ZOEAL STAGES OF *CONCHODYTES NIPPONENSIS* (DECAPODA: PALAEMONIDAE) REARED IN THE LABORATORY

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**ABSTRACT**

Zoeal stages of *Conchodytes nipponensis*, not previously known from Korea, are described from laboratory-reared material. This is the first account of the larval development of a species from the genus *Conchodytes* and the first larval description of a pontoniid species from Asian waters. The Gnathophyllidae had been considered as a synonym with the Pontoniinae by Bruce, whereas others regard both groups as distinct. Morphological comparisons between the first zoea of *C. nipponensis* and that of *Gnathophyllum americanum* indicate that the Gnathophyllidae have great affinity with the Pontoniinae. According to the viewpoint of some authors, similar larvae do not necessarily signify related adults. Therefore, the Pontoniinae and the Gnathophyllidae may be distinct.

The palaemonid subfamily Pontoniinae comprises a large number of species with life histories ranging from free-living to highly specialized associates of various marine invertebrates. Seven species assigned to *Concho- dytes* are reported from Indo-West Pacific waters: *C. kempi* Bruce, 1989; *C. maculatus* Bruce, 1989; *C. meleagrinae* Peters, 1852; *C. monodactylus* Holtzuis, 1952; *C. nipponensis* (De Haan, 1844); *C. philippinensis* Bruce, 1996; and *C. tridacnae* Peters, 1852 (see Chace and Bruce, 1993; Bruce, 1996). One of these, *C. nipponensis*, is known to live in commensal association with pectinid and pinnid bivalve mollusks and is reported to occur in the Philippines, eastern Australia, Japan (Chace and Bruce, 1993), and here for the first time in Korea. The only other pontoniid species re- ported from Korea is *Periclimenaeus gorgonidarium* (Balss, 1913) (The Korean Society of Systematic Zoology, 1997).

Larvae of the Pontoniinae are poorly documented world-wide, with larval descriptions known for only nine (about 10.8%) of the 83 genera currently described in the subfamily (Okuno, 1999). These are represented by 23 species from Atlantic waters, the Mediterranean Sea, the Red Sea, India, Australia, New Zealand, and Fiji (Table 1).

The present paper provides the first account of the larval development of a species assigned to the genus *Conchodytes*. The zoal stages of *C. nipponensis* are described and illustrated in detail, and the morphological characteristics of the first zoea are compared with those of *Pontonia pinnophylax* (Otto, 1821) and *Ponto- nia flavomaculata* Heller, 1864. The systematic relationships between the Pontoniinae and Gnathophyllidae are discussed.

**MATERIALS AND METHODS**

On 13 June 2002, one ovigerous female of *Conchodytes nipponensis* was collected from fan shells *Atrina pectinata* Linnaeus, 1758, in Jagalchi Fish Market, Busan, Korea. The female released about 250 larvae on 24 June 2003. Two hundred larvae were reared individually in Corning twelve- tissue culture plates, ranging in volume from 6 to 8 mL per well of aerated seawater of 33.3% in a growth chamber at 25°C. Larvae were fed with newly hatched *Artemia* nauplii and transferred daily to newly prepared culture plates. Some specimens in each stage were preserved in 5% neutral Formalin. Measurements and setal counts were based on ten specimens for each zoeal stage. Dissected appendages were examined using a Leitz Laborlux S microscope, and drawings were made with the aid of a camera lucida. The chromatophore pattern was determined by observing living larvae. Body length (BL) was determined from the postorbital margin to the posteromedian margin of the telson, excluding posterior setae. Carapace length (CL) was determined from the postorbital margin to the postmedian margin of the carapace. The setal armature of the appendages is described from proximal segment towards distal segment.

**RESULTS**

Six zoal stages were obtained. Four zoal stages are described and illustrated. However, the last two stages could not be described because only three and four zoae were obtained, respectively. The fifth zoae had pereiopods 1–4 with the exopods only. In the
sixth zoea, pereiopods 4–5 were not much longer than pereiopod 3. The first zoeal stage is described in detail. For the subsequent stages, only the main differences from the previous stage are given.

**First Zoea (Fig. 1).—Duration. 5–7 days.**

BL. 1.82 (1.70–1.85) mm; CL. 0.24 (0.20–0.25) mm.

