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Author(s)	KONISHI, Kooichi
Citation	北海道大學理學部紀要, 23(3), 266-295
Issue Date	1983-09
Doc URL	https://hdl.handle.net/2115/27682
Type	departmental bulletin paper
File Information	23(3)_P266-295.pdf



**Larvae of the Pinnotherid Crabs (Crustacea,
Brachyura) Found in the Plankton
of Oshoro Bay, Hokkaido¹⁾**

By

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(With 22 Text-figures, 2 Tables and 1 Plate)

More than 40 species of brachyurans have been recorded from Hokkaido and adjacent coastal waters; of these, 7 belong to the family Pinnotheridae (Yokoya, 1928; Urita, 1942; Yamaguchi and Yamada, 1955; Oshima, 1963; Sakai, 1976; Konishi, 1977). The larval development of these commensal crabs has been poorly documented until recently, when some zoeal larvae attributed to the Pinnotheridae were taken from the plankton of Oshoro Bay, on the west coast of Hokkaido facing the Sea of Japan, and examined in order to determine their parentage. The present paper describes these pinnotherid larvae and offers a preliminary key for their identification.

Materials and Methods

In the years from 1977 to 1979, monthly tow-net collections were made at Oshoro Bay at a depth of 10–20 m. The tow-net 300 μ m in mesh size, was used in the present plankton hauls. After sorting the samples, the larvae in each stage were fixed in 5 or 10% buffered formaldehyde and then preserved in 70% ethanol. Techniques for light and scanning electron microscopies are the same as described in the previous papers (Konishi, 1981a, b).

Measurements were taken: the total length=distance between the tips of dorsal and rostral spines on the carapace, and the carapace length=the distance between the base of the eyestalk and the posteriolateral margin of the carapace. In the following description, all series of setal armature are listed from proximal to distal.

1) This paper is based upon part of a dissertation presented to the Faculty of Science, Hokkaido University, Sapporo (1982).

Jour. Fac. Sci. Hokkaido Univ. Ser. VI, Zool. 23(3), 1983

Description of Larvae

1. *Pinnotheres sinensis* Shen

Source of materials: The first through third zoeal stages were found among the plankton samples collected at the bottom of the bay. These occur from early August to early September (Fig. 1A). In addition, the first zoeae, which were hatched from an ovigerous crab obtained in the mantle cavity of the mussel *Mytilus coruscus* Gould collected at this area, were also examined.

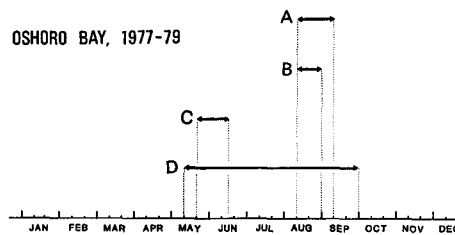


Fig. 1. Seasonal occurrence of pinnotherid larvae in Oshoro Bay, Hokkaido (1977-1979). A: *Pinnotheres sinensis* Shen, B: *Pinnotheres pholadis* de Haan, C: *Sakaina japonica* Serène, D: *Pinnixa* aff. *rathbuni* Sakai.

First zoea: The globular carapace has no spines, but is provided with a pair of setules on the mediodorsal part (Fig. 2A; Pl. IX, fig. 1). The carapace length ranges from 0.41 to 0.45 mm. The eyes are sessile at this stage. The abdomen consists of 5 somites and a trilobed telson (Fig. 3A). The abdominal somites widen posteriorly. The second abdominal somite has a transverse collar; its lateral portion is produced laterally into a knob-like projection on either side. A pair of lateral knobs are also present on the third abdominal somite. There is a pair of setules on the posteriodorsal border of the second through fifth abdominal somites. The telson bears 3 plumose spines on both sides of the triangular median lobe; the inner-most one is larger than the remainder. The external lobes of the telson are slightly serrated along the posteriolateral margin.

The antennule is represented as a small hemispherical knob provided with 2 long aesthetascs and a short seta on its terminal (Fig. 4A; Pl. IX, fig. 3). The antenna is quite rudimentary and is furnished only with a fine seta (Pl. IX, fig. 3). The mandible consists of both incisor and molar processes (Fig. 4E; Pl. IX, fig. 2). The outer surface of the mandible is sculptured. The maxillule is composed of a two-segmented endopodite, basal and coxal endites (Fig. 5A).

The distal segment of the endopodite bears 4 setae, while no setae are found on the proximal one; this setal pattern remains constant until the end of the third zoeal stage. The basal and coxal endites carry 5 (occasionally 6) and 4 bristle spines, respectively. The maxilla consists of an unsegmented endopodite, basal and coxal endites, and a scaphognathite (Fig. 5D). The tip of the endopodite is bilobed,

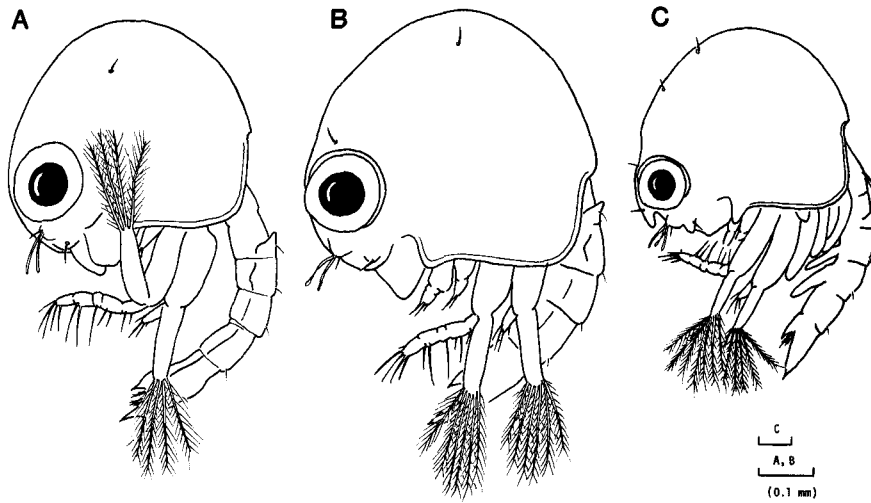


Fig. 2. First through third (A-C) zoea of *Pinnotheres sinensis* Shen, lateral view.

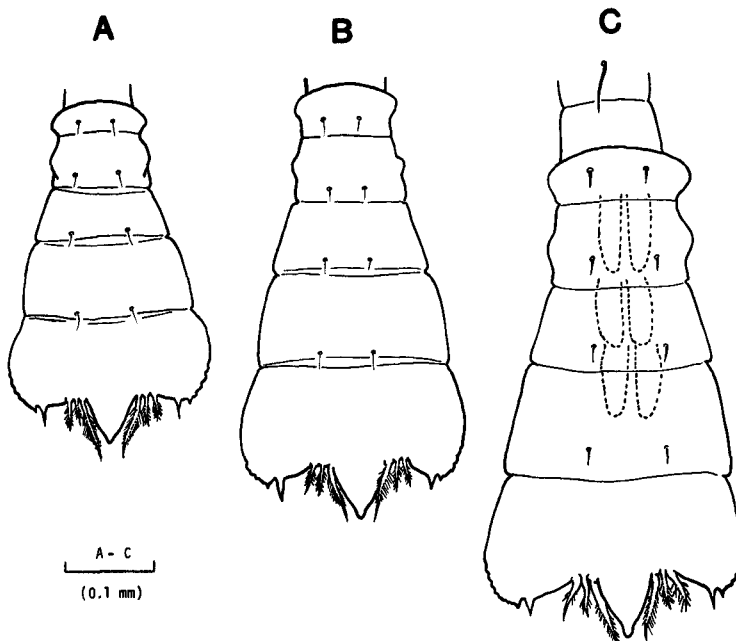


Fig. 3. Abdomens of first through third (A-C) zoea of *Pinnotheres sinensis* Shen, dorsal view.

provided with 2 setae on the distal and a seta on the proximal lobe; this feature is constant in all zoeal stages. The slightly-bilobed basal endite has 4 setae on each lobe, while the single-lobed coxal endite bears 5 (occasionally 6) setae. The scaphognathite has 4 soft plumose setae on its margin and also bears a long plumose posterior projection. The first maxilliped is made of a basipodite, a five-segmented endopodite and an exopodite (Fig. 6A). The basipodite carries 10 setae arranged 2,2,3,3. The endopodite has a setation pattern of 2,2,1,2,5. The exopodite bears 4 long natatory setae which are densely plumose. The setal pattern of the basipodite is unchanged in all zoeal stages. The second maxilliped is mainly structured as in the first maxilliped (Fig. 6D). The basipodite possesses 4 (occasionally 3) setae arranged 1,1,1,1. The two-segmented endopodite is provided with 4 terminal setae on the distal segment. The exopodite has 4 long natatory setae as in the first maxilliped. The setation of the basipodite is constant until the end of the third zoeal stage. The third maxilliped and pereopods are not recognizable at this stage.

Second zoea: The carapace length ranges from 0.51 to 0.53 mm. The eyes

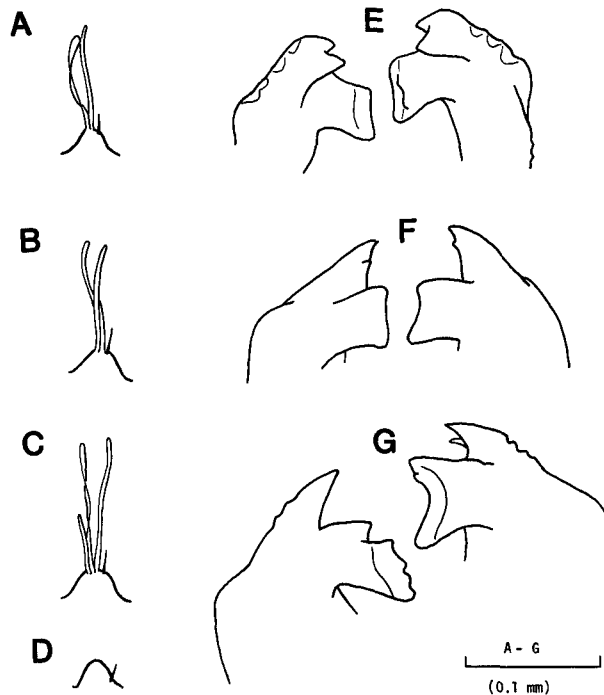


Fig. 4. Antennules (A-C) and mandibles (E-G) of first through third zoea of *Pinnotheres sinensis* Shen. D: antenna of third zoea.

are now stalked (Fig. 2B). A rostral projection is weakly recognized at this stage. There are two pairs of setules on the carapace. Very small pleopod buds begin to appear on the second through fourth abdominal somite (Fig. 3B).

