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Larval development of *Rhinolithodes wosnessenskii* Brandt (Decapoda: Anomura: Lithodidae) reared in the laboratory

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The complete larval development of *Rhinolithodes wosnessenskii* Brandt, 1848 is described, based on laboratory rearing. The species has four zoeal stages and a megalopa. The zoeas of *R. wosnessenskii* are readily distinguished from all other described zoeas of the subfamily Lithodinae by having a middorsal spine of the posterior margin of the carapace.

Keywords: larval development; *Rhinolithodes wosnessenskii*; Lithodidae; Decapoda; Anomura

Rinoceros crab, *Rhinolithodes wosnessenskii* Brandt, is a small lithodid crab inhabiting 6–73 m in depth ranging from Kodiak, Alaska, to Crescent City, California (Makarov 1938; Jensen 1995). Larval development of the family Lithodidae has been described, at least in part, for 17 species (Haynes 1984; Konishi 1986; Konishi and Taishaku 1994; Kim and Hong 2000; Hong et al. 2005): *Acantholithodes hispidus* (Stimpson, 1860), *Cryptolithodes typicus* Brandt, 1849, *Cryptolithodes expanses* Miers, 1879, *Dermaturus mandtii* Brandt, 1850, *Hapalogaster grebnitzkii* Schalfeew, 1892, *Hapalogaster dentate* (De Haan, 1844), *Hapalogaster mertensii* Brandt, 1850, *Lithodes aequispina* Benedict, 1894, *Lithodes antarctica* Jacquinot, 1844, *Lopholithodes mandtii* (Brandt, 1849), *Paralithodes brevipes* (H. Milne Edwards and Lucas, 1841), *Paralithodes camtschaticus* (Tilesius, 1815), *Paralithodes platypus* Brandt, 1850, *Paralomis granulose* (Jacquinot, 1847), *Paralomis hystrix* (De Haan, 1844), *Placetron wosnessenskii* Schalfeew, 1892, and *Rhinolithodes wosnessenskii*. The first two zoeal stages of *R. wosnessenskii* had been described by Haynes (1984), but subsequent larval stages were unknown.

The purpose of the present study is to describe the complete larval development of *R. wosnessenskii* reared in the laboratory, and to compare it with other known lithodid larvae.

Material and methods

Berried females of *R. wosnessenskii* were caught with a bottom trawl from a depth of 400–420 m of Vancouver Island (49°15′N 129°9′W), Canada, on 5 March 2002. The specimens were brought to the laboratory and kept in a container filled with aerated natural seawater (30.6–33.6‰) at 8.2–9.8°C until their eggs hatched. About 80 larvae hatched from a *R. wosnessenskii* female on 14 March 2002, and they were reared by mass culture in 5-l glass bowls.

Larvae were fed with newly hatched *Artemia* nauplii. Moulting and mortality were checked daily. After checking, the larvae were transferred to freshly prepared bottles. At each developmental stage, dead larvae and exuviae were fixed and preserved with 3% neutralized formalin solution. Each stage was dissected in ethylene glycol for microscopic observation. Drawings were made with the aid of drawing tubes attached to an optical microscope.

Measurements were taken: carapace length (CL), from the tip of the rostrum to the posterior midpoint of the carapace, excluding mid-dorsal spine.

Results

In the complete larval development of *R. wosnessenskii*, there were four zoeal and one megalopal stages.

Descriptions

First zoea (Figure 1)

Size: CL = 2.4–2.6 mm (mean 2.5 mm).
Duration: 7–15 days.

