

Larval Development of *Oregonia gracilis* (Crustacea: Decapoda: Majoidea: Oregoniidae) with a Key to the Known Oregoniid Zoeae from the Northern Pacific

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ABSTRACT

The larvae of *Oregonia gracilis* are described, illustrated and compared with those of other known species of the Oregoniidae. The first zoea of *O. gracilis* of the present study is somewhat different from that of Hart (1960) especially in having a basis and an endopod of the first maxilliped with 2, 2, 3, 3 and 3, 2, 1, 2, 5 setations, respectively and an endopod of the second maxilliped with 1, 1, 5 setation. It is found the Oregoniidae must be a homogeneous group based on the zoeal morphology. A provisional key for the identification of the known zoeae of the Oregoniidae from the northern Pacific is provided.

Keywords: Oregoniidae, *Oregonia gracilis*, larvae, morphology, key

INTRODUCTION

The graceful decorator crab, *Oregonia gracilis* Dana, 1851 is usually wearing a piece of algae, sponges, bryozoans, or hydroids which it attaches by hooked setae. Its habitat is intertidal to 436 m depth from Bering Sea to Japan (Jensen, 1995) and Korea (Kim, 1973). It belongs to the family Oregoniidae Garth, 1958, which contains 15 species of four genera world-wide (Ng et al., 2008).

Larval stages have been reported for eight species in this family (Table 1). The larvae of *O. gracilis* were first described by Hart (1960), however, his report was too brief and not adequate for the modern larval description.

Therefore, the aims of this paper are to describe the larval stages of *O. gracilis*, compare its morphology with previously described oregoniid zoeae, and provide a key for the identification of the known zoeae of the Oregoniidae from the northern Pacific.

MATERIALS AND METHODS

An ovigerous female of *Oregonia gracilis* was collected by trawl in the Burrow Bay (48°28'N, 122°40'W) on 2 February 2004, Anacortes, WA, USA. The zoeae hatched on 17 March 2004. They were reared using methods described by Ko (1995) at a constant water temperature of 15°C. Larvae were fixed and preserved in 10% neutral formalin. Dissected appendages were examined and drawn using a Leitz

Laborlux S Microscope with camera lucida. Setal counts on appendages and measurements were based on the mean of ten specimens for zoeal stage. The sequence of the larval description was based on the malacostracan somite plan and described from anterior to posterior (Clark et al., 1998). Setal armature on appendages was described from proximal to distal segments and in order of endopod to exopod. The long plumose natatory setae of the first and second maxillipeds were drawn truncated. A micrometer was used for measurements: CL (carapace length) was from the base of the rostral spine to the most posterior carapace margin, CW (carapace width) was across the widest part of the carapace, and SL (spine to spine length) was from tip of the rostral to tip of the dorsal spine. The classification follows that of Ng et al. (2008). The larvae and the spent females were deposited in Silla University, Korea (SUZCr103257).

RESULTS

The larval stage consists of two zoeal and one megalopal stages. The first zoeal stage is described and illustrated completely. For the second zoeal stage only the main differences from the first zoea are described.

First zoea (Fig. 1)

Size. CL 0.95 ± 0.09 mm. SL 3.72 ± 0.11 mm.

Carapace (Fig. 1A, E). Dorsal spine long, spinulate; rostral spine long, straight, spinulate; lateral spine spinulate; pair of posterodorsal setae present; each ventral margin with 1 plumose anterior and 4 posterior setae; eyes stalked.

Antennule (Fig. 1B). Uniramous; endopod not differenti-

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Table 1. List of species, larval stages and sources of descriptions in the Oregoniidae (Z and M=zoael and megalopal stages).

| Species | Larval stages | Authors |
|--|------------------------------|--|
| <i>Chionoecetes bairdi</i> Rathbun, 1893 | ZI M | Haynes, 1973 Jewett and Haight, 1977 |
| <i>Chionoecetes japonicus</i> Rathbun, 1932 | ZI, ZII, M | Motoh, 1976 |
| <i>Chionoecetes opilio</i> (Fabricius, 1788) | ZI ZI, ZII, M ZI ZI | Aikawa, 1929 Kurata, 1963 (as <i>C. o. elongates</i>) Kuwatani et al., 1971 Haynes, 1973 |
| <i>Chionoecetes tanneri</i> Rathbun, 1893 | ZI, ZII, M | Motoh, 1973 Hong et al., 2009 |
| <i>Hyas araneus</i> (Linnaeus, 1758) | ZI, ZII, M | Christiansen, 1973 |
| <i>Hyas coarctatus</i> Leach, 1815 | ZI, ZII, M ZI, ZII, M | Kurata, 1963 (as <i>H. c. alutaceus</i>) Christiansen, 1973 |
| <i>Hyas lyratus</i> Dana, 1851 | ZI, ZII, M | Hart, 1960 |
| <i>Oregonia gracilis</i> Dana, 1851 | ZI, ZII, M | Hart, 1960 |