The antennule bears 2 long aesthetascs and a short seta (Fig. 4B). The antenna remains as rudimentary as it had been in the first zoea. The mandible becomes slightly larger than it was during the previous stage, but is otherwise unchanged (Fig. 4F). The basal endite of the maxillule carries 7 bristle spines, 7

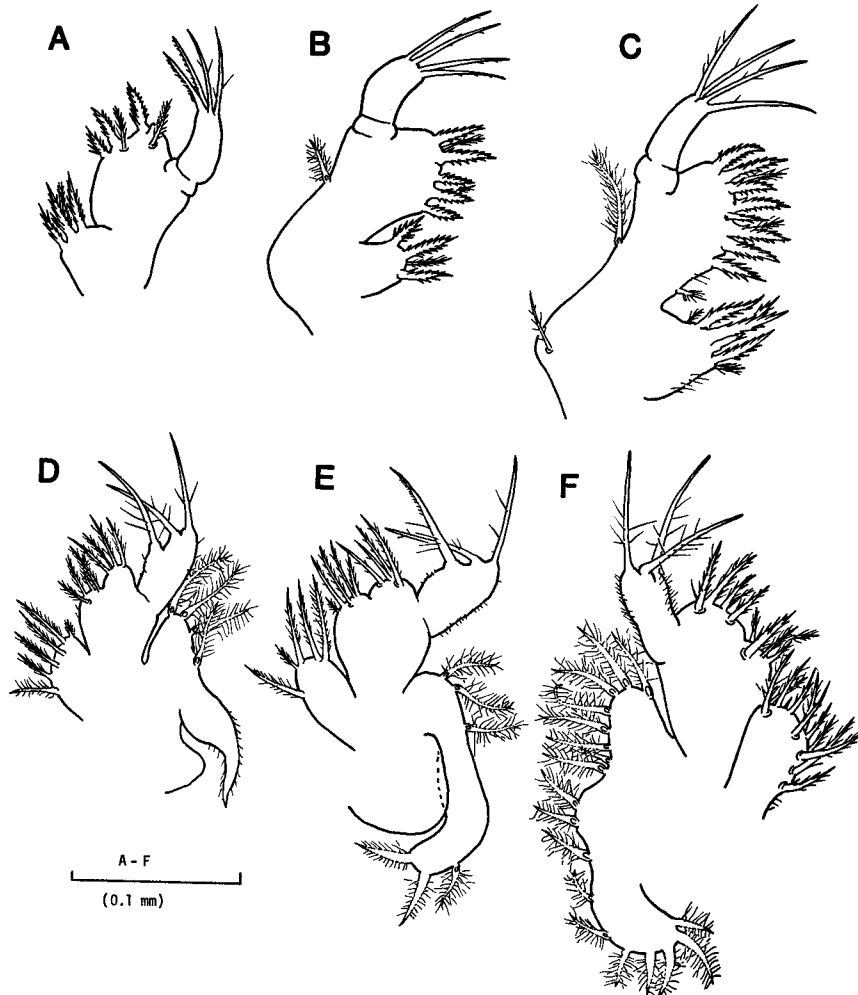


Fig. 5. Maxillules (A-C) and maxillae (D-F) of first through third zoea of *Pinnotheres sinensis* Shen.

while the coxal endite has 4 (occasionally 5) (Fig. 5B). There is a soft plumose seta on the dorsal side. The basal endite of the maxilla is slightly bilobed with 4 (occasionally 3 or 5) setae on each lobe (Fig. 5E). The coxal endite carries 5 or 6 setae. The marginal plumose setae on the scaphognathite has increased to 6-8. The two-segmented endopodite of the second maxilliped in the first zoea has been transformed into a single-segmented form (Fig. 6E). The setal arrangement of the maxillipedal basipodite is the same as in the first zoea. The exopodite

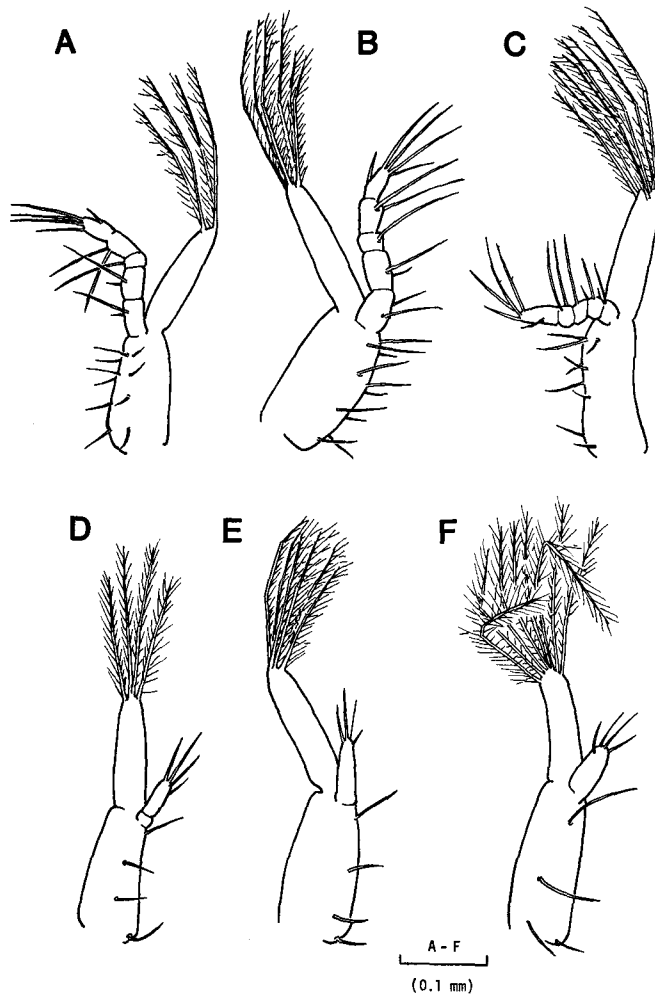


Fig. 6. First (A-C) and second (D-F) maxillipeds of first through third zoea of *Pinnotheres sinensis* Shen.

Table 1. A synopsis of main larval character of *Pinnotheres sinensis* Shen (left) *P. pholadis* de Haan (right). b: bud, v: vestigial, +: present, -: absent. * after Muraoka (1979b), ** measured from Muraoka's figure.

Character	Stage (<i>P. sinensis</i>)			Stage (<i>P. pholadis</i>)		
	Zoea I	Zoea II	Zoea III	Zoea I	Zoea I*	Zoea III
Carapace: length (mm)	0.41—0.45	0.51—0.53	0.63—0.68	0.57—0.65	0.50**	0.95
rostral spine	—	—	(+)	+	+	+
dorsal spine	—	—	—	—	—	—
lateral spine	—	—	—	+	+	+
Antennule: aesthetascs	2	2	3	2	2	3
endopodite	—	—	—	—	—	—
Antenna: protopodite	—	—	(+)	v	—	+
endopodite	—	—	—	—	—	—
exopodite	—	—	—	—	—	—
Mandible: palp	—	—	—	—	—	—
incisor process	+	+	+	+	+	+
molar process	+	+	+	+	+	+
Maxillule: endopodite	0, 4	0, 4	0, 4	0, 4	0, 4	0, 4
basal endite	5—6	7	11	5	5	9
coxal endite	4	4—5	6	4	4	4
dorsal side	—	1	2	—	—	1
Maxilla: endopodite	3	3	3	3	3	3
basal endite	8	9	10	8	8—9	10
coxal endite	5	6	11	4—5	4—5	7
scaphognathite	4	8—9	18	4	4	12
Mxp. I: basipodite	2, 2, 3, 3	2, 2, 3, 3	2, 2, 3, 3	2, 2, 3, 2	2, 2, 3, 2	2, 2, 3, 2
endopodite	2, 2, 1, 2, 5	2, 2, 1, 2, 5	2, 2, 1, 2, 5	2, 2, 1, 2, 5	2, 2, 1, 2, 5	2, 2, 1, 2, 5
exopodite	4	6	8	4	4	8
Mxp. II: basipodite	1, 1, 1, 1	1, 1, 1, 1	1, 1, 1, 1	1, 1, 1, 1	0, 1, 1, 1	1, 1, 1, 1
endopodite	0, 4	4	4	0, 5	0, 5	5
exopodite	4	6	8	4	4	8
Mxp. III and pereopods	—	b	b	—	—	b
Abdomen: no. of somites	5	5	5	5	5	5
pleopod	—	b	b	—	—	b
uropod	—	—	—	—	—	—
Telson: inner spine	6	6	6	6	6	6

bears 6 (occasionally 5) long natatory setae at the end of each maxilliped (Figs. 6B and 6E). The third maxilliped and pereopods are now recognizable as a bunch of small buds situated under the carapace.

Third zoea: The carapace length ranges from 0.63 to 0.68 mm. The setules on the carapace has now increased to four pairs (Fig. 2C). A small rostral projection is present. The pleopod buds on the second through fourth abdominal somite are more elongated than those during the second zoea (Fig. 3C, dotted line). The sixth abdominal somite is not yet separated from the telson.

The antennule bears 3 long aesthetascs and a short seta (Fig. 4C). The antenna now emerges as a small conical bud with a setules on its base (Fig. 4D). The mandible becomes somewhat larger than it was in the second zoea (Fig. 4G). The basal endite of the maxillule carries 11-12 bristle spines while the coxal endite has 6 (Fig. 5C). There are a soft plumose and a simple setae on its dorsal side. The slightly-bilobed basal endite of the maxilla carries 5 setae on each lobe, while the single-lobed coxal endite has 11 or 12 setae (Fig. 5F). The scaphognathite bears 18 soft plumose setae on its margin. The number of natatory setae on the maxillipedal exopodite has by now increased to 8 (occasionally 7) (Figs. 6C and 6F), but is otherwise unchanged. The buds of the third maxilliped and pereopods are visible outside the carapace. There is a long seta on the mediodorsal part of the first abdominal somite.

Remarks: The megalopa and juvenile crabs were not caught in the plankton hauls. The occurrence of the zoeae was relatively rare in comparison with other brachyuran zoeae. This fact may possibly be due to the scarcity of their parent crabs; the percentage of infection to their host mussel is usually less than 1% at Oshoro Bay, whereas other brachyuran crabs are found abundantly in this bay.

A synopsis of the morphological character of the zoeae is shown in Table 1. All the zoeal characteristics of the present material accord well with those of crabs taken from Tokyo Bay described by Muraoka and Konishi (1977) except for body size; the mean carapace lengths are 0.43 mm of the first zoeae from Oshoro Bay and 0.39 mm for those from Tokyo Bay. This difference may be regarded as an individual variation of different localities. Besides, it was clearly observable that no difference of the characteristics could be detected between natural and laboratory-hatched first zoeae.

The reduction of the segment number of the second maxillipedal endopodite in the present study agrees with that described in the larval development of *P. aff. sinensis* Shen from Usa Bay, southern Japan (Yatsuzuka and Iwasaki, 1979).