Carapace (Figure 1A, B). Rostrum well-developed; pronounced middorsal ridge extending full length of carapace; middorsal spine at middorsal posterior

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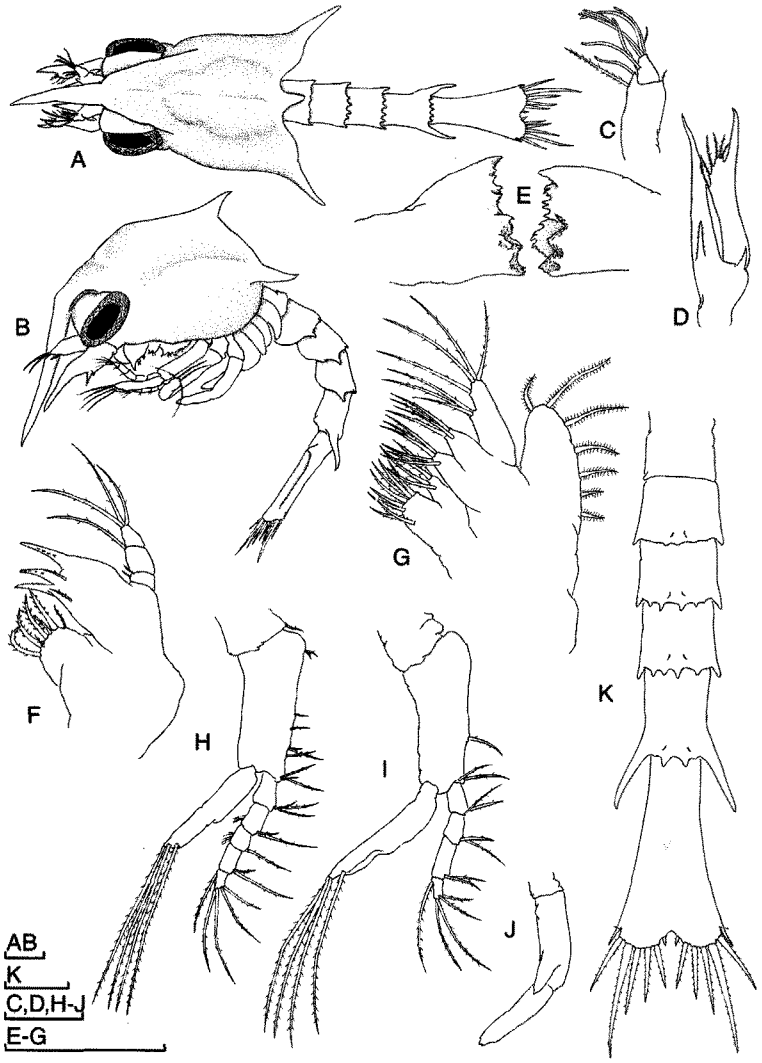

Figure 1. *Rhinolithodes wosnessenskii* Brandt. First zoea. A, dorsal view; B, lateral view; C, antennule; D, antenna; E, mandibles; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped; J, third maxilliped; K, abdomen and telson. Scale bars = 0.4 mm.

margin and posterolateral spines present; eyes stalked or partially fused to carapace.

Abdomen (Figure 1A, B, K). Five somites; posterodorsal margins of somites as follows: somite 1 unarmed, somites 2–5 each with pair of middorsal setae on posterior margin and two pairs of dorsodistal spines, outermost pair frequently smaller, spine pairs progressively increasing in size posteriorly; posterolateral margins of somites 2–4 also with pair of posterolateral spines; somite 5 with pair of strong, elongate posterolateral spines.

Telson (Figure 1K). Elongate; posterior margin with 8 + 8 processes, outermost fused naked spine, second anomuran hair, third through eighth plumodenticulated processes, of which fourth being longest; posterior margin convex, with median cleft; anal spine present (Figure 1B).

Antennule (Figure 1C). Endopod bud not delineated from protopod, naked; exopod delineated from protopod, with three subterminal aesthetascs, five terminal aesthetascs; protopod with ventral plumose seta at endopodal junction and one short seta at exopodal margin.

Antenna (Figure 1D). Endopod without setae, approximately equal length of scaphocerite; scaphocerite with elongate distal spine, inner margin with seven plumose setae; protopod with one spinose spine at base of endopod and one naked spine at base of scaphocerite.

Mandibles (Figure 1E). Asymmetrically dentate; incisor process with strong teeth and few smaller teeth; molar process with few strong teeth and few acute small teeth; no palp bud.

