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Complete larval development of the rare porcellanid crab, *Novorostrum decorocrus* Osawa, 1998 (Crustacea: Decapoda: Anomura: Porcellanidae), reared under laboratory conditions

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Abstract

The complete larval development of *Novorostrum decorocrus* Osawa, 1998, is described and illustrated on the basis of laboratory-reared material. Two zoeal stages and one megalop stage were recorded. Zoeas of *N. decorocrus* closely resemble those of *N. indicum* in the appendage characters, including the endopod of the maxillule with only a single stout seta on the distal margin. This character is unique to *Novorostrum* zoeas. However, *N. decorocrus* is distinguished from *N. indicum* by the setation on the endopod of the maxilla and the basis of the second maxilliped in both zoeal stages. The megalops of *N. decorocrus* are characterized by having a strongly elongate carapace, and differs considerably from the adults in the structure of the carapace, rostrum and third thoracic sternite, and in the armature of the pereopods. The larval duration of *N. decorocrus* suggests that this rare porcellanid is more widely distributed than currently known.

Keywords: Crustacea, Decapoda, Anomura, Porcellanidae, *Novorostrum decorocrus*, larval development

Introduction

The porcellanid genus *Novorostrum* Osawa, 1998 was established for a species formerly attributed to the genus *Petrolisthes* Stimpson, 1858, *N. indicum* (de Man, 1893) (type species) and two new species, *N. decorocrus* Osawa, 1998 and *N. phuketensis* Osawa, 1998, based on the morphology of the carapace, rostrum and ocular peduncle. Osawa (2000) subsequently described the zoeal stages of *N. indicum* and reported that they possessed two characters that supported the establishment of the genus *Novorostrum*. These characters were the exopod of the antenna possessing only small spines and the endopod of the maxillule with only a single stout seta on the distal margin. Recently, Fujita et al. (2002) pointed out that the former character is also observed in zoeas of *Petrolisthes unilobatus* Henderson, 1888, but the latter character is still useful for discriminating zoeal larvae of *N. indicum* from those of *P. unilobatus*.

Novorostrum decorocrus appears to be very rare, and has only been observed on a few rocky shores on Iriomote Island in the Ryukyu Archipelago, southern Japan (Osawa 1998; unpublished data). Fortunately, we were able recently to collect ovigerous females and to rear the larvae in the laboratory from hatching to the megalopal phase. We herein describe and illustrate the complete larval development of *N. decorocrus*, and compare the morphological characters with larvae of the congener, *N. indicum*, and with larvae of species of the allied genus *Petrolisthes*.

Materials and methods

On 20 July 2001, two ovigerous females of *N. decorocrus* were captured by hand from the intertidal rocky zone at Sonai beach of Iriomote Island. Each crab was transported to the laboratory at the University of the Ryukyus and isolated in a 1.4-litre plastic aquarium until the larvae hatched. Hatched zoeal larvae were mass-cultured in a circular plastic tank (30 cm diameter) filled with filtered sea water (8 litres). Newly hatched *Artemia* nauplii were provided as food for zoeal and megalopal larvae. Water temperature and salinity ranged from 28.0 to 28.5°C and 34.5 to 35.0‰, respectively. Approximately one-third of the water in the tank was changed daily, and then moults of larvae were checked to determine the duration of each stage.

Larvae were fixed and preserved in 50% ethylene glycol for morphological observation. Observations and drawings were made using a Nikon Optiphot-2 binocular microscope equipped with a drawing tube. Five specimens of each larval stage were examined for variations in appendage setae. Body somites are described from anterior to posterior, appendages from endopod to exopod, and segments and setae from proximal to distal. Setal formulae for the segments and distinctions between setae and spines are shown in Osawa (1997a). The long, plumose natatory setae on the exopods of the first and second maxillipeds in the zoeal stages are not fully illustrated but are drawn truncated. The terminology of setae generally follows that of Ingle (1991). Usage of the terms 'zoeas (plural)', 'megalop (singular)', 'megalops (plural)' and 'basial endite' of appendages follows the recommendation by Clark et al. (1998). Methods for measuring carapace length (CL), rostral spine length (RSL) and posterior spine length (PSL) in zoeas followed those of Osawa (1995), whereas measurement of CL of megalops followed that of Fujita et al. (2002).