2. *Pinnotheres pholadis* de Haan

Source of materials: The first and third zoeae were found in the present plankton hauls, while the second and the megalopal stages remain for future studies. The occurrence of the zoeae at Oshoro Bay was restricted to a very short period, from the middle to the end of August (Fig. 1B).

First zoea: The carapace is provided with a rostral spine, and a pair of lateral spines (Figs. 7A and 7A'). The carapace length ranges from 0.57 to 0.65 mm. The carapace also has a pair of setules on its mediodorsal part. The eyes are not stalked at this stage. The abdomen, being broadened posteriorly, is composed of 5 somites and a telson (Fig. 8A). The second abdominal somite bears a transverse collar as in the zoeae of *P. sinensis*. The third abdominal somite has a pair of lateral knobs. There is a pair of setules on the posteriodorsal border of the second through fifth abdominal somites. Occasionally a minute setule is found on the mediodorsal surface of the telson. The telson is trilobed in shape, and the external lateral margin of each outer lobe is slightly serrated with 2 terminal spines (Fig. 8A'). There are three pairs of plumose spines near the base of the triangular median lobe.

The hemispherical antennule has 2 long aesthetascs and a short seta (Fig. 9A). The antenna is very rudimentary at this stage (Fig. 9C). The mandible, consisting of both incisor and molar processes, differs slightly in shape on either side of the body (Fig. 9E). The two-segmented endopodite of the maxillule carries 4 terminal setae on its distal segment, while none on the proximal segment (Fig. 10A); this setal arrangement remains unchanged in the third zoea. The basal endite bears 5 bristle spines, and the coxal endite carries 4. The bilobed endopodite of the maxilla has 2 setae on the distal lobe and a seta on the proximal lobe (Fig. 10C). The slightly-bilobed basal endite carries 4 setae on each lobe, while the single-lobed coxal endite has 4 (occasionally 5) ones. The scaphognathite possesses 4 soft plumose

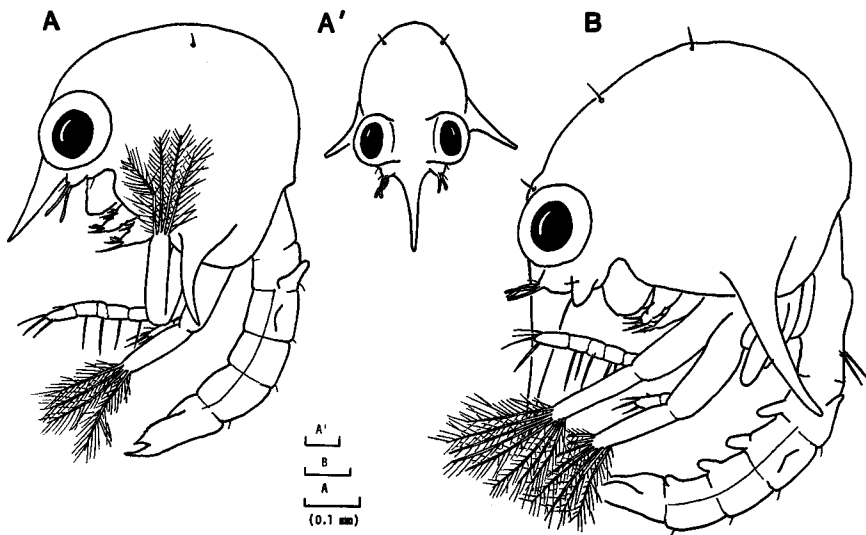


Fig. 7. First (A) and third (B) zoea of *Pinnotheres pholadis* de Haan, lateral view. A': frontal view of first zoea.

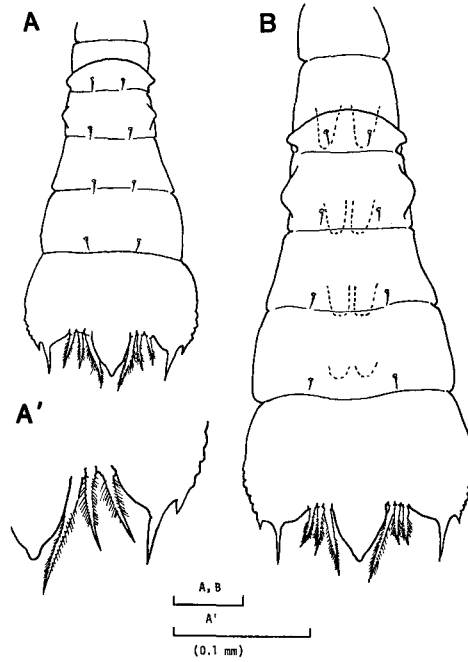


Fig. 8. Abdomens of first (A) and third (B) zoea of *Pinnotheres pholadis* de Haan. A': right lobe of telson of first zoea.

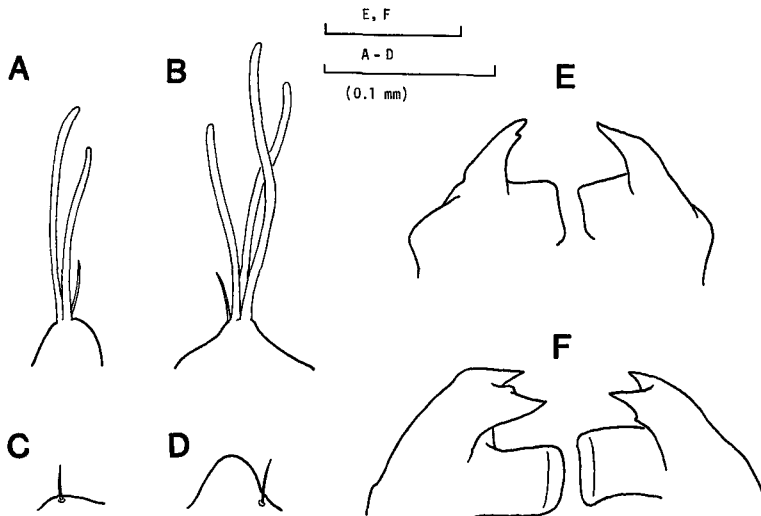


Fig. 9. Antennules (A-B), antennae (C-D) and mandibles (E-F) of first and third zoea of *Pinnotheres pholadis* de Haan.

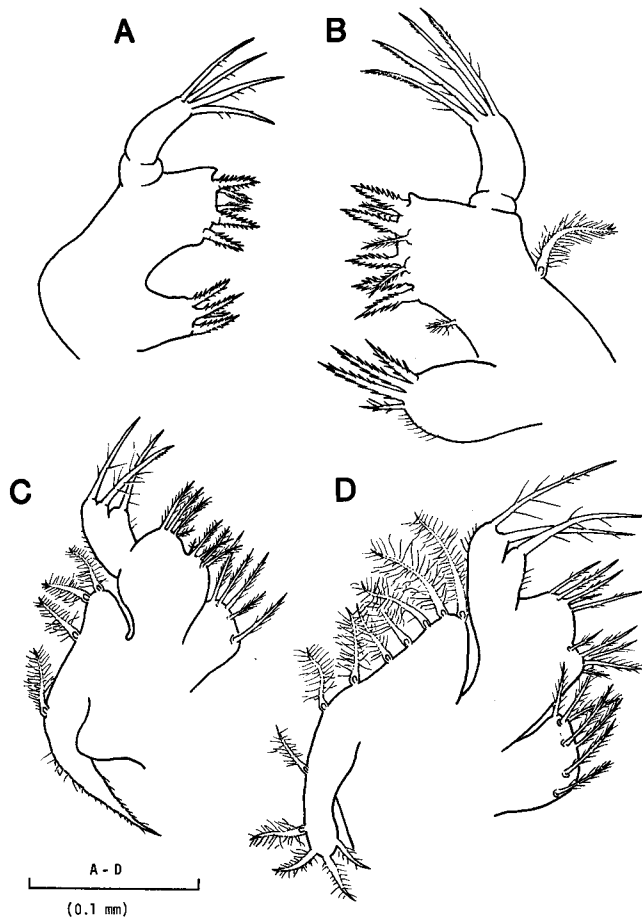


Fig. 10. Maxillules (A-B) and maxillae (C-D) of first and third zoea of *Pinnotheres pholadis* de Haan.

setae on its margin and a long plumose posterior projection. The basipodite of the first maxilliped has 9 setae, arranged 2,2,3,2 (Fig. 11A). The endopodite consists of 5 segments with a setation of 2,2,1,2,5. The exopodite carries 4 long natatory setae on its tip. The basipodite of the second maxilliped bears 4 setae (Fig. 11C). The two-segmented endopodite has 5 terminal setae on the distal segment, but none on the proximal segment. The exopodite is structured and furnished similarly to the first maxilliped. The setation of the basipodite of both maxillipeds and of the endopodite of the first maxilliped is unchanged in the third zoea.

Third zoea: The carapace length, including the rostral spine, is 0.95 mm.

There are three pairs of minute setae on the carapace (Fig. 7B). Small pleopod buds appear on the posteroventral margin of the second through fifth abdominal somite, but the fifth is much smaller than the remainder (Fig. 8B, dotted line). The sixth abdominal somite is not recognizable yet.

The antennule bears 3 long aesthetascs of unequal length and a short seta (Fig. 9B). A much reduced antenna is found as a small conical bud with a minute seta near its base (Fig. 9D). The mandible is somewhat larger than that of the first zoea, and its denticulation has slightly changed (Fig. 9F). The basal and coxal

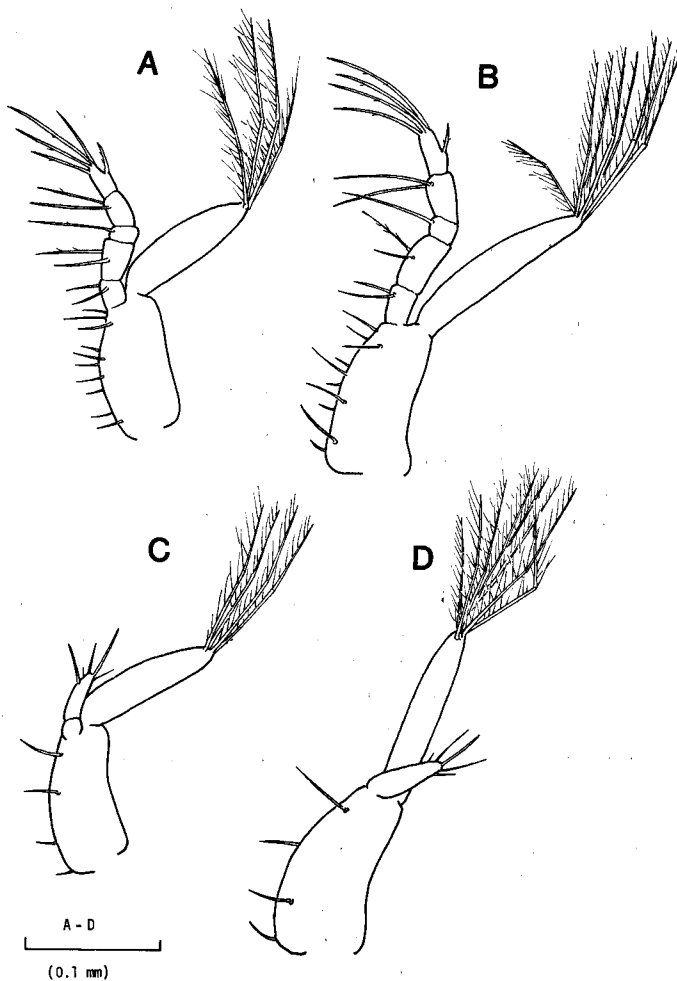


Fig. 11. First (A-B) and second (C-D) maxillipeds of first and third zoea of *Pinnotheres pholadis* de Haan.

