Observations on Zoeas of Two Xanthid Crabs from Tosa Bay, Japan

By

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(*With 7 Text-figures and 1 Table*)

Introduction

The Xanthidae (*sensu lato*), one of the largest brachyuran families includes over 130 genera and approximately 1000 species (Rice, 1980). Of these, larvae in at least the first zoeal stage are known for about 45 genera (Martin, 1984). In spite of detailed studies on larval characters of this complex group (for reviews see Rice, *op. cit.*; Martin, *op. cit.*; Martin *et al.*, 1985), there are many genera and even subfamilies for which the larvae are not yet described (Martin, personal communication).

In Japan, the Xanthidae constitute the largest group of Brachyura, with approximately 242 species (*cf.* Miyake, 1982), but although there are many descriptions of xanthid larvae (for review see Quintana, 1986), our knowledge is still far from complete.

In the summer of 1984, ten larval specimens (zoeas) with an unusual combination of features belonging to two closely related species were caught from the plankton of Tosa Bay, Shikoku Island, southern Japan. The purpose of this study is to describe these atypical larvae, which are herein regarded as probably belonging to two xanthid species (*sensu lato*), for which larvae have never been

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described. Morphological resemblances to zoeas described by Aikawa (1942) are discussed.

Materials and Methods

The present material was collected from Tosa Bay (Shikoku Island, southern Japan) by horizontal towing at 5 m depth on two occasions during the summer of 1984 and fixed with formalin immediately after collection. Collection data are shown in Table 1. The zoeal specimens sorted from plankton were dissected and stained with methylene blue; all their appendages were drawn with the aid of a camera lucida. The descriptions are based on observations of 3 stage I zoeas, 2 stage II zoeas, and 3 stage III zoeas, tentatively attributed to one xanthid species, and of 2 stage II zoeas of a closely related species.

Table 1. Oceanographic data at the time of collection of the present material at Tosa Bay, Shikoku Island in 1984.

Date	depth (m)	water temp. (°C)	salinity (ppt)	D.O. (ml/l)	zoeas collected
June 27	0	23.78	32.21	5.13	3
	4	23.60	33.22	5.01	
	10	23.29	33.84	4.95	
Aug. 6	0	29.20	32.12	4.56	7
	4	28.90	32.86	4.39	
	10	27.95	33.04	4.33	

Descriptions of the larval stages

Xanthid species "A"

(Figs 1-5)

FIRST ZOEA

Measurements: Rostral spine 1.39 mm; dorsal spine 1.73 mm; lateral spines 0.26 mm; tip of rostral to tip of dorsal spine 3.55 mm.

Carapace (Fig. 1A, B): All carapace spines present. Rostral and dorsal spines slender, extremely long, the latter slightly the longer; each lateral spine about 1/6 length of dorsal spine. A dorso-median elevation near base of dorsal spine; postero-ventral borders of cephalothorax with 3 fine setae.

Eyes. Not stalked, partly fused to carapace.

Antennule (Fig. 1C, c): Small (peduncle slightly longer than 100 μm), unsegmented, with 3 terminal aesthetascs (the shortest slender), and 2 fine setae.