The dissected or undissected larvae and the spent females are deposited in the National Science Museum, Tokyo, under the registration numbers of NSMT-Cr 15245 (first zoeas), 15246 (second zoeas), 15247 (megalops) and 15248 (spent females), respectively.

Results

Novorostrum decorocrus passed through two zoeal stages and reached the megalop phase, but no larvae metamorphosed to first-stage crab. The total duration of zoeal stages, from hatching to the end of the second stage, ranged from 12 to 14 days. The minimum durations of the first and second zoeal stages were 4 and 8 days, respectively. Morphological characters of the larvae are described below and summarized in Table I.

Table I. Morphological characters of zoeal stages of *Novorostrum decorocrus* Osawa 1998 and *N. indicum* (de Man 1893).

	First zoea		Second zoea	
	<i>N. decorocrus</i>	<i>N. indicum</i>	<i>N. decorocrus</i>	<i>N. indicum</i>
Carapace				
Posteroventral	(11–16)sp	(8–10)sp	(5–11)sp	(4–5)sp
Antennule				
Protopod	1s	Naked	(2+3–4)s	(2+3–4)s
Exopod	3a+3s	3a+3s	(3–4, 4–5, 3, 2–3, 2, 2–3)a+(3–4)s	(4, 3–4, 3, 3, 2, 3)a+3s
Antenna				
Exopod	(1–2)sp	(1–2)sp	(1–2)sp	2sp
Mandible				
Palp	Absent	Absent	Absent	Absent
Maxillule				
Coxal endite	(9–10)s	10s	(10–11)s	10s
Basial endite	7sp+(3–4)s	7sp+(3–4)s	(7–8)sp+(3–4)s	8sp+(3–4)s
Endopod	(0–1+1)s	(1+1)s	(0–1+1)s	(1+1)s
Maxilla				
Coxal endite	(9–10+6–7)s	(8–10+6–7)s	(11+7–8)s	(9–10+7)s
Basial endite	(9–10+10–11)s	(8–9+9–11)s	(10+10–12)s	(10+10–11)s
Endopod	(3+4)s	(3+2+3)s	(3+4)s	(3+2+3)s
Scaphognathite	(8–10+5–6)ps	(9–10+5)ps	(19–22)ps	21ps
First maxilliped				
Coxa	Naked	Naked	Naked	Naked
Basis	(2+2+2–3+3)s	(2+2+2–3+3)s	(2+2+2–3+3)s	(2+2+2–3+3)s
Endopod	3s, 3s, 3s, (4–5)s, (8–9)s+I	3s, 3s, 3s, 5s, 9s+I	3s+I, 3s+I, 3s+I, 5s+I, (8–9)s+I	3s+I, 3s+I, 3s+I, 5s, 9s+I
Exopod	4ps	4ps	12ps	12ps
Second maxilliped				
Coxa	Naked	Naked	Naked	Naked
Basis	2s	(1+2)s	2s	(1+2)s
Endopod	2s, 2s, (1+2)s, 5s+I	2s, 2s, (1+2)s, 5s+I	2s, 2s+I [†] , (1+2)s+I, (5–6)s+I	2s, 2s+I, (1+2)s+I, 5s+I
Exopod	4ps	4ps	(11–12)ps	12ps
Third maxilliped				
Exopod	Naked	Naked	Naked	Naked
Abdomen	3–5	3–5	3–5	3–5
Somites with posterolateral spines				
Telson				
Posterior margin	(5+5)ps	(5+5)ps	(6+6)ps	(6+6)ps
Lateral corner	1sp	1sp	1sp	1sp

Data for the zoeal morphology of *N. indicum* are from Osawa (2000). a, aesthetasc; ps, plumose seta; s, seta except for ps; sp, spine; I, dorsal long plumose seta on the endopod of the maxilliped. [†]The plumose seta is rarely absent.

***Novorostrum decorocrus* Osawa, 1998**
(Figures 1–6, Table I)

First zoea

Size. CL 1.68–1.82 mm (mean 1.77 mm; *n*=5), RSL 7.00–7.10 mm (mean 7.06 mm; *n*=5), PSL 4.30–4.40 mm (mean 4.34 mm; *n*=5).

Figure 1. *Novorostrum decorocrus* Osawa, 1998, first zoea. (A) Entire animal, lateral; (B) carapace, abdomen, telson and appendages, lateral; (C) posteroventral margin of carapace, lateral; (D) abdomen and telson, dorsal; (E) telson, posterolateral region, dorsal; (F) telson, posteromedial region, dorsal; (G–I) distal part of telsonal setae, dorsal: (G) lateral-most; (H) third seta from lateral-most; (I) fifth seta from lateral-most. Scale bars: 0.5 mm (A, B); 0.1 mm (C–H).