endites of the maxillule bear 9 and 4 bristle spines, respectively (Fig. 10B). On the dorsal side, there is a soft plumose seta. The endopodite of the maxilla carries 3 setae as in the first zoea (Fig. 10D). The slightly-bilobed basal endite has 5 setae on each lobe, and the single-lobed coxal endite has 7 setae. The margin of scaphognathite is fringed with 12 soft plumose setae. The setation of the endopodite of the first maxilliped remains unchanged (Fig. 11B). The exopodite carries 8 long natatory setae by which the number of instar is determined. The endopodite of the second maxilliped has now been transformed into an unsegmented form with 5 terminal setae (Fig. 11D), but is otherwise the same as in the first zoea. The exopodite is structured and furnished as in the first maxilliped. The buds of the third maxilliped and pereopods are partly visible from the lateral side of the carapace and they are slightly segmented.

Remarks: As can be seen in Table 1, the morphological character of the present material is almost identical with the material described by Muraoka (1979b) from Tokyo Bay. Adult crabs of the present species have been recorded previously from Oshoro Bay (Igarashi, 1970), but could not be obtained for the present study.

The reduction of the segment number of the second maxillipedal endopodite can also be recognized in the present case. The general features of the zoeal development of *P. pholadis* thus much resemble those of *P. sinensis* and *P. aff. sinensis* except for the presence of the carapace spines in the former.

3. *Sakaina japonica* Serène

Source of materials: The first zoea of the present species were frequently captured by the tow-net collections made at Oshoro Bay. The second and more advanced stages were not found during these hauls. The present zoeae may be found here for only a very short period: from late May to late June (Fig. 1C).

First zoea: The carapace is globular and provided with only a rostral spine (Fig. 12A). The carapace length, including the rostral spine, measures from 0.81 to 0.92 mm. Three or 4 plumose setae are arranged along the ventrolateral margin of the carapace. The abdomen is composed of 5 somites and a bifurcated telson (Fig. 12B). The abdominal somites are slightly widened posteriorly, and the fifth possesses posteriolateral wings on both sides of the body. The telson is narrower than the abdominal somites and bears 6 inner serrate spines between the furcae.

The conical antennule carries 3 long aesthetascs and a short seta (Fig. 12C). The antenna consists of only a pointed protopodite with a row of minute denticles (Fig. 12D). The mandible is made of incisor and molar processes (Fig. 12E). The maxillule is composed of a two-segmented endopodite, basal and coxal endites (Fig. 12F). The endopodite has 4 terminal setae on its distal segment, while the proximal segment has none. The basal endite bears 5 or 6 bristle spines and the coxal endite has 4. The maxilla consists of an unsegmented endopodite, a slightly-bilobed basal endite, a single-lobed coxal endite, and a scaphognathite (Fig. 12G).

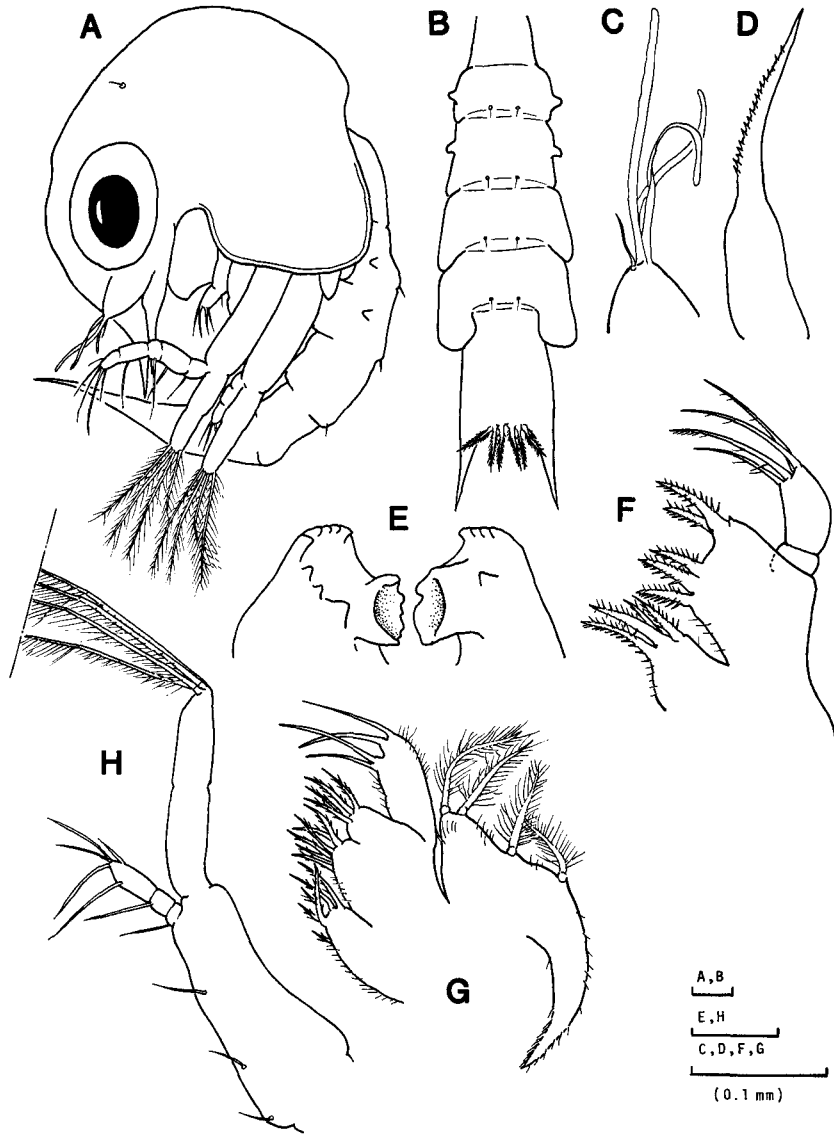


Fig. 12. First zoea of *Sakaina japonica* Serène. A: lateral view, B: abdomen, C: antennule, D: antenna, E: mandible, F: maxillule, G: maxilla, H: second maxilliped.

The endopodite is bilobed and carries 2 setae on each terminal end of the lobe. The bilobed basal endite has 4 and 6 setae, respectively, and the coxal endite bears 6 ones. The scaphognathite carries 4 marginal plumose setae and a long posterior

projection. The first maxilliped is composed of a basipodite, a five-segmented endopodite and an exopodite. The setal arrangement of the basipodite is 2,2,3,2 or 2,2,2,2. The endopodite has a setation of 2,2,1,2,5. The exopodite is slightly constricted at its middle part and bears 4 long natatory setae which are densely plumose. The second maxilliped is structured similarly to the first maxilliped (Fig. 12H). The basipodite has 4 (occasionally 3) naked setae arranged 1,1,1,1 (occasionally 1,1,1,0). The endopodite is three-segmented with a setal arrangement of 0,1,5. The exopodite bears 4 long natatory setae on its tip. The third maxilliped and pereopods are present as a bunch of small buds under the carapace.

Remarks: These zoeae are very conspicuous among the other brachyuran zoeae in this bay, because of the large size and brown colour of the living specimens. All the first zoeal characteristics of the present materials agreed well with those of laboratory-reared materials from Ariake Bay, Kyushu (Konishi, 1981a). Furthermore, as no *Sakaina* species other than *S. japonica* has been reported from Hokkaido, they can therefore be safely identified as the zoeae of *S. japonica* at least in this area.

4. *Pinnixa* aff. *rathbuni* Sakai

Source of materials: All the larval stages, from first zoea through megalopa, were taken in the plankton samples collected by tow-net. The zoeae occur from early May through late September at Oshoro Bay (Fig. 1D). Of these, 75 animals were separated from the planktonic first zoeae and were chosen for the laboratory-rearing experiment. Under laboratory conditions (15°C, 33–35‰), the present larvae passed through 4 zoeal stages and a megalopa. In addition to these stages, first through fourth juvenile crab stages were also obtained. The description given below is based on the laboratory-reared materials.

First zoea: The carapace is provided with a long rostral spine, a slightly-curved dorsal spine, and a pair of lateral spines (Fig. 13A). The total length of the carapace ranges from 1.30 to 1.49 mm. The carapace is also furnished with a pair of setules located slightly behind the base of the dorsal spine. The eyes are sessile at this stage. The abdomen consists of 5 somites and a bifurcated telson (Fig. 14A). The number of abdominal somites remains unchanged in all zoeal stages. The second and third somites have a pair of lateral knobs. Each somite also has a pair of setules on the posteriodorsal border. The fifth abdominal somite has a characteristic feature: the posterior portion extends posteriorly and laterally just like a pair of wings. Each telsonal furca carries 3 serrate spines on its inner margin, and its posterior region is covered with densely-scattered fine setules (Fig. 14A'). The number of inner furcal spines is constant throughout the zoeal stages.