Maxillule (Figure 1F). Endopod 3-segmented, with 2, 1, 3 setae; coxal endite with one plumose, four

plumodenticulate and two simple setae; basal endite with 3 strong, elongate spinelike teeth armed with minute denticles and two simple setae submarginally.

Maxilla (Figure 1G). Endopod bilobed, with 3 + 1 + 3 setae; coxal and basal endites bilobed; coxal endite with 1 + 7 setae on proximal lobe, 1 + 3 setae on distal lobe; basal endite with 1 + 4 setae on proximal lobe and 1 + 3 setae on distal lobe; scaphognathite posteriorly fused to protopod, distal lobe with 7–9 marginal plumose setae.

First maxilliped (Figure 1H). Coxa with one seta at anterodistal angle; basis with 2, 1, 1, 3, 3 setae; endopod 5-segmented, with 3, 2, 1, 2, 4 + 1 setae and additional fine setae on lateral margins of segments 2–3; exopod with four plumose natatory setae.

Second maxilliped (Figure 1I). Coxa without setae; basis with one seta near mid-length, one plumose and one serrate setae at distal angle; endopod 4-segmented, segments 1–3 each with one plumose and one serrate setae, distal segment with 4 + 1 plumose setae; exopod with four plumose natatory setae.

Third maxilliped (Figure 1J). Exopod partially segmented, with 1–3 very small protuberances; endopod naked, with 1–2 very small protuberances.

Pereopods (Figure 1B). Chelipeds distally bilobed; elongate unsegmented buds of pereopods 2–4 present; smaller pereopod 5 bud concealed beneath buds of pereopods 2–3.

Colour. The whole body tinged with yellow chromatophores except abdomen, rostrum, and endopod and exopod of first and second maxillipeds.