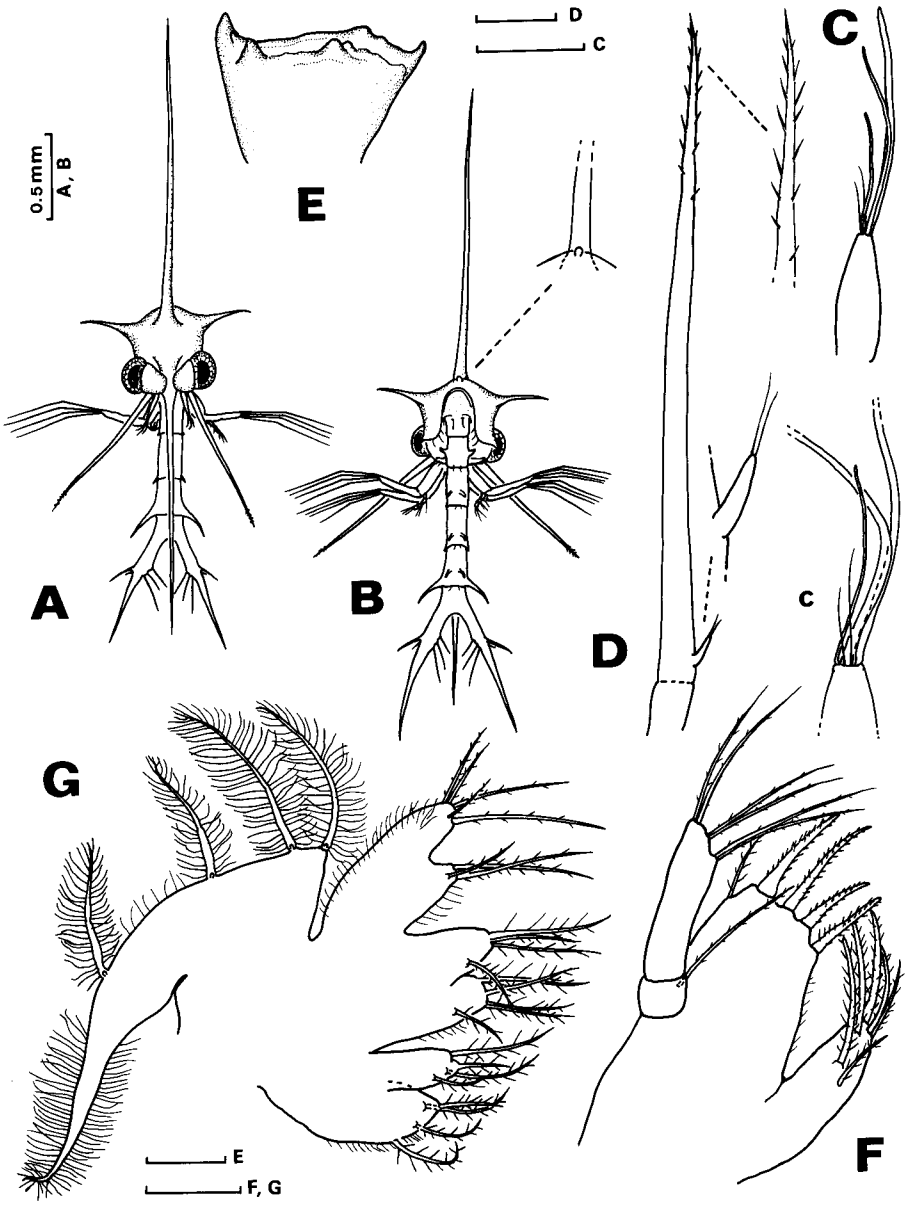

Fig. 1. Xanthid zoea, "*species A*", fiirst zoeal stage. A, larva, anterior view; B, the same, posterior view, with a detail of the dorso-median elevation; C, antennule; c, detail of apical portion (from another specimen); D, antenna, with details of exopod and tip of spinous process; E, mandible; F, maxillule; G, maxilla. Scale bars=0.1 mm for D, C; 50 μm for E-G; others, as indicated.

Antenna (Fig. 1D): Protopod spine very long, about 2/3 length of rostral spine, spinulate on its distal one-fourth (13-15 minute spinules). Exopod greatly reduced (length = 50 μm), about 0.07 times length of spinous process (= protopod), and armed terminally with 2 subequal setae. Endopod absent.

Mandible (Fig. 1E): Incisor and molar processes not differentiated, with irregular dentition on inner surface; palp absent.

Maxillule (Fig. 1F): Endopod 2-segmented, proximal segment short, with a single seta, and distal segment with 6 setae arranged into three distinct pairs. Basial endite broad, with 4 strong, rigid setae, all finely spinulose and 1 smaller seta. Short, fine setules on inner margin. Coxal endite with 6 plumodenticulate setae.

Maxilla (Fig. 1G): Endopod bilobed, proximal lobe with 3 setae, distal with 5 setae. Basial and coxal endites markedly bilobed; proximal and distal basial