The antennule is a conical process with 2 long aesthetascs and a short seta (Fig. 15A). The antenna is composed of only a long pointed protopodite with two rows of minute denticules which run along nearly two thirds of the protopodite,

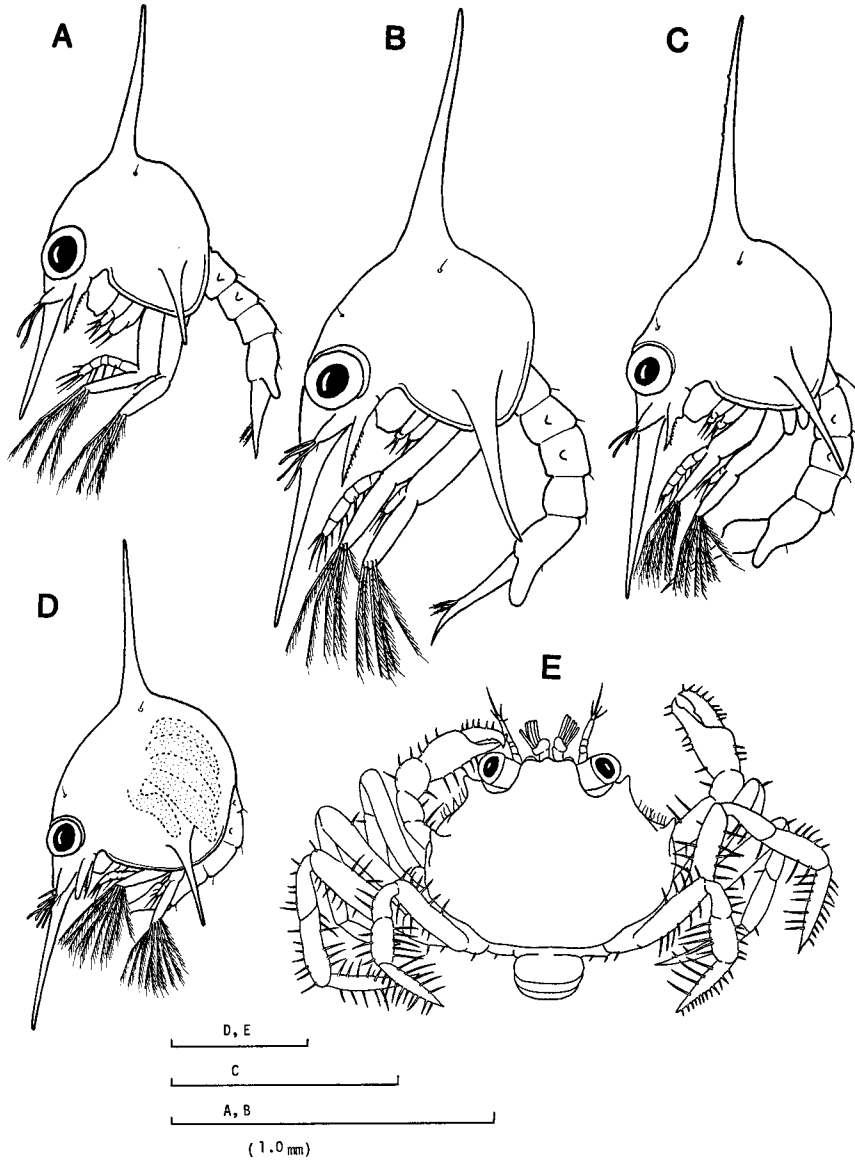


Fig. 13. First through fourth (A-D) zoea and megalopa (E) of *Pinnixa* aff. *rathbuni* Sakai, lateral (A-D) and dorsal (E) view.

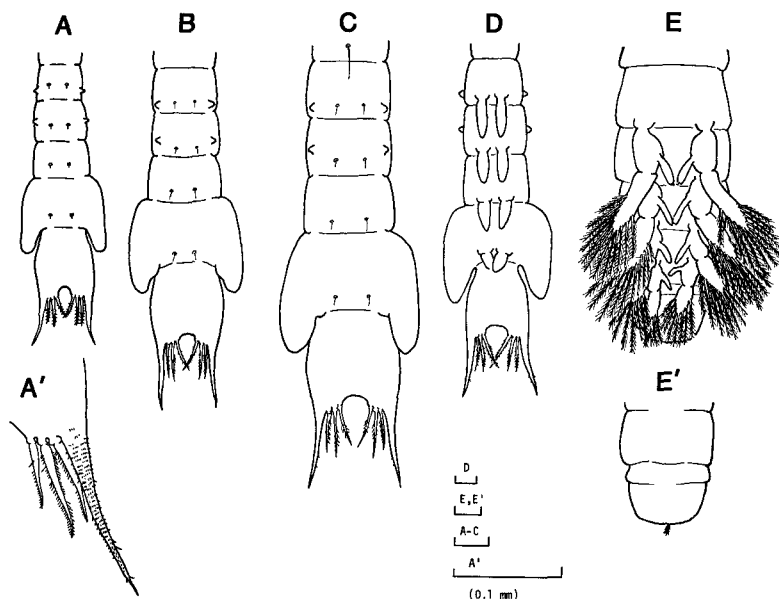


Fig. 14. Abdomens of first through fourth (A-D) and megalopa (E, E') of *Pinnixa* aff. *rathbuni* Sakai, dorsal (A-C, E') and ventral (D-E) view. A': right furca of telson of first zoea.

while the short seta is found near the base (Fig. 15F). The mandibles, consisting of both incisor and molar processes, differ slightly in their denticulation on either side of the body (Fig. 16A). The maxillule is composed of three parts: an endopodite, basal and coxal endites (Fig. 17A). The two-segmented endopodite bears 4 terminal setae on the distal segment, while the proximal segment has none; this setal arrangement, 0,4, is constant in all zoeal stages. The basal endite carries 5 bristle spines and the coxal endite has 4 (occasionally 5). The maxilla consists of an unsegmented endopodite, basal and coxal endites, and a scaphognathite (Fig. 18A). The bilobed endopodite has 2 setae on the distal lobe and a seta on the proximal lobe; this pattern remains unchanged until the end of the last zoeal stage. The basal endite is slightly-bilobed and carries 3 and 5 (occasionally 4) setae. The coxal endite is single-lobed with 4 setae. The scaphognathite bears 4 soft plumose setae which fringe the margin and has a long plumose posterior projection. The first maxilliped is made of a basipodite, a five-segmented endopodite, and an exopodite (Fig. 19A). The basipodite has 10 setae arranged 2,2,3,3 (occasionally 2,2,3,2 or 1,2,2,2). The endopodite has a setation of 2,2,1,2,5, which is constant in all zoeal stages. The third segment of the endopodite is sparsely plumose. The exopodite bears 4 long natatory setae which are densely plumose. The second maxilliped is structured similarly to the first maxilliped, consisting of a basipodite, an endopodite

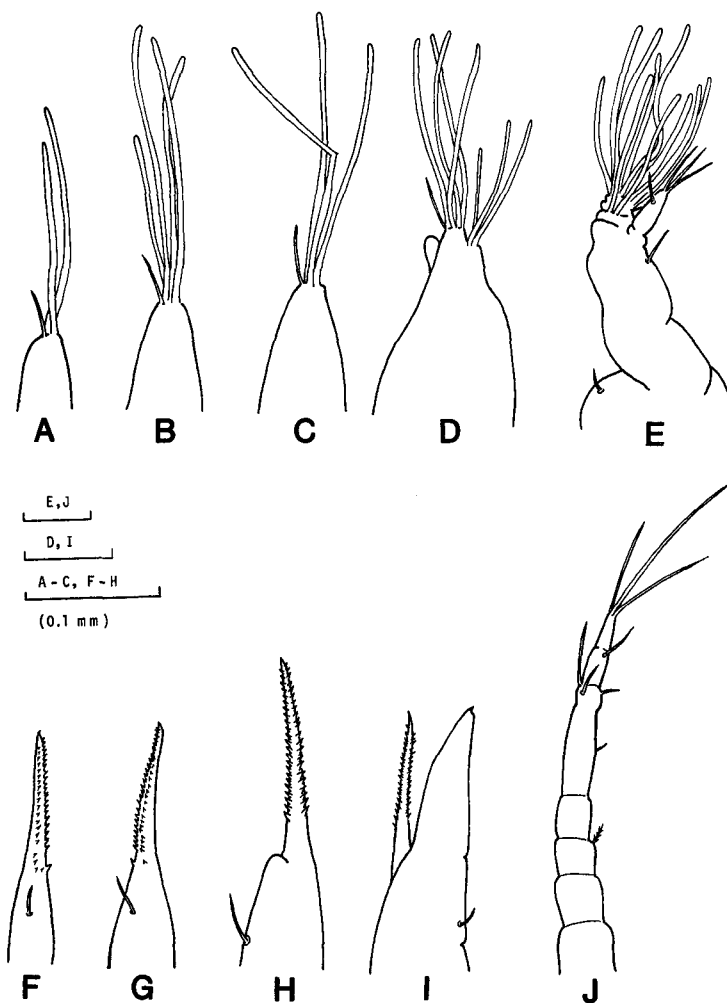


Fig. 15. Antennules (A-E) and antennae (F-J) of first through fourth zoea and megalopa of *Pinnixa* aff. *rathbuni* Sakai.

and an exopodite (Fig. 20A). The basipodite carries 4 (occasionally 3) setae. The endopodite is two-segmented and has 4 terminal and a subterminal stout seta on its distal segment, while having none on the proximal segment; this setal arrangement remains constant until the end of the last zoea. The exopodite is provided with 4 long natatory setae. The setation of maxillipedal basipodite is constant in all zoeal stages, but occasionally it shows individual variation. The rudiments of the third maxilliped and the pereopods are not found at this stage.

Second zoea: The total length of the carapace measures from 1.82 to 1.98 mm. The eyes are now stalked (Fig. 13B). The abdomen becomes larger than in the first zoea, but is otherwise unchanged (Fig. 14B).

The antennule carries 4 (occasionally 3) long aesthetascs and a short seta (Fig. 15B). The antenna is unchanged in shape, although slightly enlarged (Fig. 15G). The mandible is somewhat larger than it was in the previous stage, but is otherwise unchanged (Fig. 16B). The basal and coxal endites of the maxillule bear 5 (occasionally 6) and 4 bristle spines, respectively (Fig. 17B). On the dorsal side, there is a soft plumose seta. The slightly-bilobed basal endite of the maxilla has 4 setae on each lobe, while the coxal endite bears 4 (occasionally 5) setae (Fig. 18B). The scaphognathite carries 4-6 soft plumose setae on the posterior half of its margin and 3 on the posterior end. In both maxillipeds, the number of the natatory setae on the exopodite has increased to 6, but otherwise is the same as in the first zoea (Figs. 19B and 20B). A rudimentary third maxilliped now emerges as a bud just behind the second maxilliped (Fig. 21A).

Third zoea: The total length of the carapace ranges from 2.25 to 2.63 mm (Fig. 13C). The main features of the abdomen are unchanged except for the overall size (Fig. 14C).

