

First Zoea of *Enosteoides ornata* (Stimpson, 1858) (Crustacea, Decapoda, Anomura, Porcellanidae) Reared under Laboratory Conditions

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The first zoeal stage of *Enosteoides ornata* (Stimpson, 1858) is described and illustrated in detail. Its morphological characteristics are compared with those of other known species of the family Porcellanidae. In the family Porcellanidae its diagnostic characteristics are the exopod of an antenna armed with a seta and five spinules and the coxa of the first maxilliped having two setae. The former characteristic can be seen in most of the genus *Petrolisthes* zoeas, while the latter usually in the genus *Pachycheles* zoea. The *Enosteoides ornata* seems to be placed intermediately between the genus *Pachycheles* and the genus *Petrolisthes* based on the zoeal morphology.

Crabs of the family Porcellanidae in Korea include eight species belonging to seven genera: *Enosteoides ornata* (Stimpson, 1858), *Pachycheles stevensii* Stimpson, 1858, *Pachycheles hertwigi* Balss, 1913, *Petrolisthes japonicus* (De Haan, 1849), *Pisidia serratifrons* (Stimpson, 1858), *Polyonyx asiaticus* Shen, 1936, *Porcellana pulchra* Stimpson, 1858, and *Raphidopus ciliatus* Stimpson, 1858 (see The Korean Society of Zoological Society, 1997; Ko, 1999). The *Enosteoides ornata* is the only representative of the genus *Enosteoides* in Korea. Kim (1973) collected it on sponges in Cheju Island, recorded it as *Porcellana ornata* Stimpson, 1858, and reported that it was known Korea, Hong Kong and Japan.

The porcellanid zoeas are easily distinguished from other decapod zoeas by their extremely elongated rostral spine and a pair of posterior spines. The larvae of the genus *Enosteoides* were completely unknown. On the other hand the larval stage is known either wholly or in part for ten species of the genus *Pachycheles*, *P. haigae* Rodrigues Da Costa, 1960, *P. pubescens* Holmes, 1900, *P. rudis* Stimpson, 1859, *P. natalensis* (Krauss, 1843), *P. monilifer* (Dana, 1852), *P. tomentosus* Henderson, 1893, *P. stevensii* Stimpson, 1858, *P. garciaensis* (Ward, 1842), *P. sculptus* (H. Milne Edwards, 1837), and *P. hertwigi* Balss, 1913 (see Kurata, 1964; Knight, 1966; Boschi et al., 1967; MacMillan, 1972; Gore, 1973; Shenoy and Sankolli, 1973; Tirmizi and Yaqoob, 1979; Yaqoob, 1979a; Konishi, 1987; Osawa, 1997a; Ko, 1999); two species of the genus *Neopisosoma*, *N. angustifrons* (Benedict,

1901) and *N. neglectum* Werdning, 1986 (see Gore, 1977; Werdning and Müller, 1990); three species of the genus *Polyonyx*, *P. quadriungulatus* Glassell, 1935, *P. hendersoni* Southwell, 1956 and *P. loimicola* Sankolli, 1965 (see Knight, 1966; Shenoy and Sankolli, 1973); and 15 species of the genus *Petrolisthes*, *P. japonicus* (De Haan, 1849), *P. coccineus* (Owen, 1839), *P. carinipes* (Heller, 1861), *P. pubescens* Stimpson, 1858, *P. asiaticus* (Leach, 1820), *P. hastatus* Stimpson, 1858, *P. moluccensis* (De Man, 1888), *P. tomentosus* (Dana, 1852), *P. lamarckii* (Leach, 1820), *P. boscii* (Audouin, 1826), *P. ohshimai* (Miyake, 1937), *P. armatus* (Gibbes, 1850), *P. tridentatus* Stimpson, 1858, *P. tonsorius* Haig, 1960 and *P. rufescens* (Heller, 1861) (see Gohar and Al-Kholy, 1957; Gore, 1970, 1971; Sankarankutty and Bwathondi, 1974; Yaqoob, 1979b, c; Pellegrini and Gamba, 1985; Osawa, 1995, 1997b).

In the present paper the first zoeal stage of *Enosteoides ornata* is described and illustrated for the first time. Its characteristics are compared with those from other known species in the family Porcellanidae.