Carapace (Fig. 1A, B). Flattened dorsoventrally; rostrum unarmed, reaching one-fourth
length of peduncle of antennule; anterior dorsomedian papilla and pterygostomian spine present; anteroventral or posteroventral denticles absent; antennal spine absent; eyes sessile.

Antennule (Fig. 1D). Peduncle unsegmented; inner flagellum with long plumose seta; outer flagellum with 4 aesthetascs and plumose seta.

Fig. 1. First zoea of *Conchodytes nipponensis* (De Haan, 1844). A, dorsal view; B, carapace, lateral view; C, abdomen, lateral view; D, antennule; E, antenna; F, mandibles; G, maxillule; H, maxilla; I, first maxilliped; J, second maxilliped; K, third maxilliped; L, pereiopods 1–2. Scale bars = 0.1 mm.
Antenna (Fig. 1E). Peduncle with basal spine; endopod rod-like, with long terminal plumose seta and strong spine; scale 6-segmented, with 11 marginal setae, distolateral spine, and inner papilla.

Mandibles (Fig. 1F). Palps absent. Left and right mandibles with spine between molar and incisor processes.

Maxillule (Fig. 1G). Coxal endite with sub-terminal seta and 4 terminal setae; basal endite with 5 cuspidate setae; endopod segmented, with terminal spine and terminal seta.

Maxilla (Fig. 1H). Coxal endite with 4 setae; basal endite bilobed, each with 2 setae; endopod with fine hairs on basal lobe and terminal seta; scaphognathite with 5 marginal plumose setae.

First maxilliped (Fig. 1I). Basis with 4 setae, distolateral margin protuberant; endopod 3-segmented, with 0, 1, 3+1 setae; exopod with 4 terminal natatory setae symmetrically disposed in 2 pairs.

Second maxilliped (Fig. 1J). Coxa unarmed; basis with tubercle and 2 setae; endopod 3-segmented, with 2, 2, 4+1 setae; exopod with 2 short subterminal setae and 4 terminal natatory setae symmetrically disposed in 2 pairs.

Pereiopods 1–2 (Fig. 1L). Rudimentary, biramous as bud.

Abdomen (Fig. 1A, C). Flattened dorsoventrally; composed of 5 somites; abdominal somite 6 not differentiated; junction of thorax and abdomen flexed; somite 3 conspicuously hump-backed; somite 1 with lateromedian setae; somite 3 with 2 pairs of posterodorsal setae as well as pair of marginal setae; somite 4 with tuft of dorsal setae as well as pairs of marginal setae; somite 5 with pair of posterodorsal setae; all somites without spines; pleopods absent.

Telson (Fig. 1A). Subtriangular, with shallow posteromedian concavity and 7+7 posterior setae; outermost 2 pairs of setae plumose only on inner side; bases of all setae except outermost with row of minute spinules; anal spine absent; uropods absent.

Chromatophores. Orange chromatophores interspersed with yellow present on superolateral margin of each eye, carapace, labrum, basis of third maxilliped, endopods of second and third maxillipeds, exopods of second and third maxillipeds, rudiments of pereiopods 1 and 2, abdominal somites 1–5 laterally, and abdominal somites 3–5 dorsally. Yellow chromatophores present on peduncle of antennule, scale of antenna, and telson.

Second Zoea (Fig. 2).—Duration. 5–7 days.
BL. 1.96 (1.95–1.98) mm; CL. 0.29 (0.28–0.30) mm.

Carapace (Fig. 2A). Supraorbital spine present; eyes stalked.

Antennule (Fig. 2B). Peduncle swollen basally, 2-segmented; first segment unarmed; second with 2 terminal setae.

Antenna (Fig. 2C). Endopod with long plumose and 2 short terminal setae.

Mandibles (Fig. 2D). Left mandible with 2 spines between molar and incisor processes.

Maxillule (Fig. 2E). Basal endite with 6 cuspidate setae.

Maxilla (Fig. 2F). Scaphognathite with 7 marginal plumose setae.

First maxilliped (Fig. 2G). Unchanged.

Second maxilliped (Fig. 2H). Unchanged.

Third maxilliped (Fig. 2I). Endopod 4-segmented, with 2, 1, 2, 4+1 setae.