The terminal aesthetascs on the antennule have been reduced to 3, but are otherwise unchanged (Fig. 15C). An endopodite of the antenna is now represented as a small bud, but is otherwise as it was in the previous stage (Fig. 15H). The mandible is as it was in the previous stages except for its size, but occasionally

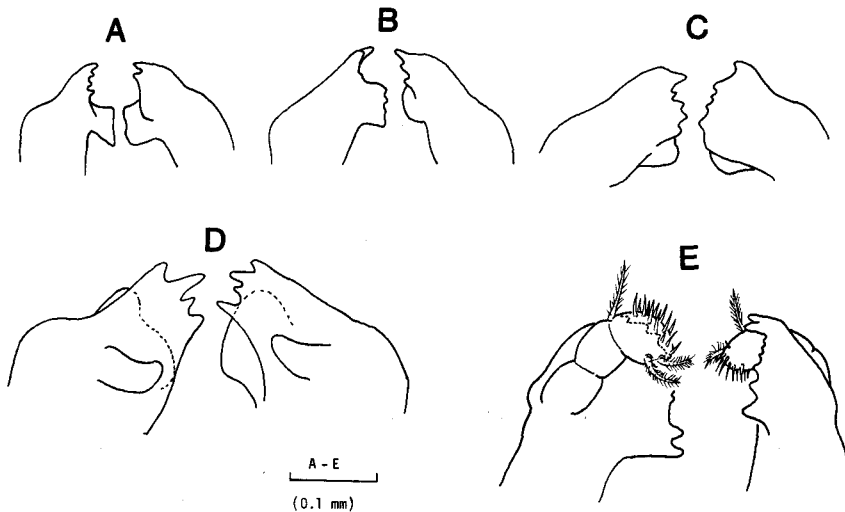


Fig. 16. Mandibles of first through fourth (A-D) zoea and megalopa (E) of *Pinnixa* aff. *rathbuni* Sakai.

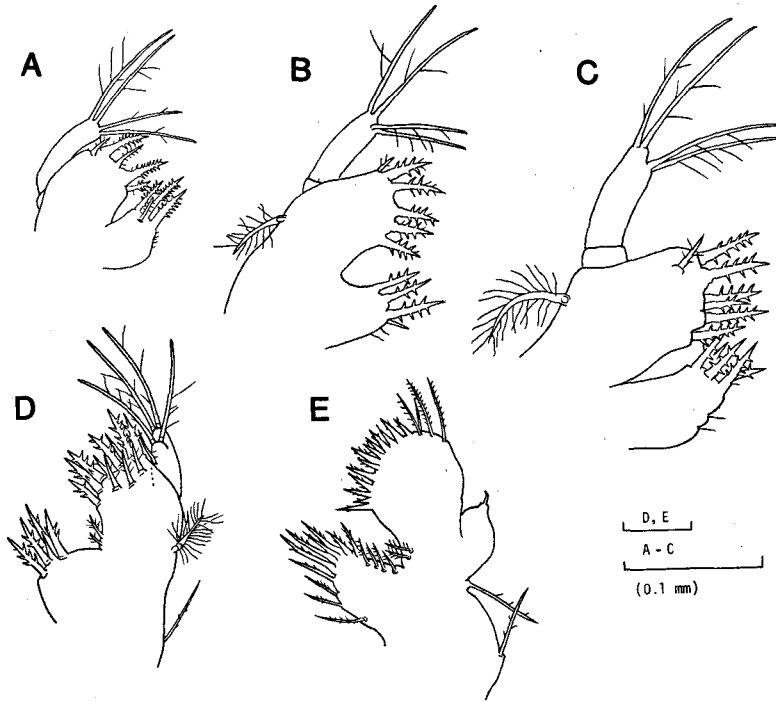


Fig. 17. Maxillules of first through fourth (A-D) zoea and megalopa (E) of *Pinnixa* aff. *rathbuni* Sakai.

some additional teeth are found (Fig. 16C). The basal endite of the maxillule bears 7 or 8 serrate spines, while the coxal endite has no additional spines (Fig. 17C). The slightly-bilobed basal endite of the maxilla possesses 5 (occasionally 4) setae on each lobe, and the coxal endite has 5 (Fig. 18C). The scaphognathite carries 10–13 soft plumose setae on its margin. The exopodite of the first and second maxillipeds bear 8 long natatory setae terminally, but otherwise remains as it was in the previous stages (Figs. 19C and 20C). The bud of the third maxilliped is now biramous, and a bunch of small buds which represent the rudimentary pereopods is now recognizable (Fig. 21B).

Fourth zoea: The total length of the carapace measures from 3.24 to 3.79 mm. The size of the carapace is larger than that of the thoracic appendages and of the abdomen. The length of the carapace spines is short in proportion to the size of the carapace; thus, the general appearance of the fourth zoea presents a “squabby” form (Fig. 13D). The sixth abdominal somite is not yet separated from the telson. On the posteroventral border of the second through fifth abdominal somite, a pair of pleopod buds is found (Fig. 14D).

The antennule bears two tiers of aesthetascs; 2 or 3 on the lower tier, while 4-6 and a seta on the terminal part (Fig. 15D). An endopodite bud appears near the terminal end. The bud of the antennal endopodite is much larger in size than the protopodite, and sometimes the tip of the bud exceeds that of the protopodite (Fig. 15I). A slight segmentation is also recognizable in the bud. The mandible now emerges as a bud which represents the palp on its basal part (Fig. 16D). The endopodite of the maxillule has 4 setae as in the previous stages, but occasionally there is a short seta on its basal part (Fig. 17D). The basal endite carries 13 bristle spines, while the coxal endite has only 5 or 6. The slightly-bilobed basal

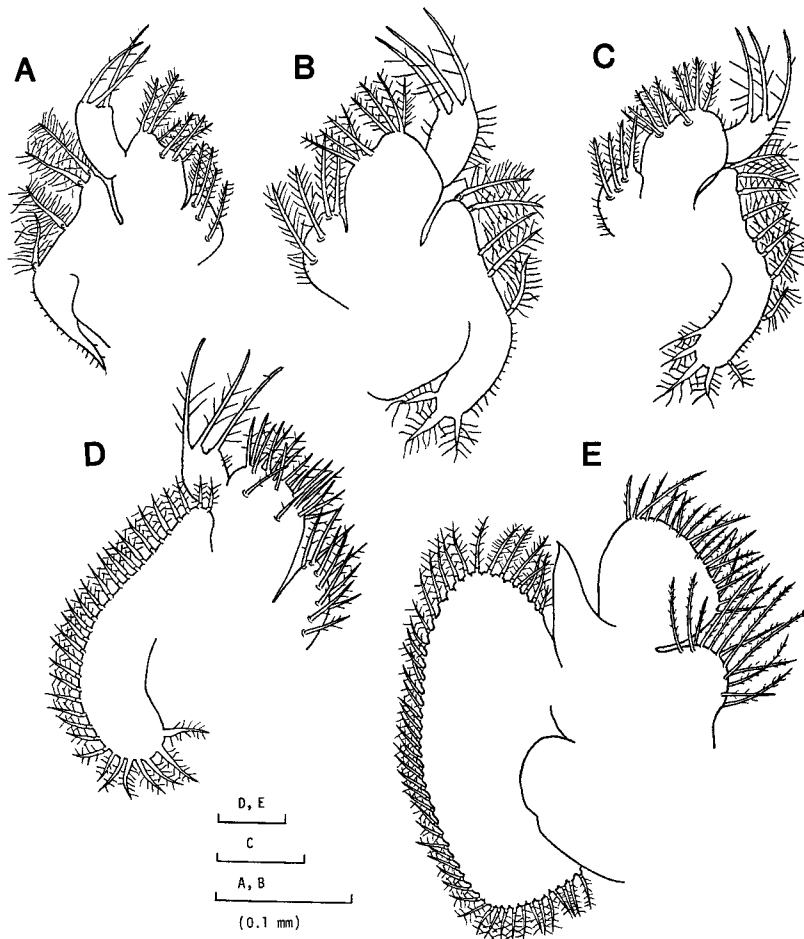


Fig. 18. Maxillae of first through fourth (A-D) zoea and megalopa (E) of *Pinnixa* aff. *rathbuni* Sakai.

endite of the maxilla carries 9 or 10 setae on each lobe and the single-lobed coxal endite has 10 (Fig. 18D). The number of the marginal plumose setae on the scaphognathite has increased to 29–32. The total length of the endopodite of the first maxilliped is now approximately equal to that of the exopodite, while sometimes exceeding it (Fig. 19D). The number of the marginal plumose setae on the maxillipedal exopodite has increased to 10 (occasionally 9) (Figs. 19D and 20D). The bud of the third maxilliped is now distinctly biramous in shape, and a small epipodite bud is recognizable in the basal region (Fig. 21C). The pereopod buds are conspicuous through the translucent carapace; they are incipiently segmented and finger-like projections. Branchial rudiments are also recognizable on the buds of the first pereopod (=cheliped) and the third maxilliped.

Megalopa: The general appearance of the megalopa is broad rather than long, slightly widened posteriorly (Fig. 13E). The carapace measures 1.59–1.80 mm in width and 1.20–1.55 mm in anterioposterior length; the mean ratio of length to width is 1.31. Two pairs of pointed processes are found on the anteriolateral margin of the carapace. The frontal region bears a small rostral projection in the middle, but this is occasionally absent. The eyes are placed in orbits. The abdomen now consists of 6 somites and a telson (Fig. 14E); occasionally the boundary between the telson and the sixth somite is obscure (Fig. 14E'). The second through fifth abdominal somites have a pair of well-developed pleopods. The exopodite of the pleopod is larger than the endopodite, and carries 11–16 long natatory setae on its terminal end. The endopodite is furnished with 2 terminal hooks. The sixth abdominal somite is smaller than the remainder in anterioposterior length, and lacks uropods. The telson has been transformed to a round plate without furcae.

The antennule consists of a three-segmented peduncle and 2 flagella (Fig. 15E). The proximal and distal segments of the peduncle each bear a seta. The outer flagellum has three tiers of aesthetascs: 4–6 on the distal, 3 on the middle, and 3–4 on the proximal tier. A setule is also found near the tip. The two-segmented inner flagellum (=endopodite) carries 3 terminal setae and a subterminal seta on the distal segment, while the proximal segment has none. The antenna is seven-segmented, providing 3 terminal long setae on the distal, a seta on the penultimate, 3 terminal and a subterminal setules (occasionally 2) on the third, and a plumose seta on the fifth segment (Fig. 15J). The third antennal segment is longer than the remainder, being slightly constricted at the subterminal portion; thus, the setation of the antenna is 0,0,1,0,4,1,3. The mandible now possesses a three-segmented palp, of which the distal segment carries 2 densely-plumose setae and 11–12 simple setae (Fig. 16E). The molar process has disappeared at this stage. The endopodite of the maxillule has been reduced to an unsegmented triangular process with a setule on the distal end (Fig. 17E). The basal endite carries 12–14 bristle spines and 6–10 setae, while the coxal endite has 6–8 bristle spines and 8–10 setae. The endopodite of the maxilla has now been transformed into an acute process without seta (Fig. 18E). The basal endite has 25–28 setae