Materials and Methods

An ovigerous female of *Enosteoides ornata* (Stimpson, 1858) was collected by SCUBA diving from Cheju Island off the southern part of Korea in July 1998. The larvae collected among those hatched in the laboratory were reared by using the methods described by Ko (1995), at a constant water temperature of $25 \pm 1^\circ\text{C}$. The larvae were fixed and preserved in 10% neutral formalin for later use. Dissected appendages were examined using a Leitz laborlux s microscope and

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drawings were made with the aid of a *camera lucida*. Setal counts on appendages and measurements were based on the mean of 10 specimens. Setal armature on appendages is described from proximal to distal segments and in order of endopod to exopod. The remaining zoeas and the spent female were deposited in Silla University, Korea.

Results

The *Enosteoides ornata* completed its zoeal development in about 12 d. The first and second zoeal stages each lasted six days. Only one megalopa was obtained, but the second zoeal and megalopal specimens could not be described because of the poor condition of the preservation and the small number of specimens.

First zoea

Carapace length 1.52 ± 0.09 mm; rostral spine length 5.38 ± 0.32 mm; posterior spine length 2.11 ± 0.07 mm.

Carapace (Fig. 1A, B) typically porcellanid, with extremely elongated rostral and posterior carapace spines; former heavily armed overall with spinules to its tip and up to 3.5 times carapace length (CL), while latter about 1.4 times CL; both posterior spines bearing a few ventral pointed spinelets near their basal portion (Fig. 1B). Lower margin of posterior carapace margin serrate. Eyes sessile.

Antennule (Fig. 1C). Elongate slightly swollen rod; 3 aesthetascs, 2 simple and 1 plumose setae on distal portion. Endopod bud present.

Antenna (Fig. 1D). Endopod fused to protopod, with single thin subterminal seta. Exopod slender rod about 1.7 times longer than endopod, with middle seta and 5 small spinules.

Mandibles (Fig. 1E). Asymmetrical, heavily dentate processes; no palp.

Maxillule (Fig. 1F). Coxal and basal endites both with 10 setae. Endopod with 1 subterminal and 3 terminal setae.

Maxilla (Fig. 1G). Lobes of coxal endite with 9+6 setae; those of basal endite with 9+9; endopod with 9 setae in three groups of 3+2+4; scaphognathite with 6 soft plumose setae around outer margin, and long plumose posterior process.

First maxilliped (Fig. 1H). Coxa with 2 setae; basis setae progressing distally 2, 2, 3, 3; endopod setae 3, 3, 3+1+1, one plumose and 9-10 distal setae. Exopod indistinctly 2-segmented, with 4 long natatory setae distally.

Second maxilliped (Fig. 1I). Coxa without seta; basis setae 1, 2; endopod setae 2, 2, 1+2, one plumose plus 7-8 distal setae; exopod as in first maxilliped.

Third maxilliped. Small buds.

Pereiopods (Fig. 1J). Pereiopod 1 chelate. Pereiopods 2-5 small buds.

Abdomen (Fig. 1K). Somite 5 with lateral spine, pair of minute setules on dorsal margin.

Telson (Fig. 1K). Seven pairs of posterior processes present, long and plumose except for first and second. First (outermost) process stout spine, second short plumose seta; from third to seventh processes armed with distinct hooklets or hooklike spinules at tips. Two pairs of minute setules found on posterior dorsal surface. Anal spine present on ventral surface.

