The Larval Stages of Benizuwai-gani, *Chionoecetes japonicus* RATHBUN Reared in the Laboratory

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This study deals with the larval stages of Benizuwai-gani, *Chionoecetes japonicus*, and with the comparison of those between *C. japonicus* and Zuwai-gani, *C. opilio*. There are two zoeae and one megalopa. The larval stages of *C. japonicus* are morphologically similar to those of *C. opilio* excepting some characters as follows: 1) Chromatophores of zoeae and megalopa are vermillion or crimson in *C. japonicus* and brown or reddish in *C. opilio*. 2) *C. japonicus* is generally bigger than *C. opilio* in zoeae and megalopa. 3) Length of postero-lateral spine on 3rd abdominal segment is more than 1.3 times the length of the 4th abdominal segment in *C. japonicus*, but is shorter than (rarely equal to) that in *C. opilio*. 4) Ischiopodite of cheliped has no spine in *C. japonicus*, but it has spine in *C. opilio*, in megalopa.

Two species of edible crabs of the genus *Chionoecetes* occur in the Japan Sea. The Zuwai-gani, *Chionoecetes opilio* (O. FABRICIUS) is caught by the Danish seine from depths of 200 to 350 meters and is the most important commercial species in some districts along the Japan Sea coast. But recently production is acutely decreasing due to probable over-fishing.

The Benizuwai-gani, *Chionoecetes japonicus* RATHBUN is captured by the basket trap from a much deeper bottom of 700 to 1,500 meters. The catching efforts for them are increasing compensating those for *C. opilio*. In recent years, annual production in the Hokuriku and San-in districts reaches about 22,300 tons of the shell crabs with a value of 2,430 million yen (8.1 US million dollars, approximately) to the fishermen (personal communication from Katsuchiyo Ito).

The descriptions of crab larvae belonging to the genus *Chionoecetes* have been published by AIKAWA¹⁻³⁾ (prezoea), KON⁴⁾ (prezoea), ITO⁵⁾ (prezoea), KURATA⁶⁻⁷⁾ (first and second zoeae and megalopa), KUWATANI, *et al.*⁸⁾ (prezoea and first zoea), HAYNES⁹⁾ (prezoea and first zoea) and MOTOH¹⁰⁾ (first and second zoeae and megalopa). All the descriptions were based on the specimens obtained from eggs of *C. opilio* except KURATA's second zoea and megalopa which were obtained from the plankton; HAYNES⁹⁾ (prezoea and first zoea of *C. bairdi* from eggs); MOTOH¹¹⁾ (brief observation of prezoea and first zoea of *C. japonicus* from eggs). FUKATAKI¹²⁾ and ITO and IKEHARA¹³⁾ surveyed the occurrence and distribution of the planktonic larvae of *Chionoecetes* in the Japan Sea.

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But actually, they could not distinguish between *C. opilio* and *C. japonicus* owing to their close resemblance except pigmentation.

As far as the present author is aware, the complete larval development of *C. japonicus* has not yet been studied. The objective of this report is to give a detailed description and to summarize differences and similarities between *C. japonicus* and *C. opilio*, providing a basis and method for future identification of zoea and megalopa of all the species belonging to the genus *Chionoecetes*.

Materials and Methods

On February 2, 1973, eight ovigerous females, caught by the basket trap at a depth of about 930 meters in Toyama Bay, Japan Sea, were placed in the wooden tank at the Fisheries Experimental Station of Toyama Prefecture. Three days later, these crabs were transported to our laboratory and placed in a plastic tank of 1,000 liter capacity. The rearing methods were almost the same as those adopted by MOTOH¹⁰⁾.

Hatching occurred on February 7 to 9, 1973. Temperature of the sea water ranged from 4.5 to 11.2°C, and specific gravity varied from 1.022 to 1.025 (ρ 15) from February to April. Heavy mortality was observed during the second zoea and megalopa. More than ten larvae were observed for each stage under microscope.

Description of Larvae

All the larvae hatched as prezoa and they molted into the first zoea in about two hours. There are two zoea and one megalopa stages in the larval development.