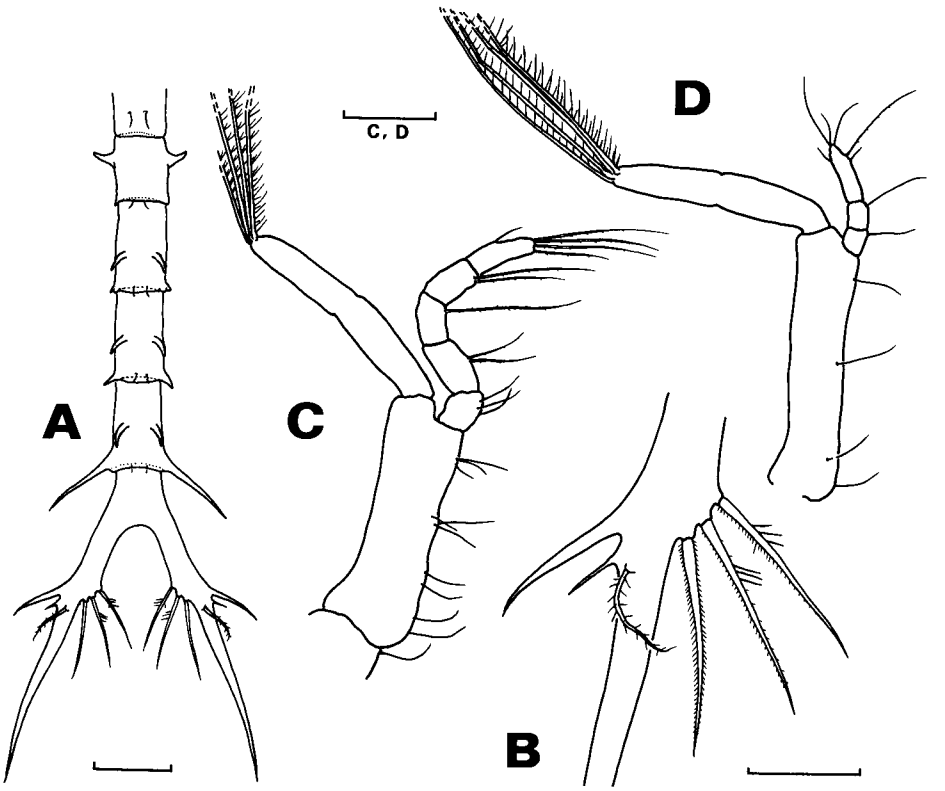

Fig. 2. Xanthid zoea, "*species A*", first zoeal stage. A, abdomen and telson, dorsal view; B, detail of setation of the telsonal furca, dorsal view; C, first maxilliped; D, second maxilliped (natatory setae of both maxillipeds partially drawn). Scale bars = 0.1 mm for B-D; 0.2 mm for A.

lobes with 5 and 4 setae respectively; proximal and distal coxal lobes with 4 and 4 setae respectively. Scaphognathite with 4 highly plumose setae along outer border and a terminal plumose projection (all more densely plumose than the indicated in figure). Fine setules on scaphognathite (between setae 3-4) and inner endites, profuse on endopod.

First maxilliped (Fig. 2C): Basipod with 10 setae along inner margin, arranged as 2, 2, 3, 3. Endopod slightly longer than exopod, markedly curved inward, 5-segmented, with 4, 2, 1, 2, 4+1 setae. Exopod incipiently 2-segmented, distally with 4 long, terminal plumose setae.

Second maxilliped (Fig. 2D): Basipod with 4 inner marginal setae. Endopod reduced, about 1/2 length of exopod, 3-segmented, with 1, 1, 5 setae. Exopod incipiently 2-segmented, with 4 long, terminal plumose setae.

Abdomen (Fig. 2A): Composed of five somites plus the telson; all somites with 2 minute dorso-median setae (those of first somite not terminal), second somite with 2 forwardly directed lateral knobs; somites 3-5 each with a pair of short, divergent dorso-lateral spines, backwardly curved. Postero-lateral margins produced as incipient spines on somite 3, moderate spines on somite 4, but very prominent spines (about 1/4 length of telson) directed posterolaterally on somite 5.

Telson (Fig. 2A, B): Bifurcated, divergent posteriorly; posterior margin markedly concave, telson plate about 1/5 length of furcae. Furcae long, slender, acutely tipped, each with 2 smooth lateral spines, the anterior spine arising from about 1/3 length of telson, the posterior about 1/3 length of anterior spine, also a sparsely plumose dorsal seta, directed backward; the remaining distal portions of furcae completely smooth; inner borders of furcae each with 3 finely denticulated setae, the innermost seta opposite the anterior outer spine.

SECOND ZOEA

Measurements: Rostral spine 1.29 mm; dorsal spine 2.37 mm; lateral spines 0.37 mm; tip of rostral to tip of dorsal spine 4.57 mm.

Carapace (Fig. 3A, B): Dorsal spine relatively longer, now 1.8 times length of rostral spine, curved backwardly. Frontal and posterior small prominences present, also a fine setule near base of lateral spine; posterolateral borders of carapace with 3 setae.

Eyes: Now stalked.

Antennule (Fig. 3C): With 5 terminal aesthetascs, no setae.

Antenna (Fig. 3D): Protopod spine long, slightly longer than rostral spine, spinulose on its distal 1/7. Exopod with 2 unequal terminal setae.