Carapace (Figure 1A–C). Typical porcellanid; rostral spine extremely long, 3.99 times CL, with numerous spinules along entire length; posterior spines with spinules along entire length, ventral spinules becoming large on proximal part; posteroventral margins of carapace with 11–16 spinules; eyes sessile.

Antennule (Figure 2A). Swollen medially and narrowing distally, with one short seta; endopod bud indistinctly marked; exopod unsegmented, with three aesthetascs and three simple setae distally.

Figure 2. *Novorostrum decorocrus* Osawa, 1998, first zoea. (A) Antennule, ventral; (B) antenna, ventral; (C) mandibles (r, right; l, left), internal; (D) maxillule, ventral; (E) same, endopod, ventral; (F) maxilla, ventral; (G) first maxilliped, mesial; (H) second maxilliped, mesial; (I) third maxilliped, mesial; (J) pereopods, mesial. Scale bars: 0.1 mm.

Figure 3. *Novorostrum decorocrus* Osawa, 1998, second zoea. (A) Carapace, lateral; (B) carapace, abdomen, telson and appendages, lateral; (C) posteroventral margin of carapace, lateral; (D) abdomen and telson, dorsal; (E) telson, posterolateral region, dorsal; (F) same, posteromedial region, dorsal; (G–I) distal part of telsonal setae, dorsal: (G) lateral-most; (H) third setae from lateral-most; (I) fifth setae from lateral-most. Scale bars: 0.5 mm (A, B, D); 0.1 mm (C, E–I).

Antenna (Figure 2B). Biramous; endopod fused with protopod, bearing one subterminal plumose seta, distal apex sharply pointed; exopod slender, tapering distally, approximately 1.3 times as long as endopod, with one or two spinules on distal half of mesial margin.

Mandible (Figure 2C). Asymmetrically dentate, incisor processes each with several strong and small teeth, molar processes serrate or spinose, palp buds absent.

Maxillule (Figure 2D, E). Coxal endite with nine or 10 (usually 10) simple/plumodenticulate setae; basial endite with seven stout spines bearing several small denticles marginally and three or four (usually four) plumodenticulate setae submarginally;

Figure 4. *Novorostrum decorocrus* Osawa, 1998, second zoea. (A) Antennule, ventral; (B) antenna, ventral; (C) mandibles (r, right; l, left), internal; (D) maxillule, ventral; (E, F) same, endopod, ventral; (G) maxilla, ventral; (H) first maxilliped, mesial; (I) second maxilliped, mesial; (J) third maxilliped, mesial; (K) pereopods, mesial; (L) pleopod on second abdominal somite, ventral. Scale bars: 0.1 mm.

Figure 5. *Novorostrum decorocrus* Osawa, 1998, megalop. (A) Entire animal, dorsal; (B) rostrum, dorsal; (C) pterygostomian flap, left side, lateral; (D) thoracic sternites, ventral; (E) first pereopod, dorsal; (F) third pereopod, lateral; (G) chela of fifth pereopod, dorsal; (H–K) pleopods on second to fifth abdominal somite, ventral; (L) telson and uropod, dorsal. Scale bars: 0.5 mm (A); 0.1 mm (B–J).

Figure 6. *Novorostrum decorocrus* Osawa, 1998, megalop. (A) Antennule, ventral; (B) antenna, ventral, middle segments omitted; (C) mandible, internal; (D) maxillule, ventral; (E) maxilla, ventral; (F) first maxilliped, ventral; (G) second maxilliped, ventral; (H) third maxilliped, ventral. Scale bars: 0.1 mm.

endopod unsegmented, with 1+1 setae, subdistal seta simple, very short (sometimes absent), distal seta plumodenticulate, long, stout.

Maxilla (Figure 2F). Coxal endite bilobed, proximal lobe with nine or 10 plumose/plumodenticulate setae, distal lobe with six or seven (usually seven) plumodenticulate setae; basal endite bilobed, proximal lobe with nine or 10 (usually 10) plumodenticulate setae, distal lobe with 10 or 11 (usually 11) simple/plumodenticulate setae; endopod unsegmented, with 3+4 sparsely plumose setae; scaphognathite with 8–10 plumose setae on anterior and lateral margins, and five or six (usually five) plumose setae on posterior margin.