First zoea (Fig. 1): The carapace has four spines, a dorsal spine and a rostral spine approximately equal in length and a pair of lateral spines. The eyes are not stalked. The length from the tip of rostral to tip of dorsal spine is 4.85 to 5.52 mm, 5.21 mm in average. The width of carapace including both lateral spines is 3.46 to 3.98 mm, 3.69 mm in average. The distance between outer margins of eyes is 0.85 to 1.20 mm, 1.02 mm in average. The abdomen consists of five segments and the telson. The telson is bifurcate. Each furca of the telson bears three setae on the inner side and a small spine each on the lateral and dorsal edge respectively. The postero-lateral margins of 3rd and 4th segments are prolonged into a pair of spines extending beyond the posterior margins of the following segments. The 2nd and 3rd segments bear a pair of lateral hooks. The antennule is conical and uniramous with three terminal processes, two broad flat aesthetes and a smaller seta. The antenna is almost as long as the rostral spine, and its peduncle tapers to a point with several rows of setules. The exopodite ends in three setae. The lengths of these setae are in the ratios: 1:1.5 to 2.3:2.4 to 4.2, 1:1.8:3.1 in average. The mandible is small with an irregular cutting edge, without palps. The endopodite of the

maxillule bears six setae of equal length that are arranged in three pairs and one more seta is present at the base of endopodite which is an apparently separate segment. The basipodite and coxopodite have seven setules respectively. The scaphognathite of the maxilla has 12 or 13 long soft plumose hairs including two or three thick ones, and the trilobate endopodite bears six setae. The basipodite and coxopodite are bilobed and have the spinal arrangement of 5 or 6-5(4) on basipodite and 4-4 on coxopodite. The end-

Fig. 1. *Chionoecetes japonicus* RATHBUN. First zoea. A, dorsal view; B, antennule; C, lateral view; D, mandible; E, antenna; F, maxillule; G, maxilla; H, first maxilliped; I, second maxilliped; J, abdomen in ventral view. A, C, $\times 20$; B, D, F, G, $\times 150$; E, H, I, $\times 75$; J, $\times 40$.

opodite of the first maxilliped has five segments with a spinal arrangement of 3-2-1-2-5 from proximal to distal segments. Four natatory hairs are present on the distal end of the exopodite. The second maxilliped also has four natatory hairs and spinal arrangement of 1-1-5 on the three segments of the endopodite. One of five spines on the terminal segment is very minute.

Second zoea (Fig. 2): The length of the larva from the tip of rostral to tip of dorsal spine is 5.72 to 6.91 mm, 6.56 mm in average and the width of carapace including both lateral spines is 3.33 to 3.92 mm, 3.69 mm in average. The second zoea has stalked eyes and the distance between outer margins of eyes is 1.57 to 1.87 mm, 1.74 mm in average. Aesthetes on the antennules are increased to nine or ten and are divided into two groups: one in the proximal group and the other in the terminal group which consist of six or seven large and two small sensory flagella. The antenna has a developing endopodite. The mandible has an unsegmented palp. The coxopodite and basipodite of the maxillule have six to eight and eight to nine spines respectively.

The endopodite of the maxillule consists of two segments with a spinal arrangement of 1-6 (rarely 2-6). An additional plumose hair is located on the protopodite of maxillule near the base of endopodite. The trilobate endopodite of the maxilla bears six setae. The bilobate basipodite bears five and the bilobate coxopodite of the maxilla bears four setae on each lobe respectively. The scaphognathite of the maxilla has 23 to 27 (mainly 26 or 27) long soft plumose hairs including two or three thick ones. Each maxilliped bears six natatory hairs on the exopodite. The inner margin of each furca of the telson bears one additional spine without setule.

Megalopa (Figs. 3, 4): The megalopa is 2.89 to 3.37 mm, 3.16 mm in average in carapace length including rostral central process and 2.11 to 2.45 mm, 2.20 mm in average, in carapace width. Seven heavy processes are present on the carapace; three rostral processes, of which central one is longer than the lateral two, a pair of anterior gastric lateral processes, and a pair of cardiac dorso-lateral ones. Spines also project ventrally from the ischiopodites of the walking legs except for the chiliped and the fourth walking leg. The fourth walking leg has no conspicuous hair projecting from the tip of the dactylopodite. The inflated peduncle of the antennule is followed by two segments. The antenna consists of eight segments. The arrangement of the setae from the base to the terminal segment is 1-2-3-0-3-4-0-4 with a slight variation in number. The well-developed mandibular palp bears about eleven spines. The endopodite of the maxillule has no spine. The scaphognathite of the maxilla is very broad with about 70 soft plumose hairs. Setae on the coxopodite have increased to eleven on one lobe and six on the other. The basipodite has six spines on one lobe and eight on the other. The endopodite has only three or four setae on its basal portion. The first maxilliped has a well-developed epipodite with

Fig. 2. *Chionoecetes japonicus* RATHBUN. Second zoea. A, dorsal view; B, mandible; C, lateral view; D, antennule; E, antenna; F, maxillule; G, maxilla; H, second maxilliped; I, first maxilliped; J, abdomen in ventral view. A, C, $\times 20$; B, D, F $\times 150$; E, H, I, $\times 75$; J, $\times 40$.