Mandible: Not dissected.

Maxillule (Fig. 3E): Endopod 2-segmented, with 1 and 6 setae respectively. Basial endite with 8 setae. Coxal endite with 7 setae. A plumose seta on outer margin of basial endite.

Maxilla (Fig. 3F): Endopod bilobed, with 3 and 5 setae respectively.

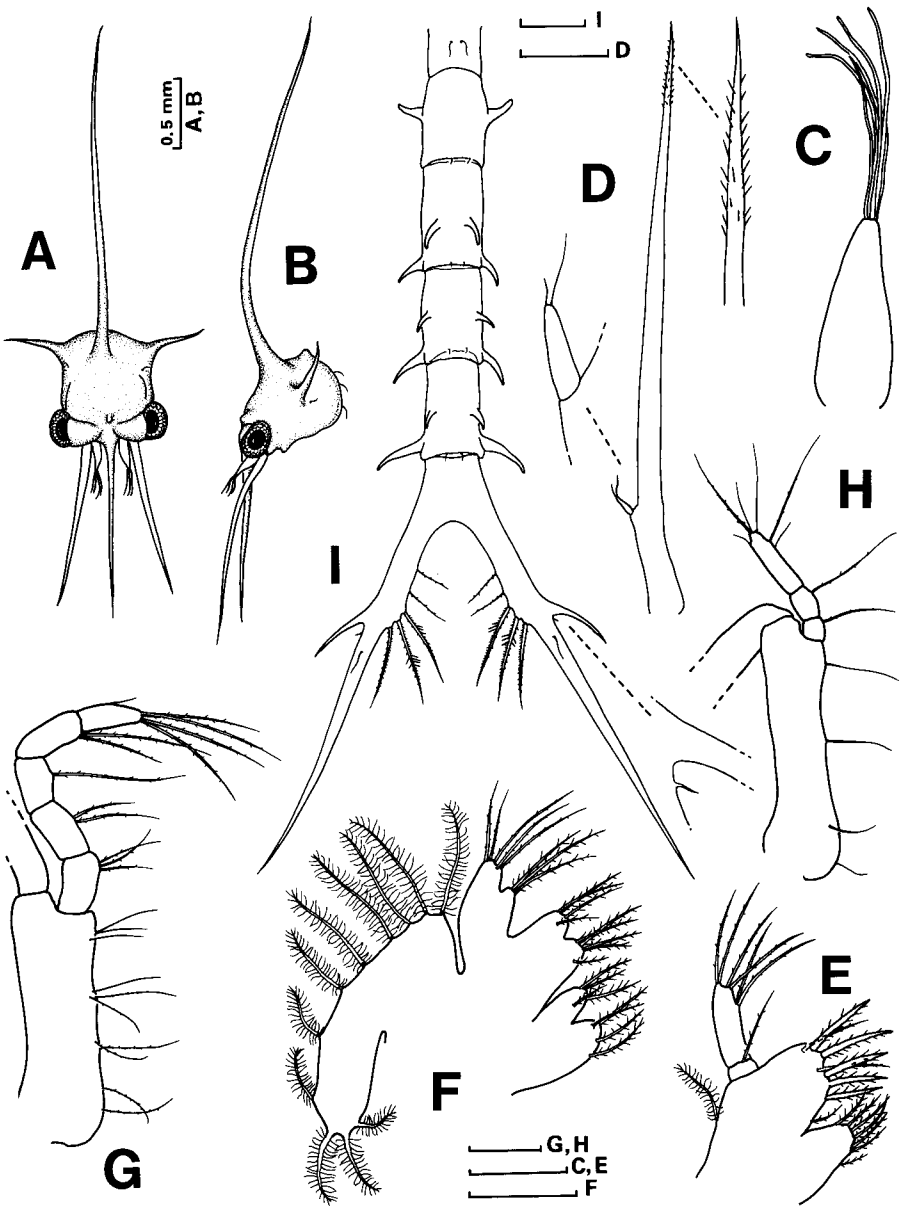

Fig. 3. Xanthid zoea, "*species A*", second zoeal stage. A, carapace, anterior view; B, carapace, lateral view; C, antennule; D, antenna, with details of exopod and tip of spinous process; E, maxillule; F, maxilla; G, first maxilliped; H, second maxilliped (exopod of both maxillipeds partially drawn); I, abdomen and telson, dorsal view, with a detail of lateral spines of furcae. Scale bars = 0.1 mm for C, E-H; 0.2 mm for D, I; others, as indicated.