ated; exopod with 2 long, stout aesthetascs, 2 shorter, thinner aesthetascs, and 1 short seta, all terminal.

Antenna (Fig. 1C). Endopod bud present; protopod spinulate, slightly shorter than rostral spine; exopod about 25% length to protopod, with 3 unequal sized setae.

Mandibles (Fig. 1D). Asymmetrical; right molar process with tooth and left molar process without tooth, confluent with incisor processes; endopod palp not differentiated.

Maxillule (Fig. 1F). Coxal endite with 7 setae; basal endite with 7 setae; endopod 2-segmented, proximal segment with 1 seta, distal segment with 2 subterminal and 4 terminal setae.

Maxilla (Fig. 1G). Coxal endite bilobed, with 4+4 setae; basal endite bilobed with 5+5 setae; endopod with 6 (3 subterminal and 3 terminal) setae; scaphognathite margin with 9 plumose setae and 1 distal stout process.

First maxilliped (Fig. 1H). Coxa with 1 seta; basis with 10 setae arranged as 2, 2, 3, 3; endopod 5-segmented, with 3, 2, 1, 2, 5 (1 subterminal+4 terminal) setae, respectively; exopod 2-segmented, proximal segment unarmed, distal segment with 4 terminal natatory setae.

Second maxilliped (Fig. 1I). Coxa unarmed; basis with 4 setae; endopod 3-segmented, with 1, 1, 5 (3 subterminal+2 terminal) setae; exopod 2-segmented, distal segment with 4 terminal natatory setae.

Third maxilliped (Fig. 1J). Biramous.

Pereopods (Fig. 1A, K). Present, cheliped bilobed.

Abdomen (Fig. 1A, L). Five somites; somite 1 with 2 dorsomedial seta; somites 2, 3 with pair of lateral processes, which larger on somite 2, somites 2-5 each with pair of posterodorsal setae; long posterolateral processes on somites 3-5, first and second ones longer than third; pleopod buds present as buds.

Telson (Fig. 1L, M). Each fork long, distally spinulate,

with 1 lateral spine, 1 dorsomedial spine; each posterior margin with 3 serrated setae.

Second zoea (Fig. 2)

Size. CL 1.37 ± 0.07 mm. SL 4.51 ± 0.09 mm.

Carapace (Fig. 2A, E). Each ventral margin with 1 plumose anterior and 9 posterior setae; eyes stalked.

Antennule (Fig. 2B). Endopod present; exopod with total of 7 long aesthetascs, 1 short seta, all terminal.

Antenna (Fig. 2C). Endopod bud about 30% length of protopod.

Mandibles (Fig. 2D). Palps present.

Maxillule (Fig. 2F). Epipod with plumose seta; coxal endite with 8 setae; basal endite with 9 setae.

Maxilla (Fig. 2G). Coxal endite with 4+4 setae; basal endite with 6+6 setae; scaphognathite with 18 marginal plumose setae.

First maxilliped (Fig. 2H). Exopod bearing distal segment with 6 terminal natatory setae.

Second maxilliped (Fig. 2I). Exopod bearing distal segment with 6 terminal natatory setae.

Third maxilliped (Fig. 2J). More developed.

Pereopods (Fig. 2K). More developed, all segments differentiated.

Abdomen (Fig. 2L). Six somites; pleopod buds more developed, those on somites 2-5 biramous; pair of dorsomedial setae present on somites 2-5.

Telson (Fig. 2L, L'). Each posterior margin with 1 plumose seta and 3 serrated setae.

Megalopa (Fig. 3)

Size. CW 1.38 ± 0.08 mm. CL 1.98 ± 0.06 mm.