First maxilliped (Figure 2G). Biramous; coxa naked; basis with 2+2+2–3+3 simple setae on ventral margin; endopod five-segmented, first to fourth segments with 3, 3, 3, 4–5 (usually five) simple/sparsely plumose setae on ventral margins, respectively, first to third segments with fine setules on dorsodistal margin, fifth segment with eight or nine plumodenticulate setae distally and one plumose seta at dorsoproximal angle; exopod incompletely two-segmented, distal segment with four plumose natatory setae terminally.

Second maxilliped (Figure 2H). Biramous; coxa without setae; basis with two setae on ventrodistal margin; endopod four-segmented, first and second segments each with two simple/sparsely plumose setae on ventral margin, third segment with 1+2 simple/sparsely plumose setae each situated at median and distal parts of ventral margin, fourth segment with five plumodenticulate setae distally and one plumose seta at dorsoproximal angle, fine setules present on dorsodistal margin of second segment and dorsomedian margin of third segment; exopod as in first maxilliped.

Third maxilliped (Figure 2I). Small, biramous, unsegmented buds.

Pereiopods (Figure 2J). Small unsegmented buds.

Abdomen (Figure 1B, D). Five somites; fifth somite longest; second to fifth somites with pair of short simple setae near posterolateral angles and distinct serration on posterodorsal margin; third to fifth segments with pair of posterolateral spines; pleopods absent.

Telson (Figure 1B, D–I). Longer than broad; posterior margin produced into broad trapezoid, with five pairs of long, stout plumose setae bearing distinct hooklets (spinules) distally (Figure 1G–I), hooklets more remarkable on lateral two pairs; lateral angles each with single stout spine and one short plumose seta (anomuran hair) (Figure 1E); posteromedian region narrow, slightly concave, bearing setules (Figure 1F); dorsal surface with two pairs of short plumose setae along midline; anal spine present.

Colour in life. Carapace, abdomen, telson and appendages essentially transparent; median gastric region red-brown; dorsal and ventral margins of rostrum and posterior spines pale orange; orange and/or red-brown chromatophores present on mandibles, proximal part of maxilla, first to fifth abdominal somites and proximal part of telson.

Second zoea

Size. CL 2.10–2.25 mm (mean 2.20 mm; $n=5$), RSL 12.38–13.00 mm (mean 12.65 mm; $n=3$), PSL 3.60–5.80 mm (mean 4.44 mm; $n=4$).

Carapace (Figure 3A–C). Rostral spine more elongate than in previous stage, 5.75 times CL; posteroventral margins of carapace with 5–11 (usually seven to nine) small spinules; eyes now stalked.

Antennule (Figure 4A). Biramous; protopod swollen proximally, with two short plumose setae on median lateral margin and with three or four short plumose setae near junction of exopod; endopod slender, naked, fused with protopod; exopod with five rows of marginal aesthetascs numbering 3–4, 4–5, 3, 2–3, 2 from proximal to distal, distal apex with two or three (usually three) aesthetascs plus three or four simple setae.

Antenna (Figure 4B). Endopod greatly lengthened, approximately 1.8 times longer than exopod, with one short plumose seta near distal apex (sometimes absent), distal apex sharply pointed; exopod with one or two spinules on subdistal mesial margin.

Mandible (Figure 4C). Similar to first zoea, no palp buds.

Maxillule (Figure 4D–F). Coxal endite with 10 or 11 simple/plumodenticulate setae marginally; basal endite with seven or eight (usually eight) stout spines marginally and three or four plumodenticulate setae submarginally; endopod unchanged.

Maxilla (Figure 4G). Coxal endite with 11+7–8 plumose/plumodenticulate setae; basal endite with 10+10–12 simple/plumodenticulate setae; endopod unchanged; scaphognathite with 19–22 marginal plumose setae.

First maxilliped (Figure 4H). Coxa and basis same as in first zoea; endopod five-segmented, setal formula (ventral or distal setae+dorsal plumose seta), 3+I, 3+I, 3+I, 5+I, 8–9+I; exopod indistinctly two-segmented, distal segment with 12 plumose natatory setae, proximal two setae short.