Basial endite with 5 and 4 setae on proximal and distal lobes respectively. Coxal endite with 4 and 4 setae on each lobe respectively. Scaphognathite fringed with 11 setae, each finely plumose; posterior stout process present in previous stage now a distally rounded lobe.

First maxilliped (Fig. 3G): Basipod with 10 setae on inner border, arranged as 2, 2, 3, 3. Endopod 5-segmented, with 3, 2, 1, 2, 4+1 setae. Exopod with 6 long, terminal setae.

Second maxilliped (Fig. 3H): Inner margin of basipod with 4 separate setae; endopod 3-segmented, with 1, 1, 6 setae; exopod with 6 (rarely 7) long, terminal setae.

Abdomen (Fig. 3I): Composed of five segments plus the telson; similar to previous stage, but posterolateral spines of segments 3 and 4 now similar in size; those of last segment shorter than in previous stage, only about 1/9 length of telson.

Telson (Fig. 3I): Furcae longer than in previous stage, so that telson plate is about 1/6 length of furcae; second lateral spine now greatly reduced; dorsal seta present, although shorter; setation of inner margin of each furca increased to 5 setae, all finely denticulate; distal portion of furcae smooth.

THIRD ZOEA

Measurements: Rostral spine 1.75 mm; dorsal spine 3.13 mm; lateral spines 0.72 mm; tip of rostral to tip of dorsal spine 5.8 mm.

Carapace (Fig. 4A, B): Dorsal spine extremely long, 1.9 times length of rostral spine, slightly curved backward, invested with sparse, minute setules, except on the proximal and distal portions; lateral spines directed obliquely backward. Two fine setules dorsally, behind base of dorsal spine, and 2 more behind the eye stalks; lateral borders of carapace fringed with 7-8 setae.

Antennule (Fig. 4D): With 4 aesthetascs + 1 seta terminally, and 2 aesthetascs subterminally. Endopod vestigial.

Antenna (Fig. 4E): Protopod spine as long as rostral spine, spinulose apically (except on tip). A well-developed endopod arising close to exopod, 3-3.5 times exopod length; exopod with 2 fine setae, unequal in length.

Mandible (Fig. 4F): Slightly larger, but not markedly different from that of first zoea; incisor and molar processes not clearly differentiated.

Maxillule (Fig. 5A): Endopod with 1 and 6 setae on proximal and distal segments respectively. Basial endite with 10 setae. Coxal endite with 9 setae. Single plumose seta on outer margin, as in second zoea.

Maxilla (Fig. 5B): Endopod bilobed, with 8 setae in total. Basial endite bilobed, with 5 setae on each lobe. Coxal endite bilobed, with 5 and 4 setae on each lobe. Scaphognathite fringed with 18-19 plumose setae.

First maxilliped (Fig. 5C): Setation on inner margin of basipod and endopod, as in the previous stage, except in the distal segment of the endopod, now with 6 setae. Exopod now with 8 terminal setae.