Carapace (Fig. 3A). Pear shape, with 1 long rostral spine, pair of spines anterior to eye stalks and another posterior,

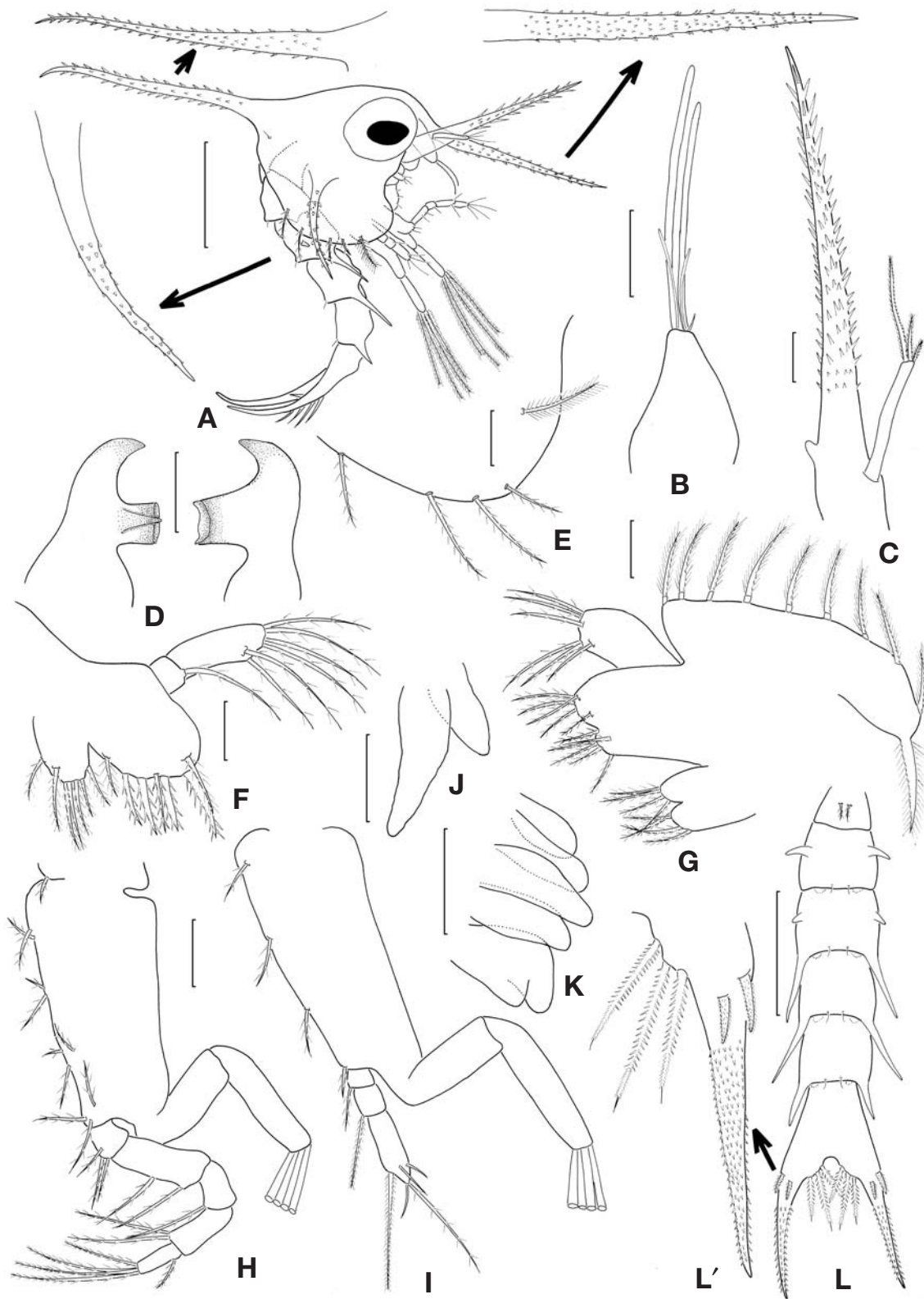


Fig. 1. *Oregonia gracilis*, first zoeal stage. A, lateral view; B, antennule; C, antenna; D, mandibles; E, lateral expansion of carapace; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped; J, third maxilliped; K, chela and pereopods; L, dorsal view of abdomen and telson; L', fork of telson. Scale bars=0.5 mm (A, L), 0.1 mm (B-E, H, I, K) and 0.05 mm (F, G, J).