Second maxilliped (Figure 4I). Coxa naked; basis with two simple setae on ventrodistal margin; endopod four-segmented, with setation of 2, 2+I, (1+2)+I, 5–6+I (dorsal plumose seta of second segment rarely absent); exopod with 11 or 12 (usually 12) plumose natatory setae, proximal two setae short.

Third maxilliped (Figure 4J). Endopod elongate, swollen, indistinctly segmented, without setae; exopod small, naked.

Pereiopods (Figure 4K). Well formed but unsegmented; first and fifth pereiopods bifid distally, showing chelate appearance.

Abdomen (Figure 3B, D). Similar to first zoea; pair of biramous pleopod buds (Figure 4L) present on second to fifth abdominal somites, respectively.

Telson (Figure 3B, D–I). Similar to first zoea except for posteromedian margin with a pair of short plumodenticulate setae and dorsal surface with four pairs of short plumose setae as illustrated.

Colour in life. Similar to first zoea. Carapace with scattered small red or orange chromatophores; antennal endopod and pereiopods with orange chromatophores.

Megalop

Size. CL 1.52–1.83 mm (mean 1.71 mm; $n=5$), TL 2.97–3.20 mm (mean 3.06 mm; $n=5$).

Carapace (Figure 5A–D). Elongate oval-shaped, approximately 1.6 times as long as broad; dorsal surface covered with minute denticles and scattered short simple setae. Rostrum (Figure 5B) broad, subtriangular, with shallow median groove; anterior margin bearing few minute denticles.

Pterygostomial flap (Figure 5C) differentiated from carapace by faint demarcations, anterior margin rounded. Thoracic sternites (Figure 5D) as illustrated; third thoracic sternite strongly depressed, median lobe broad, weakly marked, with shallow depression, lateral lobes strongly produced anteriorly, narrow, rounded.

Antennule (Figure 6A). Peduncle three-segmented; first (proximal) segment broad, with small granules on anterolateral margin and row of simple/plumose setae on lateral margin and ventral surface; second and third segments with few short simple/plumose setae; flagellum biramous; endopod two-segmented, proximal segment slightly longer than distal segment, with seven or eight simple setae, distal segment with 10 simple setae; exopod six-segmented, with row of aesthetascs on second to fifth segments, numbering proximal to distal, 0–3+7–8, 7–9+4–5, 3+3, 3, respectively, fourth and fifth segments with two or three short simple setae, distal segment with one long and short simple setae.

Antenna (Figure 6B). Peduncle four-segmented (first segment illustrated incompletely), with few short setae; second segment with small rounded lobe on anterodistal margin; third and fourth segments apparently unarmed; flagellum composed of 16–20 articles (usually 19 or 20), each with four to eight simple setae or naked on distal margin as illustrated.

Mandible (Figure 6C). Subsymmetrically scoop-like; palp three-segmented, proximal segment with two simple setae, median segment naked, distal segment with 13–15 serrate setae terminally.

Maxillule (Figure 6D). Coxal endite with 28–32 simple/plumodenticulate setae, lower part with one long simple seta; basal endite with 15–17 spines and 11–15 plumose/plumodenticulate setae terminally or subterminally, lateral margin near proximal part of endopod with one long plumose seta; endopod unsegmented, with two short plumose setae on distomesial margin.

Maxilla (Figure 6E). Coxal endite bilobed, with 38–44+18–20 simple/plumodenticulate setae, but exact number of setae difficult to count due to extremely high density; basal endite bilobed, with 18–21+29–38 simple/plumodenticulate setae; endopod unsegmented, with three to six setae on distal half; scaphognathite with 46–58 marginal plumose setae and four simple setae on dorsal and ventral surfaces.

First maxilliped (Figure 6F). Coxal and basal endites with 14–18 and 34–43 simple/plumodenticulate setae, respectively; endopod unsegmented but with slightly constricted parts and 4–11 setae on mesial margin; exopod with one to eight plumose setae on distal margin and five to eight plumose setae on lateral margin.

Second maxilliped (Figure 6G). Biramous; coxa with six or seven plumose setae; basis with five or six plumose setae; endopod five-segmented, proximal segment (ischium) fused to basis, with setation of 5–6, 8–9, 4–6, 23–29, 19–24 from proximal to distal (in distal two segments, stout serrate setae included, exact count of setae difficult because of their high density); exopod two-segmented, proximal segment with five to seven short and four to six long simple/plumose setae, distal segment (flagellum) with six to nine terminal plumose setae.