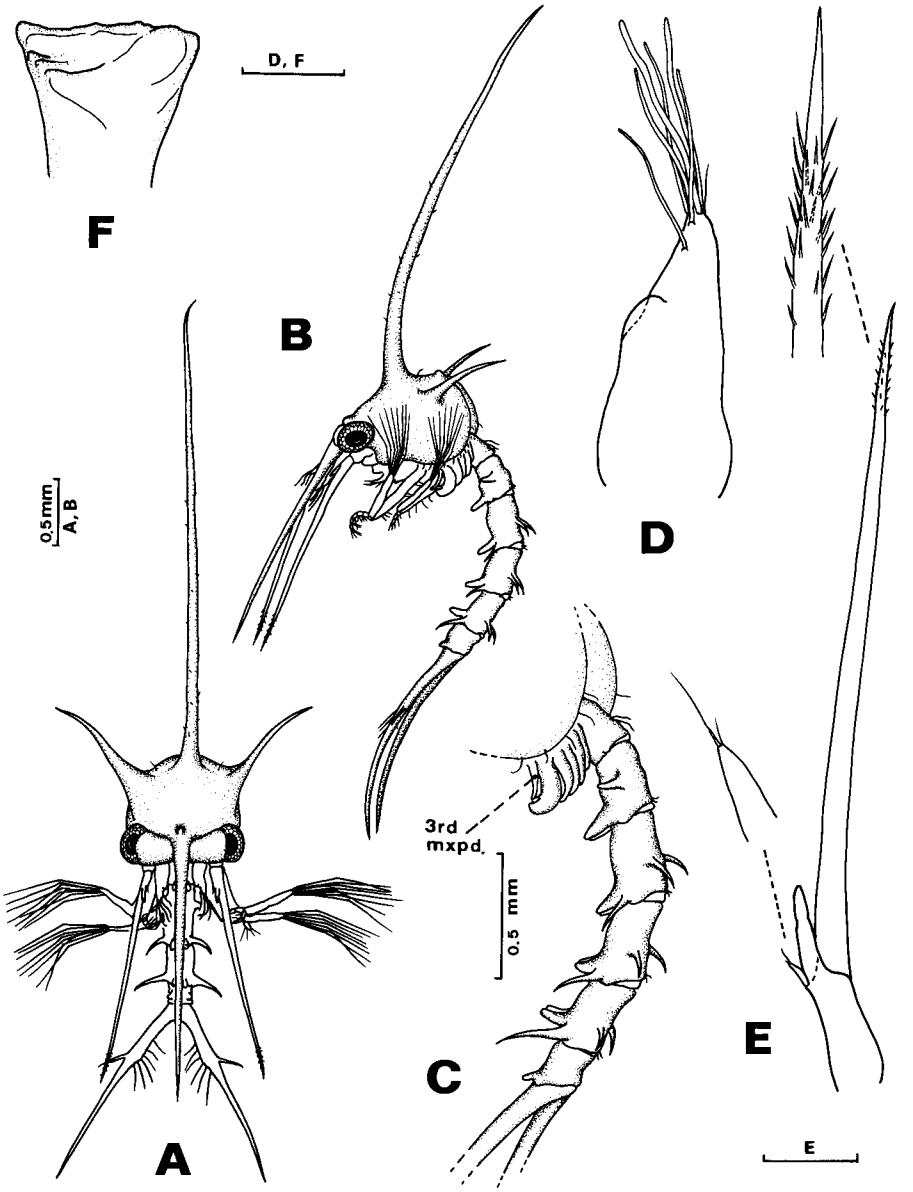

Fig. 4. Xanthid zoea, "*species A*", third zoeal stage. A, larva, anterior view; B, the same, lateral view; C, detail of rudiments of third maxilliped (3rd mxpd), pereiopods and abdomen, lateral view (telson partially drawn); D, antennule; E, antenna, with details of exopod and tip of spinous process; F, mandible. Scale bars = 0.1 mm for D, F; 0.2 mm for E; others, as indicated.