Discussion

Lebour (1943) divided the porcellanid zoeas into two groups based on the form of the telson: 1) the *Porcellana-Polyonyx* group with a telson about 1.5 times as long as wide; 2) the *Petrolisthes-Pachycheles* group with a telson about as long as wide. At present, the form of telson could be useless in separating the porcellanid zoeas at the generic level. Also, Gore (1977) used the positioning of the distal spinules on the antennal exopod for distinguishing the zoeas of the genus *Pachycheles* from those of the genus *Neopisosoma*. However, the characteristic of the antennal exopod may be more valuable than the form of the telson according to Table 1. It is quite interesting that only three or four tandem spinules on the antennal exopod can be found in the *Pachycheles* zoeas, whereas three setae and one or two spinules are found in most of the *Petrolisthes* zoeas. Although the *Enosteoides ornata* is the only species of the genus *Enosteoides* whose larval stage has been so far described, its zoeal characteristics may elucidate the status of this genus in the family Porcellanidae. Its zoea is more similar to the genus *Petrolisthes* or *Polyonyx hendersoni* zoeas than to the *Pachycheles* zoea by having the antennal exopod with seta and spinules. However, in the characteristics of the mouthpart setation (maxillule, maxilla and maxillipeds), it shows close similarity to the six *Pachycheles* zoea (*P. stevensii*, *P. hertwigi*, *P. natalensis*, *P. tomentosus*, *P. monilifer* and *P. rudis*). Therefore, the *Enosteoides ornata* seems to be placed intermediately between the genus *Pachycheles* and the genus *Petrolisthes*.

An examination of Table 1 shows that the presence of a subterminal spinule on the endopod of the maxillule is also important for identifying porcellanid zoeas at the generic level. The number of seta on the coxa of the first maxilliped may have some value. Thus, on the basis of the three characteristics above, a key could be tentatively suggested for identification of the known zoeas of the porcellanid crabs at the generic level which might be useful for planktonologist.