Third maxilliped (Figure 6H). Biramous; coxa with 11–14 plumose setae and two serrate setae; basis narrow, with three or four plumose setae; endopod five-segmented; ischium with seven or eight long plumose and 14–18 short simple setae, distolateral projection weakly produced; merus with broad, rounded lobe on mesial margin, and 14–16 long plumose and 10–17 short simple setae; carpus with 11–15 long plumose, eight or nine serrate and 10–14 short simple setae; propodus with 17–20 long plumose, six to nine serrate and five to eight short simple setae; dactyl with 14–16 long plumose setae, four to six serrate setae and one to three short simple setae; exopod elongate, overreaching distal margin of ischium, incompletely two-segmented, with one or two proximal and zero to two terminal short simple/plumose setae.

Pereiopods (Figure 5A, E–G). All legs fully developed, with numerous short simple/plumose setae and covered with minute denticles. Cheliped (first pereiopod) approximately as long as carapace, flattened dorsoventrally, with scattered short plumose setae on dorsal surface; carpus with one large proximal tooth and four to six small teeth on dorsoflexor margin, all teeth acutely pointed, extensor margin slightly serrated; propodus with rows of small acute teeth on extensor and flexor margins, dorsal surface with several small denticles; dactylus with row of small acute teeth on flexor margin, dorsal surface with small denticles. Ambulatory legs (second to fourth pereiopods) flattened, with scattered short plumose and simple setae on lateral and dorsal surfaces, lateral surfaces of merus, carpus and propodus with small denticles; merus with row of small teeth on extensor and flexor margins; carpus slightly crenulated on extensor margin; propodus with three to five small movable spines on flexor margin, lateral spine of distal pair largest, extensor margin nearly smooth; dactylus with three small movable spines on flexor margin. Fifth pereiopod short, slender, chelate; propodus with six to nine long, distally curved, serrate setae and scattered short simple/plumose setae as illustrated. No male or female gonopores.

Abdomen (Figure 5A). Six somites, with numerous short simple/plumose setae on dorsal surface, as illustrated. Pleopods (Figure 5H–K) present on second to fifth somites, biramous; endopods increasing in length posteriorly, with three or four minute hooks and zero to three marginal short plumose setae; exopods equal in size, bearing marginal plumose setae, numbering proximal to distal, 10–14, 12–15, 12–14, 11–14.

Tail fan (Figure 5L). Telson incompletely divided into seven plates with notches and faint demarcations; anteromedial plate more distinctly marked than others; anterolateral plates small, indistinct but recognizable with shallow lateral depression; intermediate and posterior plates recognizable with notches and more distinctly marked than anterolateral plates; posterior margin with 18–22 (usually 9–11 pairs) long

plumose setae, plus 6–10 (usually three to five pairs) submarginal simple setae; dorsal surface with scattered short simple/plumose setae as illustrated. Uropods biramous, endopod with 11–13 plumose setae on distal margin and four or five simple setae on distolateral margin, exopods with 15–18 plumose setae and one simple seta marginally.

Colour in life. Body and pereopods generally transparent, carapace and abdomen with scattered orange or red chromatophores; antennule, antenna and third maxilliped with orange chromatophores; chelipeds and ambulatory legs with orange-red coloured spines, denticles and fringe of setae.

Discussion

Zoeas of *Novorostrum decorocrus* closely resemble those of *N. indicum* as described by Osawa (2000) but are distinguished from the latter by the following characters: (1) the posteroventral margin of the carapace has 11–16 and 5–11 (usually seven to nine) spinules in the first and second zoeas, respectively (in *N. indicum*, there are 8–10 and four or five spinules in the first and second zoeas, respectively); (2) the endopod of the maxilla bears 3+4 setae throughout two zoeal stages (in *N. indicum* there are 3+2+3 setae); and (3) the basis of the second maxilliped bears two ventrodistal setae throughout two zoeal stages (in *N. indicum* there are two distal setae and one proximally separate seta). In addition to these distinctions, *N. decorocrus* sometimes lacks a very short subdistal mesial seta on the endopod of the maxillule throughout two zoeal stages and a dorsal plumose seta on the second segment of the second maxilliped endopod in the second zoea.