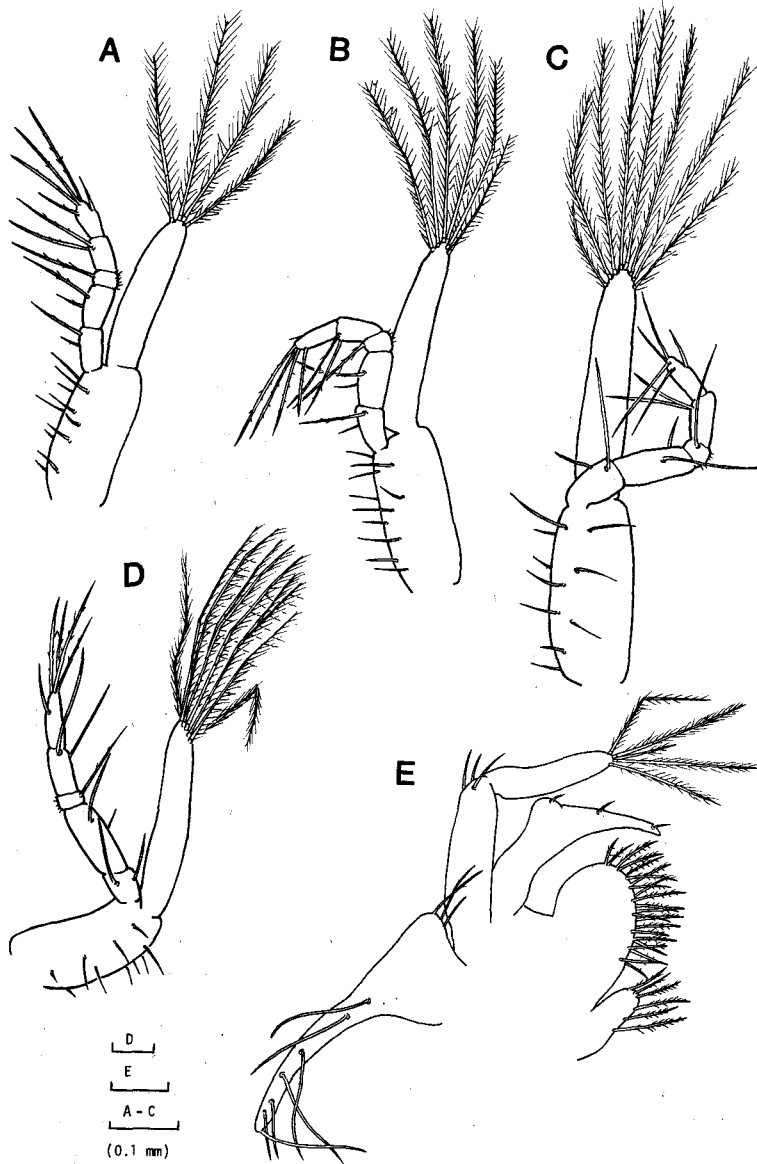


Fig. 19. First maxillipeds of first through fourth (A-D) zoea and megalopa (E) of *Pinnixa* aff. *rathbuni* Sakai.

and the coxal endite has 18–20 setae. The margin of the scaphognathite is fringed with 47–54 soft plumose setae. The first maxilliped is composed of a bilobed basipodite, an unsegmented endopodite, a two-segmented exopodite, and a triangular epipodite (Fig. 19E). The basal lobe of the basipodite carries 18–22 marginal setae, while the coxal lobe has 5–6 setae. The endopodite bears a terminal and 2 subterminal setules. The distal segment of the exopodite carries 4–5 long terminal setae which are plumose, while the proximal segment has 3 terminal setae. The epipodite bears 8–11 long marginal setae. The second maxilliped consists of a four-segmented endopodite and a two-segmented exopodite (Fig. 20E). The endopodite carries 5–6 setae on the distal, 6–8 setae on the penultimate, and 3 setae on the proximal segment. The exopodite bears 4 terminal plumose setae on the distal segment, while the proximal segment has none. The third maxilliped is composed of a five-segmented endopodite, two-segmented endo- and epipodites. The ischium and merus of the endopodite are partly fused. The dactylus is inserted into the basal part of the propodus as in the adult form, and the tip of the dactylus exceeds that of the propodus; they are also armed with long setae which are sparsely-plumose. The epipodite is provided with 23–37 long marginal setae. The chelipeds are equal in size. The second and third pairs of the ambulatory legs are longer than the others. The dactylus of the last pair lacks megalopal feelers.

It should be noted that during this stage the diet preference of larvae has changed; the megalopae did not eat the *Artemia* nauplii, while they took up a mass of concentrated planktons. It seems therefore that the megalopae select and ingest phytoplanktons as diet.

First juvenile crab: The outline of the carapace is oval and transversely elongated, measuring 1.92–2.30 mm in width and 1.48–1.53 mm in length (Fig. 22A). The two pairs of processes on the anteriolateral border now possess a row of teeth on each side. The rostral projection on the frontal region is now completely absent. The abdomen is firmly folded into the sternal groove by a locking apparatus which consists of a pair of knobs on the thoracic segment and a pair of sockets on the abdominal segment. The third maxilliped is five-segmented and has a distinct suture between the ischium and the merus at the portion one fourth of the way from the base of the endopodite. Each cheliped bears a tooth on both movable and immovable fingers (Fig. 22B). The third pair of ambulatory legs is the largest; but occasionally the length is equal to that of the second pair. The margin of both sides of the ambulatory legs carries many denticules and long setae.

Post-larval instars: The width of the carapace increases faster than the length of the carapace during the post-larval growth, so that the carapace is now transformed to a transversely-elongated form. The growth of the dimensions of the carapace after the megalopa stage is summarized diagrammatically in Fig. 22C. The differentiation of the pleopods into the genital appendages of the adult form occurs

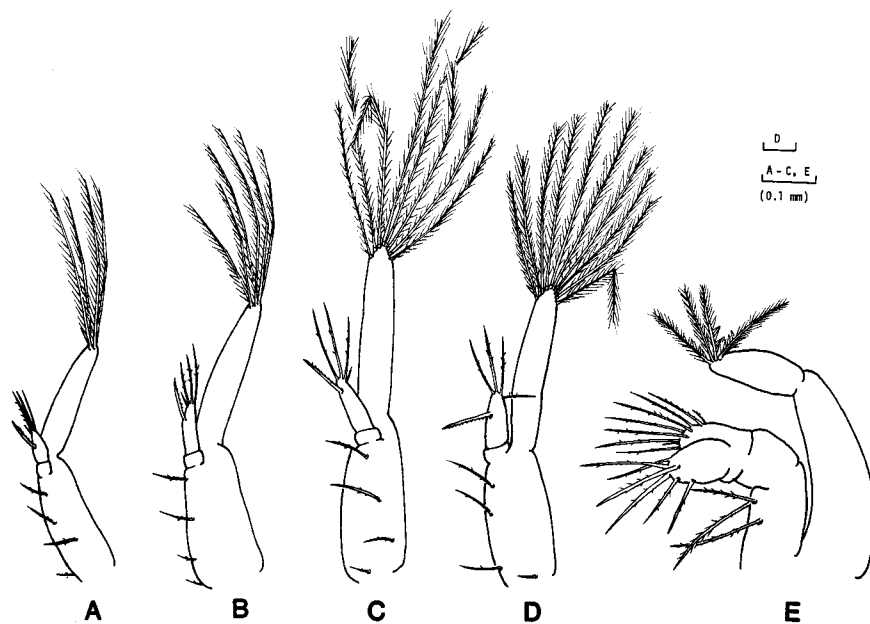


Fig. 20. Second maxillipeds of first through fourth (A-D) zoea and megalopa (E) of *Pinnixa* aff. *rathbuni* Sakai.

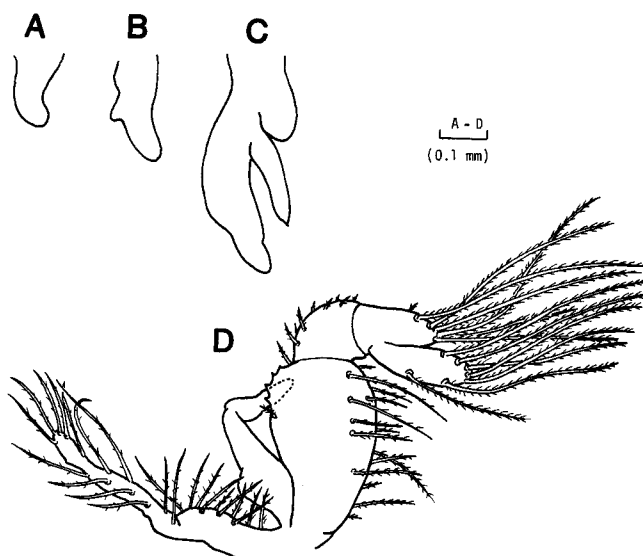


Fig. 21. Third maxillipeds of second through fourth (A-C) zoea and megalopa (D) of *Pinnixa* aff. *rathbuni* Sakai.

during the second crab stage (Figs. 22D and 22E). These post-larval instars are less active than those of the larval period.

Remarks: The zoeae of the present species are found more abundantly than those of other crabs in the plankton of Oshoro Bay, especially in June; they are easily distinguished by the unique shape of their abdomen. The megalopa was captured on only one occasion of plankton collections; this may be due to the shift of their life style from planktonic to benthic. No adult crabs have yet been collected in the same area where the larvae were found. The morphological character of the juvenile crabs obtained by the laboratory-rearing experiment seems to be insufficiently identified for allocation of these crabs to definite species.

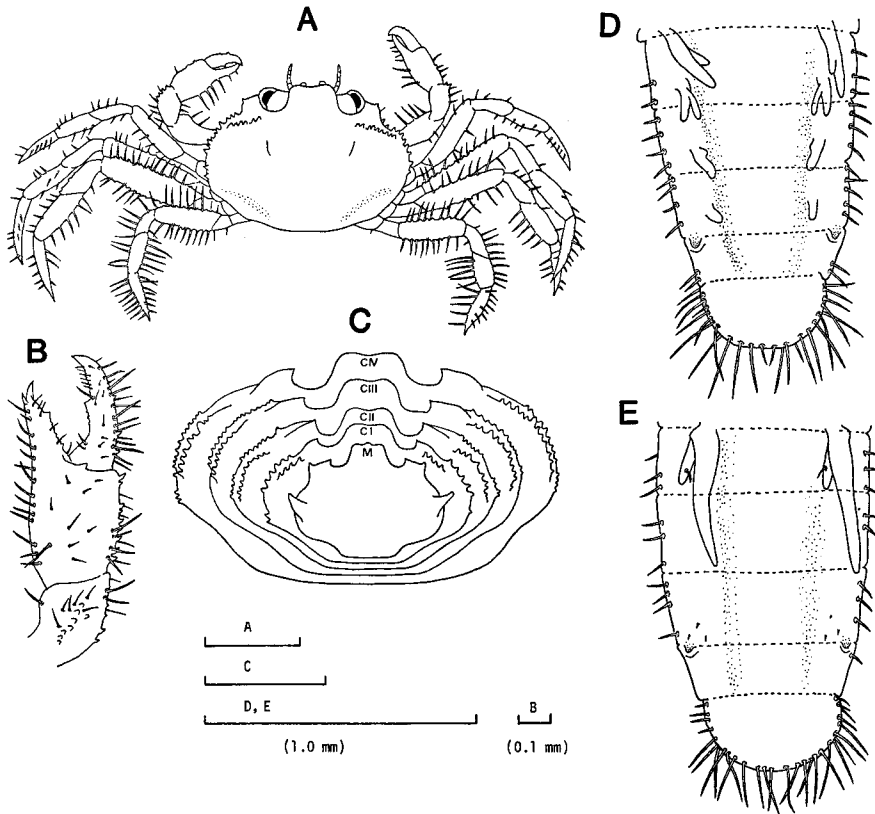


Fig. 22. Post-larval instars of *Pinnixa* aff. *rathubni* Sakai. Dorsal view (A) and cheliped (B) of first crab stage. A semidiagrammatic figure indicating outline of megalopa (M) and first through fourth (CI-CIV) crab (C). Abdomens of female (D) and male (E) of second crab in ventral view.