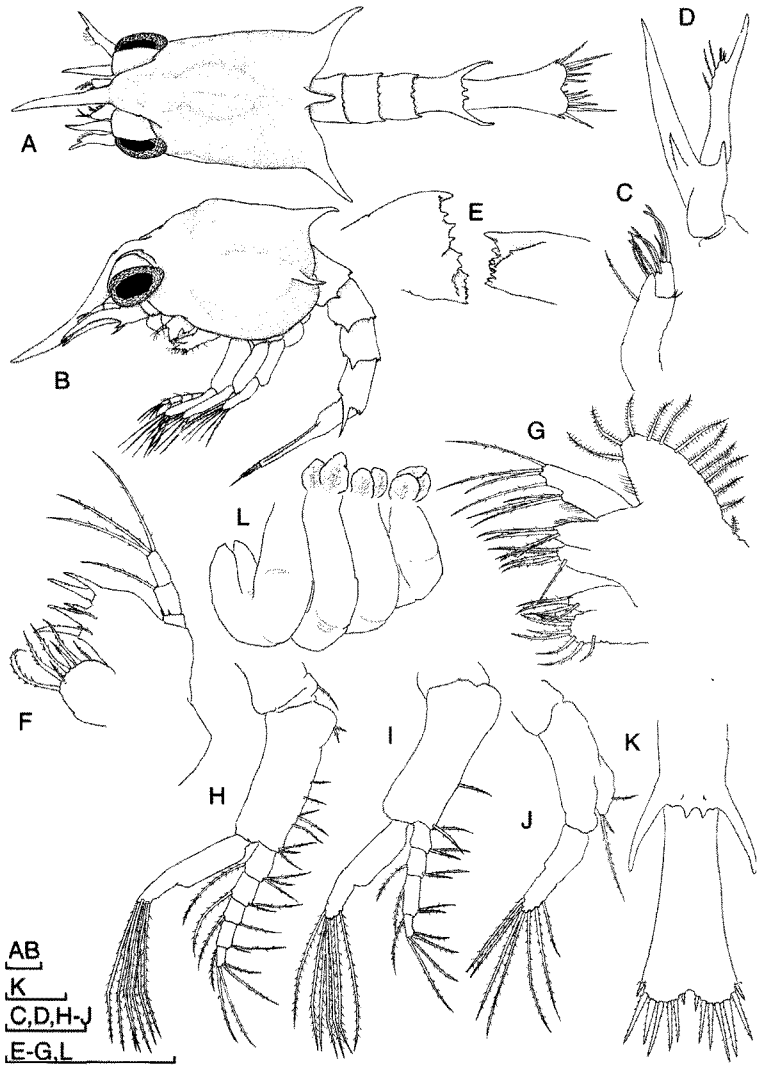

Figure 2. *Rhinolithodes wosnessenskii* Brandt. Second zoea. A, dorsal view; B, lateral view; C, antennule; D, antenna; E, mandibles; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped; J, third maxilliped; K, telson; L, pereopods and gills. Scale bars = 0.4 mm.

Second zoea (Figure 2)

Size: CL = 2.7–2.9 mm (mean 2.8 mm).
Duration: 7–9 days.

Carapace (Figure 2A, B). Larger; eyes more prominently stalked.

Abdomen (Figure 2A, B). Somites 3–5 with minute pleopod buds developing ventrally.

Telson (Figure 2K). Unchanged.

Antennule (Figure 2C). Endopod bud unchanged; exopod with 3 + 2 subterminal and three terminal aesthetascs; protopod with one plumose seta at endopodal junction and two short setae at exopodal margin.

Antenna (Figure 2D). Unchanged.

Mandibles (Figure 2E). Larger.

Maxillule (Figure 2F). Endopod and coxal endites unchanged; basal endite with five strong teeth with minute denticles and two simple submarginal setae.

Maxilla (Figure 2G). Endopod and endites unchanged; scaphognathite with 11–12 plumose marginal setae.

First maxilliped (Figure 2H). Coxa and basis setation unchanged; endopod setal formula now 3 + 1, 2 + 1, 1 + 1, 2, 4 + 1; exopod with seven plumose natatory setae.

Second maxilliped (Figure 2I). Coxa and basis setations unchanged; endopod with 2, 2 + 1, 2 + 1, 4 + 1 setae; exopod with seven plumose natatory setae.

Third maxilliped (Figure 2J). Protopod naked; endopod bud with two terminal and one subterminal setae; exopod with 6–7 plumose natatory setae.

Pereopods (Figure 2L). Larger.

Gills (Figure 2L). Paired arthrobranchs on pereopods 2–4; pleurobranch bud developing on pereopod 4.

Figure 3. *Rhinolithodes wosnessenskii* Brandt. Third zoea. A, dorsal view; B, lateral view; C, antennule; D, antenna; E, mandibles; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped; J, third maxilliped; K, telson; L, pereopods and gills. Scale bars = 0.4 mm.