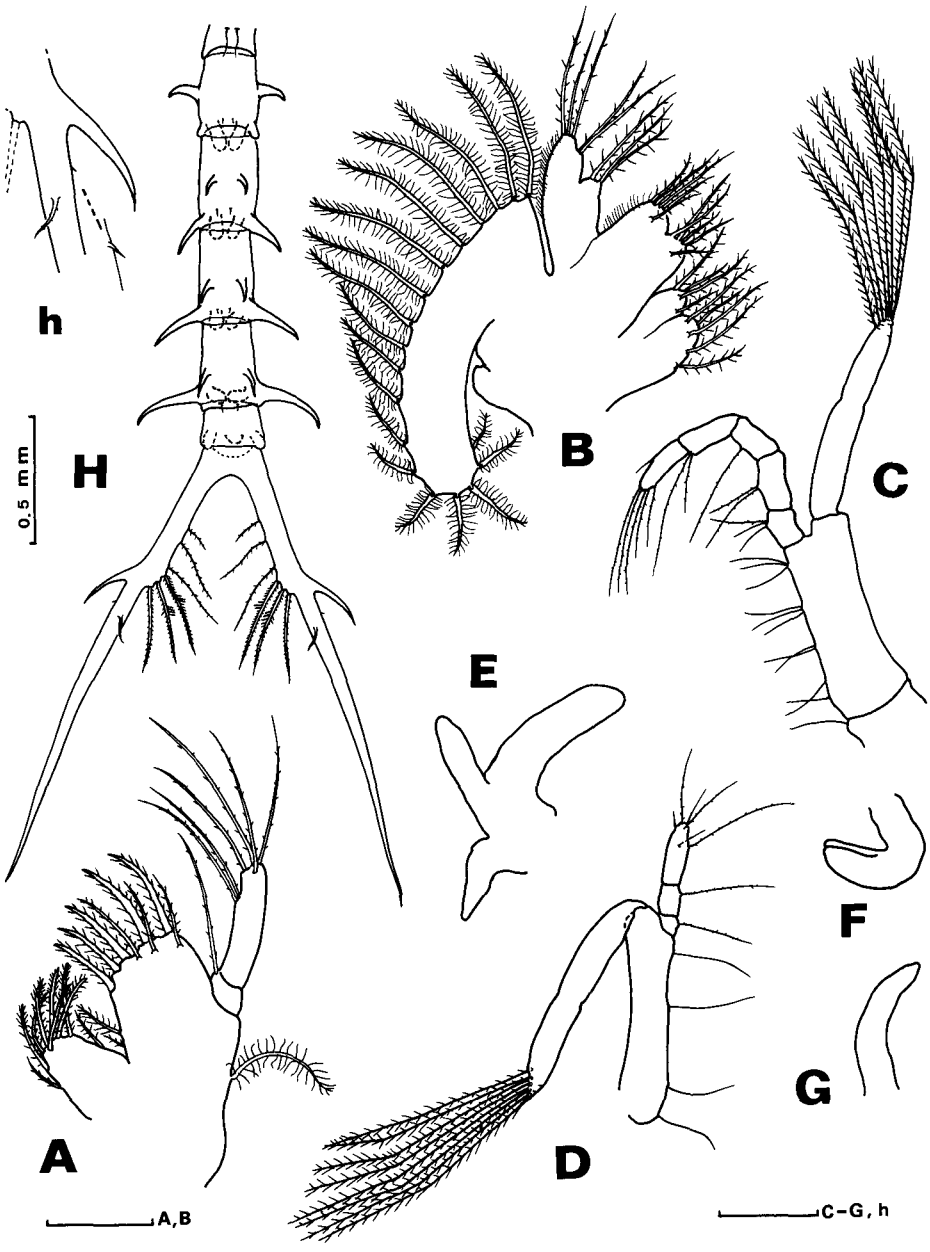

Fig. 5. Xanthid zoea, "*species A*", third zoeal stage. A, maxillule; B, maxilla; C-E, first to third maxillipeds; F, cheliped; G, fifth pereiopod; H, abdomen and telson, dorsal view; h, mid portion of telsonal furca, with a detail of the minute (lower) lateral spine. Scale bars = 0.1 mm for A, B; 0.2 mm for C-G, h; 0.5 mm for H.

Second maxilliped (Fig. 5D): Setation of inner margin of basipod and endopod as in previous stage. Exopod with 8 terminal setae.

Third maxilliped (Figs 4C, 5E): Rudimentary, biramous, unarmed, with proximal projection probably corresponding to epipod of subsequent stages.

Pereiopods (Figs 4C, 5F, G): Unsegmented rudiments, first pair with developing chelae, visible laterally beneath zoeal carapace.

Abdomen (Figs 4C, 5H): Now with 6 somites plus the telson; sixth somite broader than long, without spines. Posterolateral spines of somites 3–5 greatly developed, those of fifth somite almost as long as somite. Pleopods as buds, present ventrally on somites 2–6, last pair small.

Telson (Fig. 5H, h): Furcae slender, longer than in previous stages, about 15 times length of telson plate. Anterior lateral spine little changed (length 0.23 mm); posterior lateral spine further reduced and only observable under high magnification (length 10 μm); medio-dorsal seta present on each furca. Setation of inner margin increased to 6+6 setae. Distal portion of furcae completely smooth, as in previous stages.

Xanthid species "B"

(Figs 6 and 7)

SECOND ZOEA

Measurements: Rostral spine 1.62 mm; dorsal spine 1.86 mm; lateral spines 0.33 mm; tip of rostral to tip of dorsal spine 3.96 mm.

Carapace (Fig. 6A, B): All carapace spines present; rostral and dorsal spines extremely long, the latter slightly the longer; lateral spines short. A minute frontal, dorso-median tubercle near base of rostrum. Posterolateral borders of cephalothorax with 3 setae.

Eyes. Stalked.

Antennule (Fig. 6C): Unsegmented, with 5 distal aesthetascs and 1 fine seta.

Antenna (Fig. 6D): Protopod spine slender, slightly curved, as long as rostral spine, smooth, unarmed distally. Exopod very rudimentary (length, 25 μm, excluding setae), armed distally with 2 setae. Endopod bud-like, broad, longer than exopod.

Mandible (Fig. 6E): Incisor and molar processes not well differentiated.

Maxillule (Fig. 6F): Endopod 2-segmented, with 1 and 6 setae respectively. Basial endite broad, unilobed, with 8 setae in total. Coxal endite also unilobed, with 7 setae. Single plumose seta on outer margin of basial endite.