In spite of the limited characteristics of these materials, however, it can be seen that this crab belongs to the genus *Pinnixa*, because the adult crab of this zoea has the above-described uniquely structured abdominal somite, being expanded laterally, is restricted to the members of this pinnotherid genus at least along the coast of Hokkaido; although the zoeae of pinnotherid crabs of *Fabia* and of the hapalocarcinid crab bear similar features, they are not distributed in northern Japan. Five species of *Pinnixa* have been reported from Japan, and 2 of the species, *Pi. rathbuni* and *Pi. tumida*, have been discovered off Hokkaido (Yamaguchi and Yamada, 1955; Oshima, 1963). On the other hand, the present larvae closely

Table 2. A synopsis of main larval character of *Pinnixa* aff. *rathbuni* Sakai.
b: bud, r: reduced, +: present, -: absent.

Character	Stage				
	Zoea I	Zoea II	Zoea III	Zoea IV	Megalopa
Carapace: length (mm)	1.30-1.49	1.82-1.98	2.25-2.63	3.24-3.79	1.20-1.53
rostral spine	+	+	+	+	(r)
dorsal spine	+	+	+	+	-
lateral spine	+	+	+	+	-
Antennule: aesthetascs	2	3-4	3	6-9	10-12
endopodite	-	-	-	b	0, 4
Antenna: protopodite	+	+	+	+	-
endopodite	-	-	b	b	0, 0, 1, 0, 4, 1, 3
exopodite	-	-	-	-	-
Mandible: palp	-	-	-	+	0, 0, 12-15
incisor process	+	+	+	+	+
molar process	+	+	+	+	-
Maxillule: endopodite	0, 4	0, 4	0, 4	0, 4	r
basal endite	5	5-6	7-8	13	18-24
coxal endite	4-5	4	4	5	14-18
dorsal side	-	1	1	2	2
Maxilla: endopodite	3	3	3	3	r
basal endite	7-8	8	10	18-20	25-28
coxal endite	4	4	4-5	10-11	18-20
scaphognathite	4	7-9	10-13	29-32	47-54
Mxp. I: basipodite	2, 2, 3, 3	2, 2, 3, 3	2, 2, 3, 3	2, 2, 3, 3	5-6, 18-21
endopodite	2, 2, 1, 2, 5	2, 2, 1, 2, 5	2, 2, 1, 2, 5	2, 2, 1, 2, 5	3
exopodite	4	6	8	9-10	4-5, 3
epipodite	-	-	-	b	+
Mxp. II: basipodite	1, 1, 1, 1	1, 1, 1, 1	1, 1, 1, 1	1, 1, 1, 1	-
endopodite	0, 5	0, 5	0, 5	0, 5	3, 0, 6-8, 5-6
exopodite	4	6	8	9-10	0, 4
epipodite	-	-	-	-	-
Mxp. III and pereopods	-	b	b	b	+
Abdomen: no. of somites	5	5	5	5	6
pleopod	-	-	-	b	+
uropod	-	-	-	-	-
Telson: furca	+	+	+	+	-
inner spine	6	6	6	6	-

resemble those of *Pi. rathbuni* previously described by Sekiguchi (1978) and Muraoka (1979a), although there are some differences between these two kinds of larvae: 1) the number of zoeal instar in *Pi. rathbuni* is 5, while in the present case it is 4; 2) the setation of their appendages, especially in the megalopa, differs. Although the larval characteristics are not significantly different in the setations of the appendages, the disagreement in the number of instar between *Pi. rathbuni* and the present larvae is thought to be important in the identification of the level of species. Furthermore, the male cheliped of the juvenile crabs studied in the present experiment does not have a strongly-curved dactylus, a characteristic feature of *Pi. rathbuni* that was pointed out in his description of juveniles by Sakai (1955). Thus, in spite of very close resemblance of the present juvenile crab to that of *Pi. rathbuni*, exact identification is not possible here. At the moment, therefore, the present crabs are assigned provisionally to *Pi. aff. rathbuni*.

Table 2 gives a synopsis of the main morphological characteristics of the larvae of the present species. Beside these, a morphological difference was found between the zoeae of laboratory-reared and the planktonic materials; the same fact was previously noted in the zoeae of *Pinnaxodes mutuensis* Sakai (Konishi, 1981b). However, no remarkable differences were detected in their main significant characteristics. The present megalopa is very similar in general appearance to that of the post-larval juveniles, unlike those found in typical brachyurans. About this crab-like appearance of the megalopa, Faxon (1879) concluded that the development of *Pi. sayana* Stimpson was remarkable in the complete suppression of megalopa stage. It seems likely from the present study that Faxon's conclusion was inadequately formulated, because this type of megalopa always carries abdominal pleopods with long natatory setae, showing that they apparently belong to the megalopa stage according to the definition by Williamson (1969).

Key for Identification of Zoeae

Up to the present, 3 species of pinnotherid crabs have been recorded from Oshoro Bay: *Pinnotheres sinensis*, *P. pholadis* and *Pinnaxodes mutuensis*. The results of the present larval study strongly suggest that at least 2 additional pinnotherid species, *Sakaina japonica* and *Pinnixa aff. rathbuni*, may live in this area. On the other hand, no larval stage of *Px. mutuensis* was collected. The absence of the larvae of *Px. mutuensis* and of adult *Sakaina* and *Pinnixa* is therefore an unsolved problem at present. In this respect, more careful examination of both planktonic and benthic samples is necessary in any future study.

Finally, a preliminary key for the identification of pinnotherid zoeae found in the plankton of Oshoro Bay is given here as follows:

- A. Antenna is reduced or absent; usually lacks exopodite B
- AA. Antenna is well-developed; sometimes has exopodite . . other brachyurans
- B. Fifth abdominal somite not expanded; telson is trilobed C
- BB. Fifth abdominal somite expanded posteriolaterally; telson is bifurcated . . . D

- C. Carapace without spine *Pinnotheres sinensis*
 CC. Carapace with a rostral and a pair of lateral spines.. *Pinnotheres pholadis*
 D. Carapace with only a rostral spine *Sakaina japonica*
 DD. Carapace with all (rostral, dorsal and lateral) spines
 *Pinnixa* aff. *rathbuni*

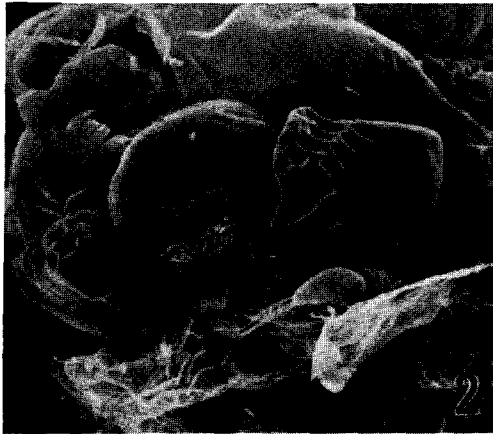
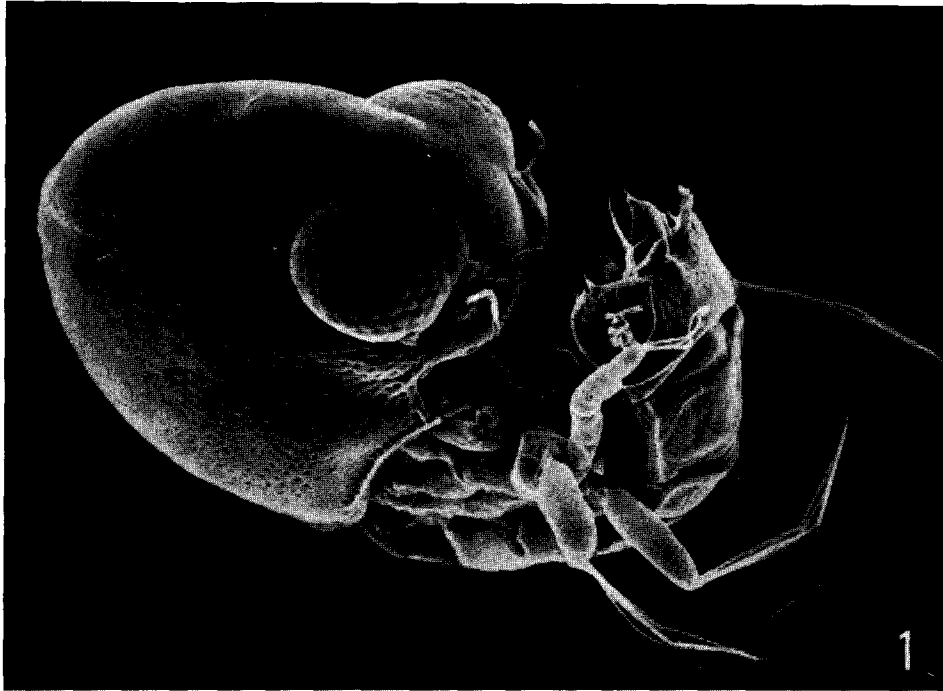
Summary

Planktonic zoeae, belonging to the family Pinnotheridae (Crustacea, Brachyura), were collected at Oshoro Bay in the years from 1977 to 1979. Based on the zoeal characteristics described above they are assigned to 4 pinnotherid species: *Pinnotheres sinensis* Shen, *P. pholadis* de Haan, *Sakaina japonica* Serène *Pinnixa* aff. *rathbuni* Sakai. A preliminary key for identification of these planktonic zoeae is given.

The author wishes to express his gratitude to Prof. Fumio Iwata, Hokkaido University, for his constant guidance and critical reading of the manuscript. Thanks are also due to Dr. Shin Kubota and Mr. Kazuro Shinta, Hokkaido University, who kindly helped the author to obtain the materials.

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Explanation of Plate IX

Figs. 1-3. Scanning electron micrographs of first zoea of *Pinnotheres sinensis* Shen. 1, Whole animal ($\times 170$); 2, mandibles, frontal view ($\times 340$); 3, antennule (a) and vestigial antenna (arrow) ($\times 750$).