about 17 soft hairs. The broad endopodite has three spines at the distal end and numerous spines on the basipodite. One plumose and three or four terminal hairs are present on

Fig. 3. *Chionoecetes japonicus* RATHBUN. Megalopa. A, dorsal view; B, antennule; C, antenna; D, mandible; E, maxillule; F, distal portion of chiliped; G, lateral view of carapace; H, maxilla. A, G, $\times 30$; B, D, H, $\times 75$; E, F, $\times 150$.

the exopodite. The endopodite of the second maxilliped consists of four segments with a spinal arrangement, from proximal to distal, of 0-2-5-7. Four natatory hairs are now present on the terminal end of the exopodite. The well-developed epipodite is also present, with approximately 35 soft simple hairs. The third maxilliped has developed tremendously at metamorphosis from the second zoea to the megalopa. The endopodite has become quite massive and consists of four segments with numerous spines. The epipodite is well-developed with about 20 soft non-plumose hairs. The abdomen consists of six segments and the telson. Pleopods are present on 2nd to 5th segments and bear about 16 long plumose hairs for locomotion, with a variation in the number of hairs ranging 14 to 17. There are seven (rarely six) plumose hairs on the uropod each side.

Differences in larval characters between *C. japonicus* and *C. opilio* The larval stages of *C. japonicus* are morphologically similar to those of *C. opilio* described by

Fig. 4. *Chionoecetes japonicus* RATHBUN. Megalopa. A, first maxilliped; B, second maxilliped; C, third maxilliped; D, abdomen in ventral view; E, pereopods 1st to 5th; F, abdomen in lateral view. A, B, C, $\times 75$; D, E, F, $\times 30$.

KURATA⁶⁾, KUWATANI *et al.*⁸⁾, HAYNES⁹⁾ and MOTOH¹⁰⁾. Variation in the number of setae on the appendages of the two species is responsible for a substantial portion of the differences between them. In case of the first zoea, the differences between two species are as follows:

- 1) the chromatophores are brown or reddish brown in *C. opilio* and vermilion or crimson in *C. japonicus*,
- 2) the length of posterior lateral spine on 3rd abdominal segment is more than 1.3 times the length of 4th abdominal segment in *C. japonicus*, but is shorter than (rarely equal to) that in *C. opilio*.

In the second zoea, another differences, in addition to the two characters mentioned above, become apparent in the distance between outer margins of eyes and in the number of setae on scaphognathite as shown in Table 2. Finally, in the megalopa, *C. japonicus* is slightly larger in size than *C. opilio* as shown by present author and MOTOH¹⁰⁾. Further, differences between both species in the megalopa are as follows:

- 1) chromatophores are brown or reddish brown in *C. opilio* and vermilion or crimson in *C. japonicus* as in the zoeal stages, 2) the ischiopodite of the cheliped has a spine in *C. opilio* but does not have in *C. japonicus*.

Table 1. Comparison of the characters of the first zoea of *Chionoecetes opilio* (O. FABRICIUS), *C. bairdi* RATHBUN and *C. japonicus* RATHBUN

Characters	KURATA (1968 & 69) (<i>Ch. o.</i>)	KUWATANI <i>et al.</i> (1971) (<i>Ch. o.</i>)	HAYNES (1973) (<i>Ch. o.</i> & <i>Ch. b.</i>)	MOTOH (1973) (<i>Ch. o.</i>)	MOTOH (<i>Ch. j.</i>)
Length of larvae from tip of rostral to tip of dorsal spine in mm	4.5 to 4.9	*	3.96 to 4.55 (average, 4.17)	4.8 to 5.4 (average, 5.22)	4.85 to 5.52 (average, 5.21)
Width of larvae includ- ing both lateral spines in mm	*	*	2.52 to 2.97 (average, 2.73)	3.3 to 3.6 (average, 3.34)	3.46 to 3.98 (average, 3.69)
Distance between outer margins of eyes in mm	*	*	*	0.9 to 1.0 (average, 0.93)	0.85 to 1.20 (average, 1.02)
Proportional length of three setae on antenna	1: ? : 2	*	*	1: 1.7 to 2.3: 2.7 to 3.8 (ave., 1: 1.8: 3.1)	1: 1.5 to 2.3: 2.4 to 4.2 (ave., 1: 1.8: 3.1)
Terminal process of antennule	*	5	5	3	3
Spines outer margin of telson furca	3	2	3	2	2
Lateral knobs on ab- dominal segments	2nd and 3rd	2nd and 3rd	2nd and 3rd	2nd and 3rd	2nd and 3rd
Spines on endopodite of maxillule	1-6	1-6	1-6	1-6	1-6
Spines on basipodite of maxillule	*	7	7	7	7
Spines on coxopodite of maxillule	*	7	7	7	7
Spines on endopodite of maxilla	3-3-1	3-2-1	3-3	3-3	3-3
Spines on basipodite of maxilla	*	5-5	5-5	5 or 4-5 or 4	5 or 6-5 or 4
Spines on coxopodite of maxilla	*	4-4	4-4	4-4	4-4
Setae on scaphognathite	16	13	11 (rarely 12)	12 or 13	12 or 13
Spinal arrangement on endopodite of 1st maxilliped	*	3-2-1-2-5	3-2-1-2-5	3-2-1-2-5	3-2-1-2-5
Spinal arrangement on protopodite of 1st maxilliped	*	3-3-3-3	2-2-3-3	2-2-3-3	2-2-3-3
Spinal arrangement on endopodite of 2nd maxilliped	1-1-5	1-1-4	1-1-5	1-1-5	1-1-5
Spinal arrangement on protopodite of 2nd maxilliped	*	1-1-1-1	1-1-1-1	1-1-1-1	1-1-1-1