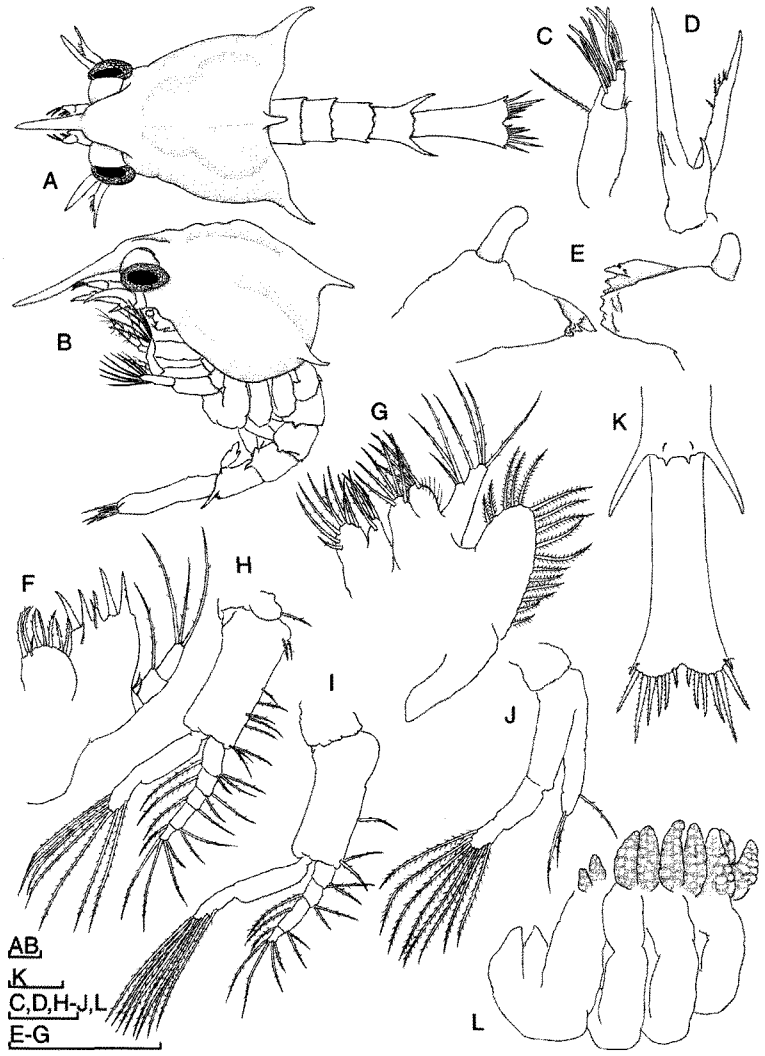

Figure 4. *Rhinolithodes wosnessenskii* Brandt. Fourth zoea. A, dorsal view; B, lateral view; C, antennule; D, antenna; E, mandibles; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped; J, third maxilliped; K, telson; L, pereopods and gills. Scale bars = 0.4 mm.

Third zoea (Figure 3)

Size: CL = 2.9–3.2 mm (mean 3.0 mm).
Duration: 8–13 days.

Carapace (Figure 3A, B). Larger.

Abdomen (Figure 3A, B). Pleopod buds somewhat larger on somites 3–5.

Telson (Figure 3K). Unchanged.

Antennule (Figure 3C). Exopod with 3 + 2 + 3 or four aesthetascs.

Antenna (Figure 3D). Scaphocerite with six plumose setae.

Mandibles (Figure 3E). Mandibular palps present.

Maxillule (Figure 3F). Endopod and basal endite unchanged; coxal endite with one plumose, four plumodenticulate and three subterminal setae.

Maxilla (Figure 3G). Endopod and endites unchanged; scaphognathite now with 9–13 plumose marginal setae.

First maxilliped (Figure 3H). Coxa, basis and endopod setation unchanged; exopod with 7–8 plumose natatory setae.

Second maxilliped (Figure 3I). Coxa, basis and endopod setation unchanged; exopod with eight plumose natatory setae.

Third maxilliped (Figure 3J). Coxa, basis and endopod setation unchanged; exopod with eight plumose natatory setae.

Pereopods (Figure 3L). Appreciably larger; chelipeds with and dactyl clearly delineated, surfaces unarmed; ambulatory legs with 3–4 segments delineated.