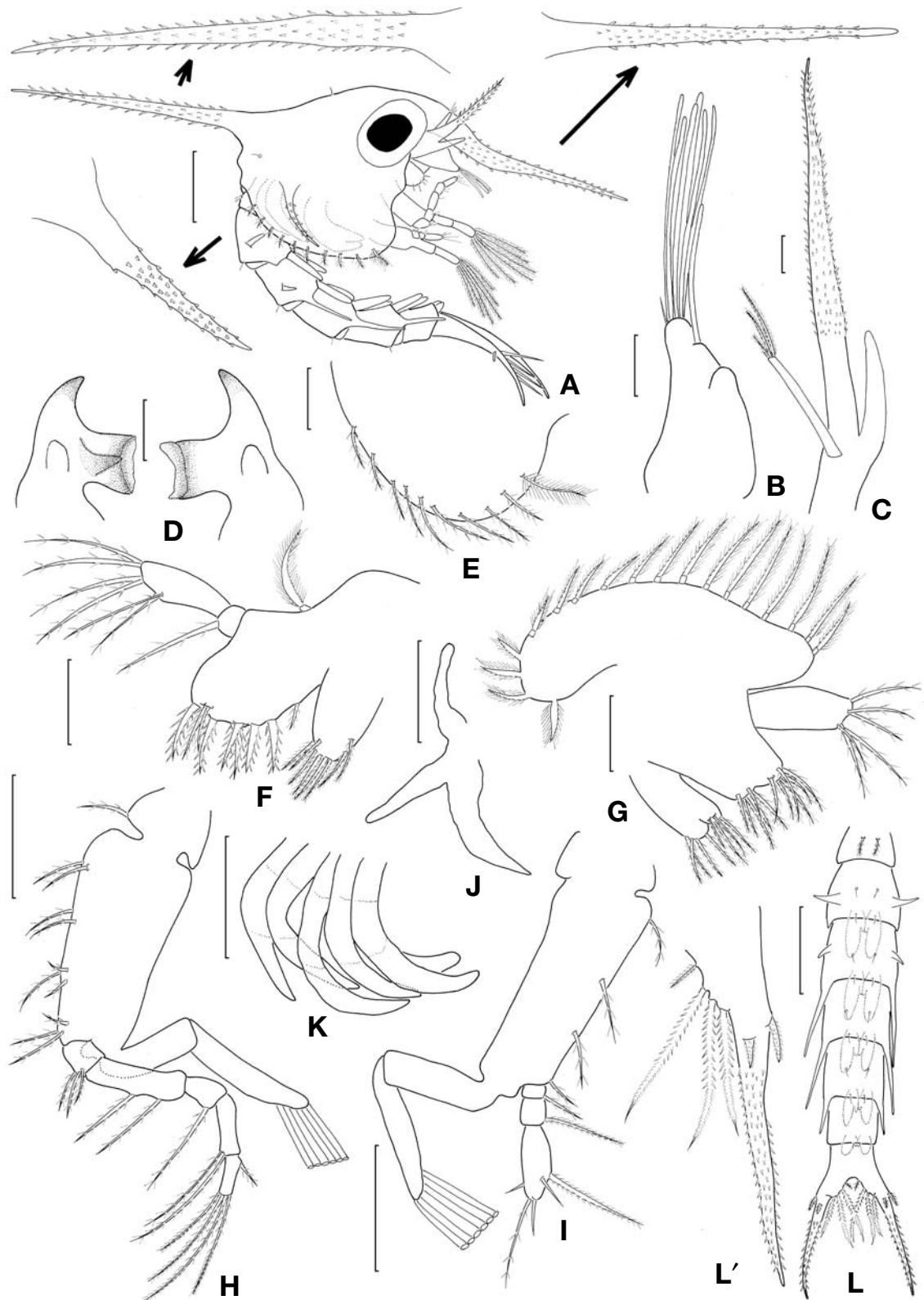


Fig. 2. *Oregonia gracilis*, second zoeal stage. A, lateral view; B, antennule; C, antenna; D, mandibles; E, lateral expansion of carapace; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped; J, third maxilliped; K, chela and pereopods; L, dorsal view of abdomen and telson; L', fork of telson. Scale bars=0.5 mm (A, K, L), 0.1 mm (B-D, F, G) and 0.25 mm (E, H-J).