Osawa (1995) divided 19 *Petrolisthes* species, for which larval morphology was known at that time, into six groups based on the zoeal characters. Fujita et al. (2002) updated Osawa's (1995) grouping for 28 species including *P. unilobatus* and added a new group for the latter species. As discussed for zoeas of *N. indicum* by Osawa (2000), *N. decorocrus* zoeas also have close affinities with *Petrolisthes* Group 1 of Osawa (1995), which contains *P. japonicus* (de Haan, 1849) and *P. ornatus* Paulson, 1875. All three species share the following characters: in the first zoea, (1) the basial endite of the maxillule has seven marginal spines; (2) the maxilla usually has five (sometimes four or six) plumose setae on the posterior lobe of the scaphognathite; (3) the endopod of the first maxilliped is five-segmented, the fifth segment possesses a plumose seta on the dorsoproximal angle; (4) the telson is longer than broad, with all posterior plumose setae bearing distal hooklets (spinules); and in the second zoea, (5) the mandible lacks a palp; and (6) the telson has six pairs of plumose setae on the posterior margin. However, the setation on the endopod of the maxillule throughout the zoeal stages immediately distinguishes *Novorostrum* species from the other porcellanid genera including *Petrolisthes*. In *Novorostrum* species, the endopod of the maxillule has only a single stout seta on the distal margin, but it usually possesses three to seven setae in other porcellanid species for which larval morphology is known (see Osawa 2000). In addition to this distinction, *Novorostrum* differs from *Petrolisthes* Group 1 in having 8–16 (first zoea) and 4–11 (second zoea) spinules on the posteroventral margin of the carapace. *Petrolisthes japonicus* has only one or two spinules (see Osawa 1995) and *P. ornatus* is illustrated as unarmed (see Yaqoob 1977, Figure 1A, B).

The present study contributes the first description of the megalop of *Novorostrum* species. The megalops of *N. decorocrus* appear to be distinguished from those of both *P. japonicus* and *P. ornatus*, discussed above, by having a more strongly elongate carapace (see Yaqoob

1977; Osawa, personal observation). The shape of the carapace also distinguishes *N. decorocrus* from *P. elongatus* (H. Milne Edward, 1837) and *P. unilobatus*, two related species based on morphological similarities in larvae and adults (see Wear 1964; Greenwood 1965; Osawa 1998; Fujita et al. 2002).

The megalopal morphology of *N. decorocrus* is considerably different from that of the adults: (1) the carapace is elongate-oval in the dorsal view (subtrapezoidal in the adults); (2) the rostrum is subtriangular (trilobate in the adults); (3) the median lobe of the third thoracic sternites is indistinct (developed as long as the lateral lobes in the adults); and (4) the palms of the chelipeds and carpi and propodi of the ambulatory legs lack distinct projections on the extensor margin, which are observed in the adults. In the adults, the armature on the chelipeds and ambulatory legs immediately distinguishes *N. decorocrus* from two congeners, *N. indicum* and *N. phuketensis*. However, the megalop of *N. decorocrus* lacks such a unique character.

In the present study, the zoeal phase of *N. decorocrus* has a putative planktonic period of 12–14 days at a water temperature of 28.0–28.5°C under laboratory conditions. This duration generally agrees with that of other sympatric porcellanids, such as *Petrolisthes asiaticus* (13–17 days) and *P. hastatus* (12–13 days) (at a water temperature of 29.0–29.5°C under laboratory conditions; see Osawa 1997b). These two *Petrolisthes* species are known to be widely distributed in the Indo-Pacific region (see Kropp 1984; Haig 1989). This indicates that *N. decorocrus* zoeas have a dispersal potential comparable to *P. asiaticus* and *P. hastatus*, and the distribution of *N. decorocrus* is possibly wider than currently known. However, this species has been observed on only a few rocky shores on Iriomote Island of the western Ryukyu Archipelago, southern Japan. On the other hand, Jensen (1989, 1991) reported that megalops of two north-eastern Pacific porcellanids, *Petrolisthes cinctipes* (Randall, 1839) and *P. eriomerus* Stimpson, 1871, settled gregariously in response to conspecific adults. Jensen and Armstrong (1991) subsequently determined that the zonation patterns observed for these two sympatric species were apparently more a passive consequence of physiological limitations and substratum preferences than the result of continuing biotic interaction. These may suggest that *N. decorocrus* has a much narrower substratum preference as juveniles and adults than sympatric porcellanids such as *P. asiaticus* and *P. hastatus*, although detailed ecological data on these species are needed.

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