A key to genera of porcellanid zoeas

1. The exopod of an antenna is armed with 1-3 setae and the endopod of the maxillule always has a subterminal spinule

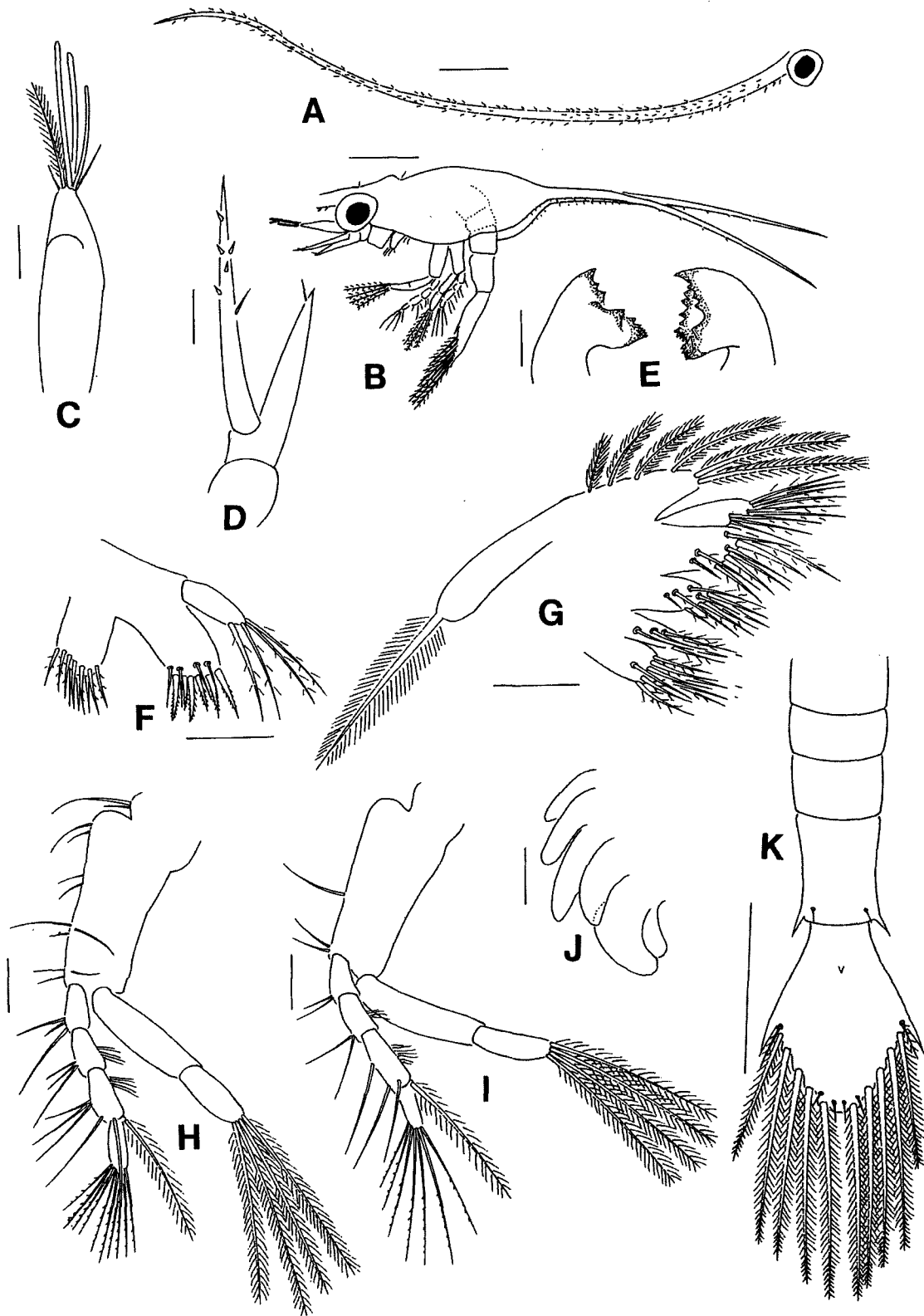


Fig. 1. *Enosteoides ornata* (Stimpson), first zoeal stage. A, Rostral carapace spine. B, Lateral view and posterior carapace spine. C, Antennule. D, Antenna. E, Mandible. F, Maxillule. G, Maxilla. H, First maxilliped. I, Second maxilliped. J, Pereiopods. K, Dorsal view of abdomen and telson. Scale bars=0.1 mm (C-J) and 0.5 mm (A, B, K).

Table 1. Comparison of the first zoeal characteristics in 31 species of the family Porcellanidae