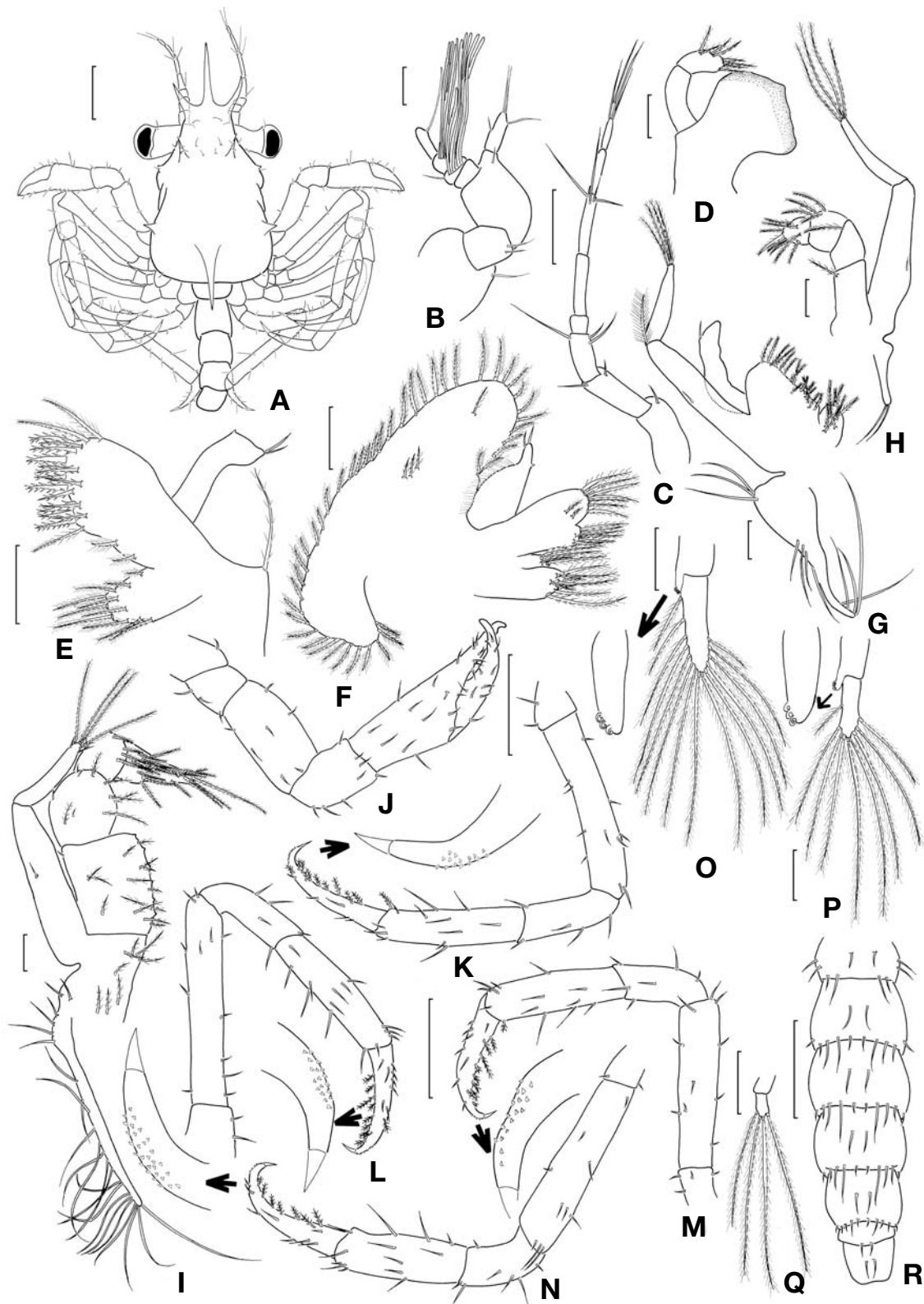


Fig. 3. *Oregonia gracilis*, megalopal stage. A, dorsal view; B, antennule; C, antenna; D, mandible; E, maxillule; F, maxilla; G, first maxilliped; H, second maxilliped; I, third maxilliped; J, chela; K-N, pereopods 2-5; O, pleopod 2; P, pereopod 4; Q, pereopod 5; R, dorsal view of abdomen and telson. Scale bars=0.5 mm (A, J-N, R), 0.1 mm (B, D-I) and 0.25 mm (C, O-Q).

pair of spines on hepatic and epibranchial regions, 1 long cardiac medial spine.