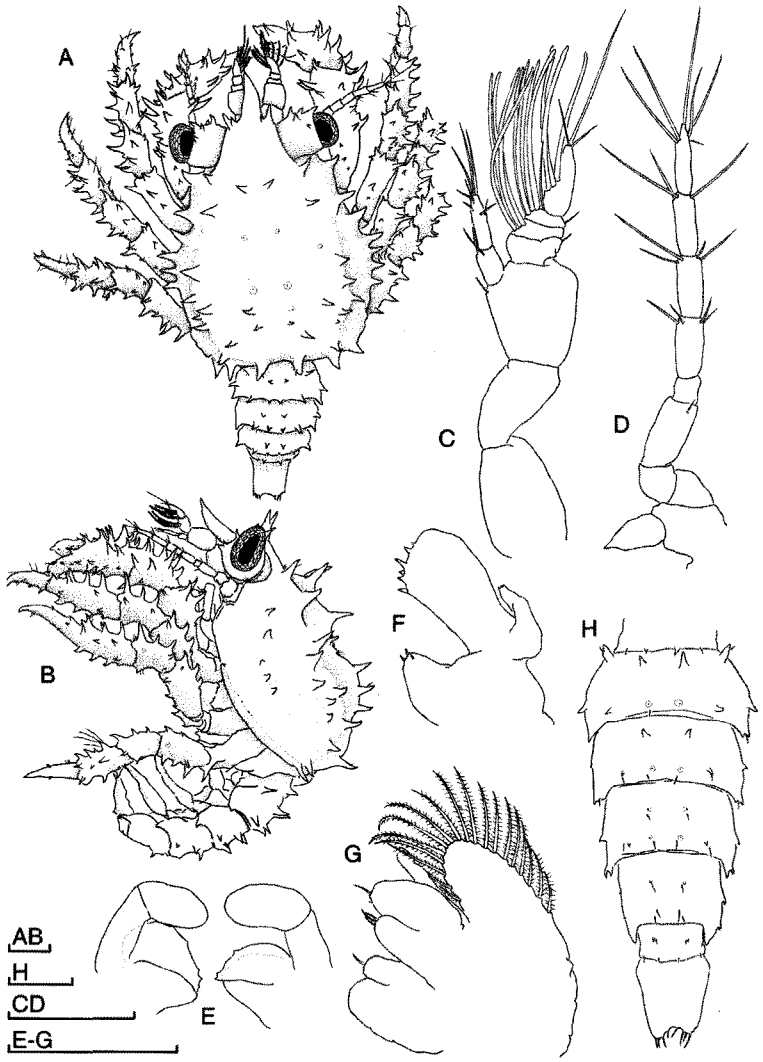

Figure 5. *Rhinolithodes wosnessenskii* Brandt. Megalopa. A, dorsal view; B, lateral view; C, antennule; D, antenna; E, mandibles; F, maxillule; G, maxilla; H, abdomen and telson. Scale bars = 0.4 mm.

Gills (Figure 3L). Paired arthrobranchs clearly developed on pereopods 2–4, rudimentary on chelipeds; pleurobranch bud developing on pereopod 4.

Fourth zoea (Figure 4)

Size: CL = 3.2–3.5 mm (mean 3.3 mm).
Duration: 6–9 days.

Carapace (Figure 4A, B). Larger.

Abdomen (Figure 4A, B). Unequally biramous naked pleopod buds on somites 2–5.

Telson (Figure 4K). Unchanged.

Antennule (Figure 4C). Endopod bud larger; exopod with 4–6, 2, 5 aesthetascs.

Antenna (Figure 4D). Unchanged.

Mandibles (Figure 4E). Unchanged.

Maxillule (Figure 4F). Unchanged.

Maxilla (Figure 4G). Endopod and endites unchanged; scaphognathite with 14–16 plumose marginal setae on distal lobe; proximal lobe distinct, elongate, naked.

First maxilliped (Figure 4H). Unchanged.

Second maxilliped (Figure 4I). Unchanged.

Third maxilliped (Figure 4J). Unchanged.

Pereopods (Figure 4L). Larger.

Gills (Figure 4L). Pereopods 1–4 each with pair of arthrobranch buds.

Megalopa (Figures 5 and 6)

Size: CL = 2.2–2.4 mm (mean 2.3 mm).

Carapace (Figure 5A, B). Globular, with 25–30 simple spines on dorsal surface and dorsolateral margins; rostrum moderately broad, with two pairs of