Species	Antenna exopod	Maxillule endopod	Maxilla endopod	Maxilliped 1		Maxilliped 2			Authors
				Coxa	Basis	Coxa	Basis	Endopod	
<i>Pachycheles</i>									
<i>P. stevensii</i>	3P ^a , 1LP ^b	4	9	2	2(1), 2, 2, 3	0	1, 2	2, 2, 1+2, 5(6)+1	Konishi, 1987
<i>P. hertwigi</i>	3P, 1LP	4	9	2	2, 2, 2, 3	0	1, 2	2, 2, 1+2, 5+1	Ko, 1999
<i>P. natalensis</i>	3P	4	9	2	2, 2, 2, 3	0	1, 2	2, 2, 1+2, 5+1	Yaqoob, 1979a
<i>P. tomentosus</i>	3P	4	9	2	2, 2, 2, 3	0	1, 2	2, 2, 1+2, 6+1	Tirmizi and Yaqoob, 1979
<i>P. monilifer</i>	3P	4	9	2	2, 2(3), 2, 3	0	1, 2	2, 2, 1+2, 5+1	Gore, 1973
<i>P. pubescens</i>	3(4)P	3-4	8	2	2, 2, 2(3), 3	0	1, 2	2, 2, 1+2, 5(6)+1	MacMillan, 1972
<i>P. rudis</i>	3P	4	9	2	2, 2, 2, 3	0	1, 2	2, 2, 1+2, 5+1	Knight, 1966
<i>P. haigae</i>	4P	4	9	ND ^d	2, 2, 3, 3	ND	1, 1	3, 3, 1+1, 7+1	Boschi et al., 1967
<i>P. garciaensis</i>	3(4)P	3	8	0	1, 1(2), 2, 3	0	1, 0	0, 2, 2, 5+1	Osawa, 1997a
<i>P. sculptus</i>	3P	3	8	0	1, 2, 2, 3	0	1, 2	2, 2, 2, 5+1	Osawa, 1997a
<i>Neopisosoma</i>									
<i>N. angustifrons</i>	2P, 1LP	4	8	0	2, 2, 2, 3	0	1, 2	2, 2, 1+2, 5+1	Gore, 1977
<i>N. neglectum</i>	1P	4	8	0	2, 2, 3, 3	0	1, 2	2, 2, 1+2, 5+1	Werdning and Müller, 1990
<i>Enosteoides</i>									
<i>E. ornata</i>	1S ^c , 5P	4	9	2	2, 2, 3, 3	0	1, 2	2, 2, 1+2, 7(8)+1	Present study
<i>Polyonyx</i>									
<i>P. quadriungulatus</i>	10P	2(3)	9	2	1, 2, 2, 3	0	1, 2	2, 2, 2, 7+1	Knight, 1966
<i>P. hendersoni</i>	1S, 2P	3	8	1	1, 2, 2, 3	0	1, 3	3, 3, 2, 6+1	Shenoy and Sankolli, 1973
<i>P. loimicola</i>	14P	3	9	1	1, 2, 2, 2	0	2, 2	2, 2, 3, 5+1	Shenoy and Sankolli, 1973
<i>Petrolisthes</i>									
<i>P. japonicus</i>	2(3)S	3+1P	8(9)	0	2, 2, 3, 3	0	1, 3	2, 2, 1+2, 5+1	Osawa, 1995
<i>P. coccineus</i>	3S, 2P	4+1P	8	0	1, 1, 2, 2(3)	0	1, 1	1, 2, 1+2, 3(4)+2	Osawa, 1995
<i>P. carinipes</i>	3S, 2P	4+1P	9	0	1, 2, 2, 3	0	1, 1	1(2), 2, 1+2, 3(4)+2	Osawa, 1995
<i>P. pubescens</i>	3S, 1P	4+1P	8	1	1, 1, 2(3), 3	0	1, 1	1, 2, 1+2, 4+2	Osawa, 1995
<i>P. lamarckii</i>	3S, 1P	4+1P	9	0	1, 1, 1, 3	0	1, 1	1, 2, 1+2, 5+1	Yaqoob, 1979b
<i>P. boscii</i>	3S, 1P	4+1P	9	ND	2, 2, 2, 3	ND	1, 2	2, 2, 1+2, 5+1	Yaqoob, 1979c
<i>P. asiaticus</i>	3S, 1P	4+1P	8(9)	0	1, 1, 1, 3	0	1, 1	1, 2, 3, 4+2	Osawa, 1997b
<i>P. hastatus</i>	3S, 1P	4+1P	8(9)	0	1, 1, 1, 3	0	1, 1	1, 2, 3, 4+2	Osawa, 1997b
<i>P. moluccensis</i>	3S, 1(2)P	4+1P	8	1	1, 1, 2, 3	0	1, 1	1, 2, 3, 4+2	Osawa, 1997b
<i>P. tomentosus</i>	3S, 1P	3+1P	8	1	1, 1, 2, 3	0	1, 1	1, 2, 3, 4+2	Osawa, 1997b
<i>P. ohshimai</i>	3S, 1P	2+1P	8	ND	6	ND	1, 1	2, 2, 1, 5	Sankarankutty and Bwathondi, 1974
<i>P. armatus</i>	2S	3+1P	8	0	1, 1, 2, 3	0	1, 1	2, 2, 1+2, 5+1	Gore, 1970
<i>P. tridentatus</i>	1S	3+1P	9	0	2, 2, 2, 3	0	1, 2	2, 2, 1+2, 5+1	Gore, 1971
<i>P. tonsorius</i>	1S	4+1P	9	0	2, 2, 3, 3	0	1, 2	2, 2, 1+3, 5+1	Pellegrini and Gamba, 1985
<i>P. rufescens</i>	ND	3	5	ND	1, 1, 2	ND	0	3, 2, 4, 4	Gohar and Al-Kholly, 1957

^a Spinules, ^b Lateral spinules, ^c Seta, ^d No data

-*Petrolisthes* (except in *P. rufescens*)
- 2. The exopod of an antenna is armed with a seta and five spinules and the coxa of the first maxilliped has 2 setae*Enosteoides*
- 3. The exopod of an antenna is armed with more than 10 spinules and the coxa of the first maxilliped has 1 or 2 setae*Polyonyx* (except in *P. hendersoni*)
- 4. The exopod of an antenna is armed with only 3 or 4 spinules and the coxa of the first maxilliped has 2 setae*Pachycheles* (except in *P. garciaensis* and *P. sculptus*)
- 5. The exopod of an antenna is armed with 1-3 spinules and the coxa of the first maxilliped has no seta*Neopisosoma*

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