Antennule (Fig. 3B). Peduncle 3-segmented, segment 1 with 1 seta, segment 2 with 2 setae, segment 3 with 1 seta; endopod with 2 subterminal and 2 terminal setae; exopod 4-segmented, segment 1 without seta, segment 2 with 6 aesthetascs and 1 short seta, segment 3 with 4 proximal aesthetascs and segment 4 with 1 subterminal aesthetasc.

Antenna (Fig. 3C). Eight-segmented, with 1, 2, 3, 0, 0, 4, 0, 4 setae.

Mandible (Fig. 3D). Palp 2-segmented, distal segment with 8 marginal setae.

Maxillule (Fig. 3E). Coxal endite with 11 setae; basal endites with 20 setae; endopod with 2 terminal setae.

Maxilla (Fig. 3F). Coxal and basal endites each with 12 and 15 setae, respectively; endopod with 2 terminal setae; scaphognathite with 44 marginal plumose setae and 4 surface setae.

First maxilliped (Fig. 3G). Epipod with 11 long simple setae; coxal and basal endites each with 8 and 15 setae, respectively; endopod with 2 setae; exopod 2-segmented, proximal segment with 1 medial simple and 1 distal plumose setae, distal segment with 4 long terminal plumose setae.

Second maxilliped (Fig. 3H). Epipod with 2 terminal simple setae; coxa and basis not differentiated; endopod 4-segmented, with 1, 2, 4, 8 setae; exopod 2-segmented, proximal segment with 1 medial seta, distal segment with 4 long terminal plumose setae.

Third maxilliped (Fig. 3I). Epipod with 23 long simple and 8 proximal setae; coxa and basis not differentiated; endopod 5-segmented, with 15, 10, 5, 9, 7 setae; exopod 2-segmented, proximal segment with 1 medial seta, distal segment with 4 long terminal plumose and 2 short terminal setae.

Chela (Fig. 3J). All segments with a few small setae; tip slightly hooked.

Pereopods 2-5 (Fig. 3K-N). All segments well differentiated, sparsely armed with setae; dactylus with corneous scales on distal outer surface, tip sharp pointed.

Pleopods (Fig. 3O-Q). Endopod with 3 hooks except in pleopod 5; pleopods 1-5 each with 14, 14, 14, 9, 4 plumose setae on distal segment, respectively.

Abdomen and telson (Fig. 3R). Abdomen 6-segmented, with a few of small setae on surface; telson broad, rounded, with 2 dorsomedial setae.

DISCUSSION

The first zoea of *Oregonia gracilis* in the present study

Table 2. Differences between the larval description of *Oregonia gracilis* by Hart (1960) and the present study.

| Characters | Hart (1960) | Present study |
|----------------------------|-----------------------------|------------------------------------|
| ZOEA I | | |
| Carapace | | |
| lateral margin | 4-6 setae | 5 setae |
| Antennule | 2 aesthetascs+ 1 seta | 4 aesthetascs+ 1 seta |
| Maxilliped 1 | | |
| basis | 9 setae | 2, 2, 3, 3 (10) setae |
| endopod | 3, 1, 1, 2, 5 setation | 3, 2, 1, 2, 5 setation |
| Maxilliped 2 | | |
| endopod | 1, 1, 4 setation | 1, 1, 5 setation |
| Maxilliped 3 | no description | biramous bud |
| Abdominal somite 5 | | |
| lateral posterior spine | long | small |
| ZOEA II | | |
| Antennal protopod | 0.7 rostral spine length | 0.5 rostral spine length |
| Antennule | 5-7 aesthetascs | 7 aesthetascs+1 seta |
| Maxillule | | |
| endopod | no description | 1, 2+4 setae |
| basal endite | no description | 9 setae |
| coxal endite | no description | 8 setae |
| Maxilla | | |
| endopod | no description | 3+3 setae |
| basal endite | no description | 6+6 setae |
| coxal endite | no description | 4+4 setae |
| Maxilliped 1 | | |
| coxa | no description | 1 seta |
| MEGALOPA | | |
| Antennule | no description | 11 aesthetascs +1 seta |
| Antenna | no description | 1, 2, 3, 0, 0, 4, 0, 4 setation |
| Mandible | | |
| palp | no description | 8 setae |
| Maxillule | | |
| endopod | no description | 2 setae |
| basal endite | no description | 20 setae |
| coxal endite | no description | 11 setae |
| Maxilla | | |
| endopod | no description | 2 setae |
| basal endite | no description | 15 setae |
| coxal endite | no description | 12 setae |
| scaphognathite | no description | 48 setae |
| Maxillipeds 1-3 | | |
| exopods | no description | 4, 4, 6 setae |
| Pleopods 1-5 | | |
| exopods | 14, 14, 12, 10, 4 setae | 14, 14, 14, 9, 4 setae |