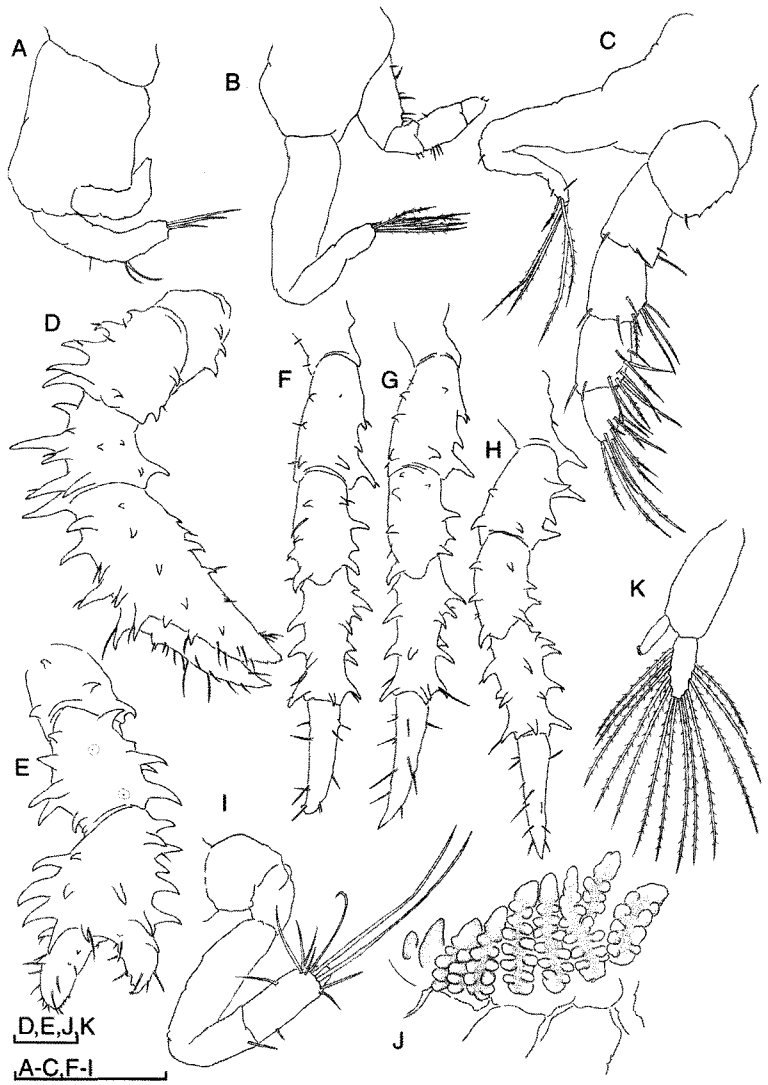

Figure 6. *Rhinolithodes wosnessenskii* Brandt. Megalopa. A, first maxilliped; B, second maxilliped; C, third maxilliped; D, right cheliped; E, left cheliped; F, second pereopod; G, third pereopod; H, fourth pereopod; I, fifth pereopod; J, gills; K, pleopod. Scale bars = 0.4 mm.

dorsal spines. Ocular peduncles moderately short, stout, each with five simple spines; no ocular acicle apparent.

Abdomen (Figure 5A, B, H). Abdominal tergites each as broad plate, somites 1–6 each with dorsal and dorolateral spines and setae; biramous pleopods (Figure 6B, K) on somites 2–5; exopods well developed, each with 11–13 marginal, plumose setae; endopods each with appendix interna consisting of three apical hooks.

Telson (Figure 5H). Subqudrate plate, terminal margin concave, with 7–8 setae, fine spine-like setae or small spines on either side.

Antennule (Figure 5C). Biramous; peduncle 3-segemented; exopod 4-segemented; first segment with one short seta; second with four aesthetascs; third with four aesthetascs and two short simple setae; fourth elongate, with three aesthetascs proximally and two short and one long simple setae distally; endopod 2-segmented, with two short setae on basal segment and three terminal and five subterminal setae on distal segment.

Antenna (Figure 5D). With supernumerary segments apparent; acicle terminating acutely; peduncle weakly 4-segmented, flagellum usually with five articles, setal formula variable.

Mandibles (Figure 5E). Reduced and simplified, incisor and molar processes indicated only by pairs of small protuberances; palps 2-segmented, naked.

Maxillule (Figure 5F). Endopod unsegmented, naked; coxal endite with 3–4 setae; basal endite with 6–9 spine-like cuspidate setae.

