 7 (or I, 6). In *C. quintus*, that of the endopod is 1, I, 5.

(2) Formulae of the initial unimerous leg 2 (at copepodid I), leg 3 (at copepodid II), and leg 4 (at copepodid III) are: Exopod, III, I, 3 and endopod, III, 3. In *C. quintus*, as in *Herrmannella rostrata*, the exopods of legs 3 and 4 typically have a formula of II, 1, I, 3.

(3) The inner coxal element of all biramous legs appears in the stage immediately following the stage first bearing the leg.

(4) The inner armature (usually spine) of leg 1 basis in Clausidiidae, Oncaeidae and Myicolidae appears first at copepodid II.

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