Pereiopod 1 (Fig. 2J). Coxa unarmed; basis with tubercle and 2 setae; endopod 4-segmented, with 2, 1, 2, 2 setae; exopod with 2 short subterminal setae and 4 terminal natatory setae.

Pereiopod 2 (Fig. 2K). Coxa unarmed; basis with 2 setae and tubercle; endopod 4-segmented, with 2, 1, 2, 2 setae; exopod with 2 short setae and 4 terminal natatory setae.

Pereiopods 3–4 (Fig. 2L). Uniramous.

Abdomen (Fig. 2A). Somite 6 with 2 pairs of dorsal setae.

Telson (Fig. 2A). Posterior margin with 8+8 setae; outermost pair of setae plumose only on inner side; uropods visible.

Third Zoea (Fig. 3).—Duration. 4–6 days.
BL. 2.09 (2.08–2.10) mm; CL. 0.34 (0.33–0.35) mm.

Carapace (Fig. 3A, B). Anteroventral margin bifid.

Antennule (Fig. 3C). Peduncle 2-segmented, each with 7 plumose setae.

Antenna (Fig. 3D). Scale 4-segmented, with 12 plumose setae and terminal spine; endopod 3-segmented: first and second segments unarmed; third with 4 terminal setae.

Mandibles (Fig. 3E). Left and right mandibles with 3 spines between molar and incisor processes.
Fig. 2. Second zoea of Conchodytes nipponensis (De Haan, 1844). A, dorsal view; B, antennule; C, antenna; D, mandibles; E, maxillule; F, maxilla; G, first maxilliped; H, second maxilliped; I, third maxilliped; J, pereiopod 1; K, pereiopod 2; L, pereiopods 3–4. Scale bars = 0.1 mm.
Fig. 3. Third zoea of *Conchodytes nipponensis* (De Haan, 1844). A, dorsal view; B, carapace, lateral view; C, antennule; D, antenna; E, mandibles; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped; J, third maxilliped; K, pereiopod 1; L, pereiopod 2; M, pereiopods 3–4; N, telson and uropods. Scale bars = 0.1 mm.
Maxillule (Fig. 3F). Basial endite with 7 cuspidate setae.

Maxilla (Fig. 3G). Unchanged.

First maxilliped (Fig. 3H). Unchanged.

Second maxilliped (Fig. 3I). Unchanged.

Third maxilliped (Fig. 3J). Endopod 4-segmented, with 2, 1, 3, 4+1 setae.

Pereiopod 1 (Fig. 3K). Endopod 4-segmented, with 2, 1, 3, 2 setae.

Pereiopod 2 (Fig. 3L). Endopod 4-segmented, with 2, 1, 3, 2 setae.

Pereiopods 3-5 (Fig. 3M). Pereiopod 3 biramous as bud. Pereiopods 4 and 5 uniramous.

Abdomen (Fig. 3A). Composed of 6 somites.

Telson and uropods (Fig. 3N). Telson with 7+7 posterior setae and pair of lateral spines. Uropods free: endopod rudimentary; exopod with 6 marginal plumose setae.

**Fourth Zoea** (Fig. 4).—Duration. 5–7 days.

BL. 2.17 (2.13–2.25) mm; CL. 0.35 (0.33–0.38) mm.

Carapace (Fig. 4A). Unchanged.

Antennule (Fig. 4B). Peduncle 2-segmented, with 12 and 7 plumose setae.

Antenna (Fig. 4C). Scale with 14 plumose setae and terminal spine.

Mandibles (Fig. 4D). Unchanged.

Maxillule (Fig. 4E). Unchanged.

Maxilla (Fig. 4F). Unchanged.

First maxilliped (Fig. 4G). Unchanged.

Second maxilliped (Fig. 4H). Unchanged.

Third maxilliped (Fig. 4I). Unchanged.

Pereiopod 1 (Fig. 4J). Unchanged.

Pereiopod 2 (Fig. 4K). Endopod 4-segmented, with 2, 1, 4, 2 setae.

Pereiopod 3 (Fig. 4L). Coxa unarmed; basis with 2 setae and tubercle; endopod 5-segmented, with 0, 0, 0, 2, 2 setae; exopod with short subterminal seta and 4 terminal natatory setae.

Pereiopods 4–5 (Fig. 4M). Pereiopod 4 biramous. Pereiopod 5 unchanged.