Maxilla (Figure 5G). Endopod unsegmented, naked; coxal and basal endites still bilobed, coxal endite with 0 and 1 marginal seta on proximal and distal lobes, respectively; basal endite with three and two setae on proximal and distal lobes, respectively; scaphognathite with 18–20 moderately short marginal plumose setae.

First maxilliped (Figure 6A). Coxa naked; broad subrectangular basis naked; endopod unsegmented, naked; exopod unsegmented, with three plumose setae marginally and three submarginal setae.

Second maxilliped (Figure 6B). Endopod 4-segmented; basal segment with seven short simple setae; second segment with two setae; penultimate segment with five setae; ultimate segment with two terminal simple setae; exopod 2-segmented; proximal segment unchanged; distal segment with five plumose setae.

Third maxilliped (Figure 6C). Endopod 5-segmented, all segments with numerous setae, those of ultimate and penultimate segments often serrated or barbed; exopod incompletely 2-segmented, with 5 terminal + 2 subterminal plumose setae.

Pereopods (Figure 6D–I). Chelipeds unequal in length, right somewhat larger, both with numerous sharp spines. Ambulatory legs (Figure 6F–H) with numerous setae on dactyls, propodi, carpi and meri all with prominent sharp spines and scattered setae. Fifth pereopod (Figure 6I) very small, carried under carapace, propodus with three long and eight short setae.

Gills (Figure 6J). Arthrobranchs of chelipeds slightly larger than in stage IV; arthrobranchs of second to fourth and pleurobranch of fourth becoming lobular.

Discussion

The first and second zoeal stages of *R. wosnessenskii* were described by Haynes (1984). However, his description slightly differs from the present study. It would appear that our larvae were appreciably larger than Haynes's specimens. However, the discrepancy reflects a difference in measurement of carapace length. Carapace length of our specimens was measured from the tip of the rostrum to the posterior midpoint of the carapace, excluding mid-dorsal spine, while in his specimens it was measured from the posterior margin of the ocular orbit to the mid-dorsal posterior margin of the carapace, excluding any mid-dorsal spine (Table 1).

Rhinolithodes wosnessenskii belongs to the family Lithodidae. The morphological characteristics of the family Lithodidae zoea are as follows: uropods, if present, lack an endopod, even in the final zoeal stage; the third maxilliped has an endopod in the first zoeal stage; abdominal somites lack mediodorsal spines; the telson lacks an anal spine (Gurney 1942; MacDonald et al. 1957; Pike and Willamson 1960; Kurata 1964; Konishi 1986). These morphological characteristics of the family Lithodidae zoea coincide with those of our specimens.

Rhinolithodes wosnessenskii belongs to the subfamily Lithodinae, family Lithodidae including *Cryptolithodes*, *Lithodes*, *Lopholithodes*, *Paralithodes*, *Paralomis* and *Rhinolithodes*. These six subfamily Lithodinae are markedly different in the spines of the carapace. *Rhinolithodes wosnessenskii* zoeas have a middorsal spine of the posterior margin of the carapace that is readily distinguished from all other described zoeas of the subfamily Lithodinae. In *Lithodes*, *Lopholithodes*, *Paralithodes* and *Paralomis*, the middorsal spine of the posterior margin of the carapace is absent (Konishi 1986; Konishi and Taishaku 1994). In *Cryptolithodes* zoeas, the carapace lateral spines and middorsal spine are absent (Hart 1965; Kim and Hong 2000). Therefore, the diagnostic characteristic showing *R. wosnessenskii* belongs to the subfamily Lithodinae is the middorsal spine of the posterior margin of the carapace.

Table 1. Comparison of carapace length and measurement portion of the zoeal stages of *Rhinolithodes wosnessenskii*.

	Present study	Haynes (1984)
Carapace length (mm)		
Zoea I	2.5 (2.4–2.6)	1.29 (1.21–1.34)
Zoea II	2.8 (2.7–2.9)	1.30 (1.21–1.34)
Measurement of carapace length	From the tip of the rostrum to the posterior midpoint of the carapace	From the posterior margin of the ocular orbit to the posterior midpoint of the carapace

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