shows some differences from that described by Hart (1960) in setations of the maxillipeds (Table 2). The basis and endopod of the first maxilliped have 2, 2, 3, 3 (10) and 3, 2, 1, 2, 5 setations in the present zoea, whereas they are 9

Table 3. Comparison of the first zoeal characteristics of seven known species in the Oregoniidae (ZI and ZII=first and second zoeae).

| Species Authors | <i>Chionoecetes bairdi</i> Haynes, 1973 | <i>Chionoecetes japonicus</i> Motoh, 1976 | <i>Chionoecetes opilio</i> Motoh, 1973 | <i>Chionoecetes tanneri</i> Hong et al., 2009 | <i>Hyas araneus</i> Christiansen, 1973 | <i>Hyas coarctatus</i> Christiansen, 1973 | <i>Oregonia gracilis</i> Present study |
|--|--|--|---|--|---|--|---|
| SL (mm) | ZI 4.2 | ZI 5.2 | ZI 4.8-5.4 (ZII 6.2) | ZI 5.5 | ZII 4.8 | ZII 3.9 | ZI 3.7 (ZII 4.4-4.6) |
| Carapace | | | | | | | |
| dorsal spine | long, spinulate | long, spinulate | long, spinulate | long, spinulate | long, spinulate | long, spinulate | long, spinulate |
| lateral spine | long, spinulate | long, spinulate | long, spinulate | long, spinulate | long, spinulate | long, spinulate | long, spinulate |
| Antennal exopod (exopod/protopod %) | 2 setae+1 spine (27%) | 3 setae (25%) | 3 setae (25%) | 2 setae+1 spine (23%) | 2 setae+1 spine (25%) | 2 setae+1 spine (23%) | 3 setae (25%) |
| Maxillule | | | | | | | |
| endopod | 1, 2+4 setae 7 setae | 1, 2+4 setae 7 setae | 1, 2+4 setae 7 setae | 1, 2+4 setae 7 setae | 1, 2+4 setae 7 setae | 1, 2+4 setae 7 setae | 1, 2+4 setae 7 setae |
| basial endite | 7 setae | 7 setae | 7 setae | 7 setae | 7 setae | 7 setae | 7 setae |
| coxal endite | 7 setae | 7 setae | 7 setae | 8 setae | 7 setae | 7 setae | 7 setae |
| Maxilla | | | | | | | |
| endopod | 3+3 setae | 3+3 setae | 3+3 setae | 3+3 setae | 3+3 setae | 3+3 setae | 3+3 setae |
| basial endite | 5+5 setae | 5+5 setae | 5+5 setae | 5+5 setae | 5+5 setae | 5+5 setae | 5+5 setae |
| coxal endite | 4+4 setae | 4+4 setae | 4+4 setae | 4+4 setae | 4+4 setae | 4+4 setae | 4+4 setae |
| scaphognathite | 11 setae | 12-13 setae | 12-13 setae | 12 setae | 7-9 setae | 8-10 setae | 10 setae |
| Maxilliped I | | | | | | | |
| basis | 10 setae | 10 setae | 10 setae | 9 setae | 10 setae | 10 setae | 10 setae |
| endopod | 3, 2, 1, 2, 5 setation | 3, 2, 1, 2, 5 setation | 3, 2, 1, 2, 5 setation | 3, 2, 1, 2, 5 setation | 3, 2, 1, 2, 5 setation | 3, 2, 1, 2, 5 setation | 3, 2, 1, 2, 5 setation |
| Maxilliped II | | | | | | | |
| basis | 4 setae | 4 setae | 4 setae | 4 setae | 4 setae | 4 setae | 4 setae |
| endopod | 1, 1, 5 setation | 1, 1, 5 setation | 1, 1, 5 setation | 1, 1, 5 setation | 1, 1, 5 setation | 1, 1, 5 setation | 1, 1, 5 setation |
| Abdomen | | | | | | | |
| somite 1 | 2 dorsal setae | no data | no data | 2 dorsal setae | 2 dorsal setae | 2 dorsal setae | 2 dorsal setae |
| lateral processes on somites 2, 3 | larger on somite 2 | larger on somite 3 (ZI) same size (ZII) | larger on somite 3 (ZI) larger on somite 3 (ZII) | larger on somite 2 | larger on somite 2 | larger on somite 2 | larger on somite 2 |
| posterolateral process on somite 4 | > length of somite 5 | ≅ length of somite 5 | > length of somite 5 | > length of somite 5 | ≅ 1/2 length of somite 5 | ≅ 1/2 length of somite 5 | ≥ length of somite 5 |
| Telson | | | | | | | |
| fork | 2 outer spines+ 1 spinule | 2 outer spines | 2 outer spines spinule (Kurata, 1963) | 2 outer spines | 2 outer spines | 2 outer spines | 2 outer spines |