Abdomen (Fig. 4A). Unchanged.

Telson and uropods (Fig. 4N). Telson narrower, with 4+4 marginal setae and pair of lateral spines. Uropods developed: endopod with 10 setae; exopod with 14 setae and outermost tooth.

**Discussion**

Of the descriptions of the pontoniid larvae known so far, only three have been detailed: *P. flavomaculata* described by Costanzo et al. (1996), *P. pinnophylax* described by Calafiore et al. (1991), and *Periclimenaeus stylostris* Bruce, 1969, described by Bruce and Coombes (1995). However, the description of *P. stylostris*, collected from Trengon Bay, Australia, includes only the postlarva. Useful comparison of early zoeas, therefore, is possible only between *C. nipponensis*, *P. flavomaculata*, and *P. pinnophylax*. The first zoea of the three species can be distinguished from each other by the length of the rostrum, the setation and number of distal segments of the scale of the antenna, the setation of the coxal endite of the maxillule and the basial endite of the maxilla, and the presence or absence of a tubercle on the bases of the second and third maxillipeds (Table 2).

Gurney and Lebour (1941), in their revision of Gurney’s (1936, 1938) grouping, separated the larvae of the Pontoniinae into two groups, ancylocaris and mesocaris, by the shape of the body and the relative length of the pereiopods 4–5 to the pereiopod 3. The larvae of *C. nipponensis* have the body double flexed at the junction of the thorax and the abdominal somite, and the abdominal somite 3. Furthermore, pereiopods 4–5 are not much longer than pereiopod 3 in the sixth zoea of *C. nipponensis*. These characteristics reveal that the larvae of *C. nipponensis* belong to Gurney and Lebour’s (1941) mesocaris group. In the larvae of *P. flavomaculata* and *P. pinnophylax*, Calafiore et al. (1991) and Costanzo et al. (1996) provided no available information on the shape of the body and the relative lengths of pereiopods 4–5 to pereiopod 3. Therefore, it is unknown whether *P. flavomaculata* and *P. pinnophylax* belong to mesocaris group. However, other characteristics such as the scale of the antenna with inner papilla in the first zoea, the distolateral margin of the basis of the first maxilliped protuberant, the dactyl of the endopod of the second maxilliped with fringe of spinules, and pereiopod 4 with the exopod from the sixth zoea onward indicate that the two species probably belong to the mesocaris group.

The systematic relationships between the Pontoniinae and the Gnathophyllidae are confusing. The four genera *Gnathophylloides*, *Gnathophyllum*, *Levicaris*, and *Pycnocaris* were regarded as members of the palaemonid subfamily Pontoniinae until Holthuis (1955) transferred them to the separate family Gnathophyllidae. On the other hand, in his work on the first zoea of *Gnathophyllum americanum* Guérin, 1856, Bruce (1986) regarded the Gnathophyllidae as belonging to the Palae-
Fig. 4. Fourth zoea of *Conchodytes nipponensis* (De Haan, 1844). A, dorsal view; B, antennule; C, antenna; D, mandibles; E, maxillule; F, maxilla; G, first maxilliped; H, second maxilliped; I, third maxilliped; J, pereiopod 1; K, pereiopod 2; L, pereiopod 3; M, pereiopods 4–5; N, telson and uropods. Scale bars = 0.1 mm.
monidae and synonymized the former with the Pontoniinae. Subsequently, despite larval similarity, Chace and Bruce (1993) concluded tentatively that the unique mouthparts of the Gnathophyllidae discarded the possibility of the synonomy.

The presence or absence of posterior dorsomedical papilla on the carapace and outer seta or lobule of the base of the maxillule, the number of the endites of the maxilla, and the arrangement of distal natatory setae of the exopods of the maxillipeds are important characters separating the first zoea of carideans at family level (Gurney, 1938; Yokoya, 1957; Albornoz and Wehrmann, 1997). The first zoea of C. nipponensis has a strong resemblance to that of G. americanum: (1) carapace without posterior dorsomedical papilla; (2) base of maxillule without outer seta or lobule, endopod of maxillule segmented; (3) maxilla with three endites; (4) bases of second and third maxillipeds with tubercle and two setae; and (5) exopods of maxillipeds with four distal natatory setae, symmetrically disposed in two pairs. These similarities indicate that the Gnathophyllidae have great affinity with the Pontoniinae. Moreover, the only differences that can be observed in the first zoea of C. nipponensis