*, not given.

Table 2. Comparison of the characters of the second zoea of *Chionoecetes opilio* (O. FABRICIUS) and *C. japonicus* RATHBUN

Characters	KURATA (1969, <i>Ch.o.</i>)	MOTOH (1973, <i>Ch. o.</i>)	MOTOH (<i>Ch. j.</i>)
Length of larvae from tip of rostral to tip of dorsal spine in mm	6.0 to 6.9	6.2 to 7.1 (average, 6.2)	5.72 to 6.91 (average, 6.53)
Width of larvae including both lateral spines in mm	*	3.6 to 3.9	3.33 to 3.92 (average, 3.69)
Distance between outer margins of eyes in mm	*	1.3 to 1.5 (average, 1.4)	1.57 to 1.87 (average, 1.74)
Proportional length of three setae on antenna	1:?:2	1:1.90:2.87	1:1.82:3.00
Terminal Processes of antennule	*	9	7 to 9
Spines outer margin of telson furca	3	2	2
Lateral knobs on abdominal segments	2nd and 3rd	2nd and 3rd	2nd and 3rd
Spines on endopodite of maxillule	1-6	1-6	1-6
Spines on basipodite of maxillule	*	7 or 8	8 or 9
Spines on coxopodite of maxillule	*	6 or 8	7 or 8
Spines on endopodite of maxilla	*	3-3	3-3
Spines on basipodite of maxilla	*	6-6	6-6
Spines on coxopodite of maxilla	*	4-4	4-4
Setae on scaphognathite	*	20-23 (mainly 22 or 23)	23-27 (mainly 26 or 27)
Spinal arrangement on endopodite of 1st maxilliped	*	3-2-1-2-5	3-2-1-2-5
Spinal arrangement on protopodite of 1st maxilliped	*	2-2-3-3	2-2-3-3
Spinal arrangement on endopodite of 2nd maxilliped	*	1-1-5	1-1-5
Spinal arrangement on protopodite of 2nd maxilliped	*	1-1-1-1	1-1-1-1

*, not given.

Discussion

In order to identify brachyuran zoeae, AIKAWA¹⁾ proposed the following four characters: 1) spine on the carapace, 2) character of the second antenna, 3) character of the telson including its armature, and 4) grouping of chromatophores. According to his criteria, the characters of *C. japonicus* zoea may be summarized as follows: all the spines present on carapace, second antenna B-type, telson A-type, chromatophores of vermilion or crimson in color present on second to fifth abdominal segments, protopodite of the first maxilliped, on the carapace and mandible. These characters almost agree with those for *C. opilio* except color and the following characters. According to HAYNES⁹⁾, the first zoea of *C. bairdi* and *C. opilio* from the Bering Sea has three aesthetes and two setae on the antennule, whereas in *C. opilio*¹⁰⁾ and *C. japonicus* the antennule has two aesthetes and one seta. Also according to HAYNES⁹⁾, in the first zoea, the length of the posterior lateral spines on 3rd abdominal segment extends beyond the posterior margin of the adjacent segment about one-third the length of the spine in *C. bairdi*, but in *C. opilio* they barely reaches the posterior margin of the adjacent segment. In point of this, in *C. japonicus*, the posterior lateral spine is more than 1.3 times the length of 4th abdominal segment, but is shorter than (rarely equal to) those in *C. opilio*.¹⁰⁾

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