setae and 3, 1, 1, 2, 5 setation in Hart's, respectively. Also, an endopod of the second maxilliped is 1, 1, 5 setation in the present zoea, whereas it is 1, 1, 4 setation in Hart's. As shown in Table 3, our setations agree well with those of six known zoeae of the Oregoniidae, it is considered that some setae of the maxillipeds of the first zoea are overlooked by him. Also, it is revealed that Hart's description for the second zoea and the megalopa are too brief to compare with our study.

The larval description of *Hyas lyratus* by Hart (1960) is not informative enough for use within the scope of this study, so, the first zoeal characteristics of seven known species except *Hyas lyratus* in the Oregoniidae are compared (Table 3). The first zoeae of the Oregoniidae are very similar to each other in having the following characteristics: 1) carapace spines are long and spinulate, 2) exopod of antenna is approximately 25% length to protopod, with 3 or 2 setae and a spine terminally, 3) endopod of maxillule is with 1, 2+4 setae, 4) endopod of maxilla is with 3+3 setae, 5) basis and endopod of first maxilliped are each with 10 setae and 3, 2, 1, 2, 5 setation, respectively (except in *Chionoecetes tanneri*), 6) basis and endopod of second maxilliped are each with 4 setae and 1, 1, 5 setation, respectively, 7) lateral processes are on abdominal somites 2 and 3, 8) posterolateral process on somite 4 is more than half length to somite 5, and 9) telson fork is with 2 outer spines. Therefore, the Oregoniidae are found to be a homogeneous group on the respect of zoeal morphology.

It seems to be difficult to distinguish zoeae of *O. gracilis* from those of other known oregoniid species because of their overall similarities of zoeal morphology. Hence, the following provisional key is provided to aid in the identification of seven known species of zoeae of the Oregoniidae from the northern Pacific. The characteristics employed are usually consistent during the zoeal development.

A key to the seven known species of zoeae of the Oregoniidae from the northern Pacific

- 1. Basis of first maxilliped with 10 setae 2
 - Basis of first maxilliped with 9 setae *Chionoecetes tanneri*
- 2. Size of lateral process on abdominal somite 2 ≤ that of abdominal somite 3 3
 - Size of lateral process on abdominal somite 2 > that of abdominal somite 3 4
- 3. Red chromatophores on abdomen when alive *Chionoecetes japonicus*
 - Red chromatophores absent on abdomen when alive *Chionoecetes opilio*
- 4. Telson fork with 2 outer spines 5
 - Telson fork with 2 outer spines and 1 spinule

- *Chionoecetes bairdi*
- 5. Posterolateral process on somite 4 longer than 1/2 length of somite 5 6
 - Posterolateral process on somite 4 longer than length of somite 5 *Oregonia gracilis*
- 6. SL of second zoea over than 4.5 mm *Hyas araneus*
 - SL of second zoea less than 4.0 mm *Hyas coarctatus*

ACKNOWLEDGEMENTS

The authors are grateful to Dr. Stephen Sulkin (Shannon Point Marine Center, U. S. A.) for inviting the second author as a visiting researcher in 2003 and wish to thank Mrs Se Jin Ok for preparing figures. This work was supported by the Korean Research Foundation Grant funded by the Korean Government (KRF-2008-531-C00062).

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Received January 19, 2010
Accepted March 11, 2010