### Table 2. Morphological difference of the first zoea of three species of the Pontoniinae.

<table>
<thead>
<tr>
<th></th>
<th>C. nipponensis (present study)</th>
<th>P. flavomaculata (Costanzo et al., 1996)</th>
<th>P. pinnophylax (Calafiore et al., 1991)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rostrum</td>
<td>&lt;1/2AP</td>
<td>=1/2AP*</td>
<td>=1/2AP*</td>
</tr>
<tr>
<td>Antenna scale</td>
<td>6-segmented</td>
<td>5-segmented</td>
<td>5-segmented</td>
</tr>
<tr>
<td>Antenna scale</td>
<td>(11 marginal setae, inner papilla, distolateral spine)</td>
<td>(12 marginal setae, inner papilla)</td>
<td>(12 marginal setae, inner papilla)</td>
</tr>
<tr>
<td>Maxillule coxal endite</td>
<td>1+4 setae</td>
<td>1+5 setae</td>
<td>1+5 setae</td>
</tr>
<tr>
<td>Maxilla basial endite</td>
<td>2+2 setae</td>
<td>1+2 setae</td>
<td>2+2 setae</td>
</tr>
<tr>
<td>Maxilliped II basis</td>
<td>2 setae, tubercle</td>
<td>2 setae</td>
<td>2 setae</td>
</tr>
<tr>
<td>Maxilliped III basis</td>
<td>2 setae, tubercle</td>
<td>2 setae</td>
<td>2 setae</td>
</tr>
</tbody>
</table>

* = data from figure; AP = peduncle of antennule.

### Table 3. Morphological difference of the first zoea of C. nipponensis and G. americanum.

<table>
<thead>
<tr>
<th></th>
<th>C. nipponensis (present study)</th>
<th>G. americanum (Bruce, 1986)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rostrum</td>
<td>&lt;1/2AP</td>
<td>1/2AP</td>
</tr>
<tr>
<td>Antennule outer flagellum</td>
<td>4 aesthetascs, plumose seta</td>
<td>3 aesthetascs, plumose seta</td>
</tr>
<tr>
<td>Antenna scale</td>
<td>6-segmented</td>
<td>4-segmented</td>
</tr>
<tr>
<td>Antenna scale</td>
<td>(11 plumose setae, distolateral spine, inner papilla)</td>
<td>(9 plumose setae, inner papilla)</td>
</tr>
<tr>
<td>Maxillule coxal endite</td>
<td>1+4 setae</td>
<td>0+3 setae</td>
</tr>
<tr>
<td>Maxilla basial endite</td>
<td>2+2 setae</td>
<td>1+1 setae</td>
</tr>
<tr>
<td>Maxilliped I endopod basis</td>
<td>3-segmented 4 setae</td>
<td>1-segmented 3 setae</td>
</tr>
<tr>
<td>Maxilliped II endopod</td>
<td>0, 2, 4+1 setae</td>
<td>0, 2, 4+0 setae</td>
</tr>
<tr>
<td>Maxilliped III endopod</td>
<td>2, 2, 4+1 setae</td>
<td>2, 2, 3+1 setae</td>
</tr>
</tbody>
</table>

AP = peduncle of antennule.
G. americanum are usually found at the generic or specific level of caridean larvae (Table 3). Recently, Williamson and Rice (1996) and Williamson (2001) proposed that similar larvae do not necessarily signify related adults, and therefore, the Pontoniinae and the Gnathoplyllidae may be distinct. Further evidence from molecular sequencing data as well as other larvae of other gnathophyllid genera including Gnathophyllum, which was recently erected by d’Udekem d’Acoz (2001), will be necessary to establish the systematic relationships between the two groups.

ACKNOWLEDGEMENTS

The authors sincerely thank Dr. D. I. Williamson of Port Erin Marine Laboratory, Isle of Man, U. K., for his critical reading and suggestion of the manuscript. Drs K.-I. Hayashi, J. N. Kim, J. Okuno, and Y. Hanamura are acknowledged for providing valuable literature. This work was supported by a grant No. R04-2001-00022 from the Korea Science and Engineering Foundation.

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RECEIVED: 18 February 2003.