Maxilla (Fig. 6G): Endopod bilobed, proximal lobe with 3 setae, distal with 2+3 setae. Basial and coxal endites markedly bilobed; proximal and distal basial lobes with 5 and 4 setae respectively; proximal and distal lobes of coxal endite each with 4 setae. Scaphognathite with 10–11 setae, highly plumose (more than illustrated). Very fine setulation on endopod.

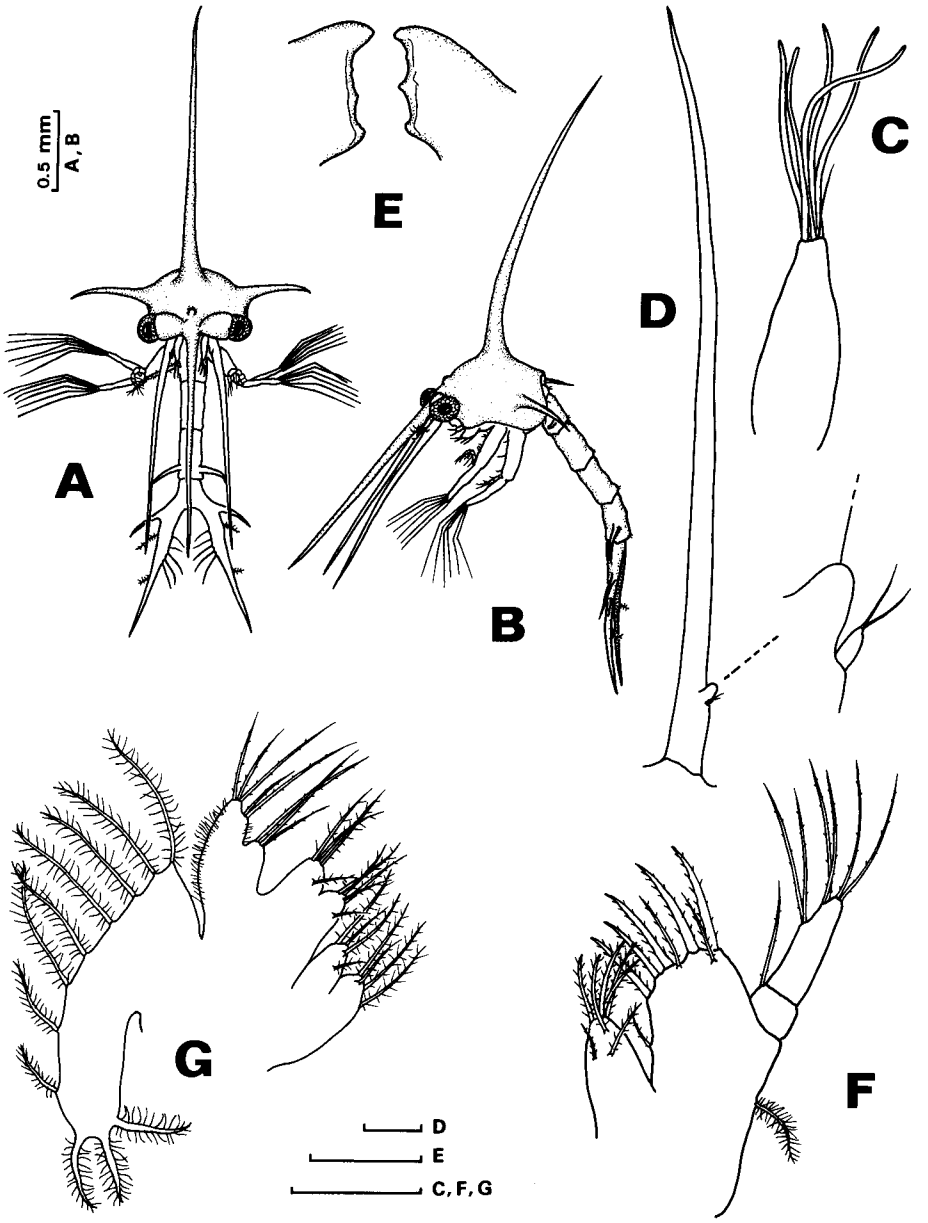

Fig. 6. Xanthid zoea, "*species B*", second zoeal stage. A, larva, anterior view; B, the same, lateral view; C, antennule; D, antenna, with a detail of endo- and exopod; E, both mandibles; F, maxillule; G, maxilla. Scale bars = 0.1 mm, except for A and B.

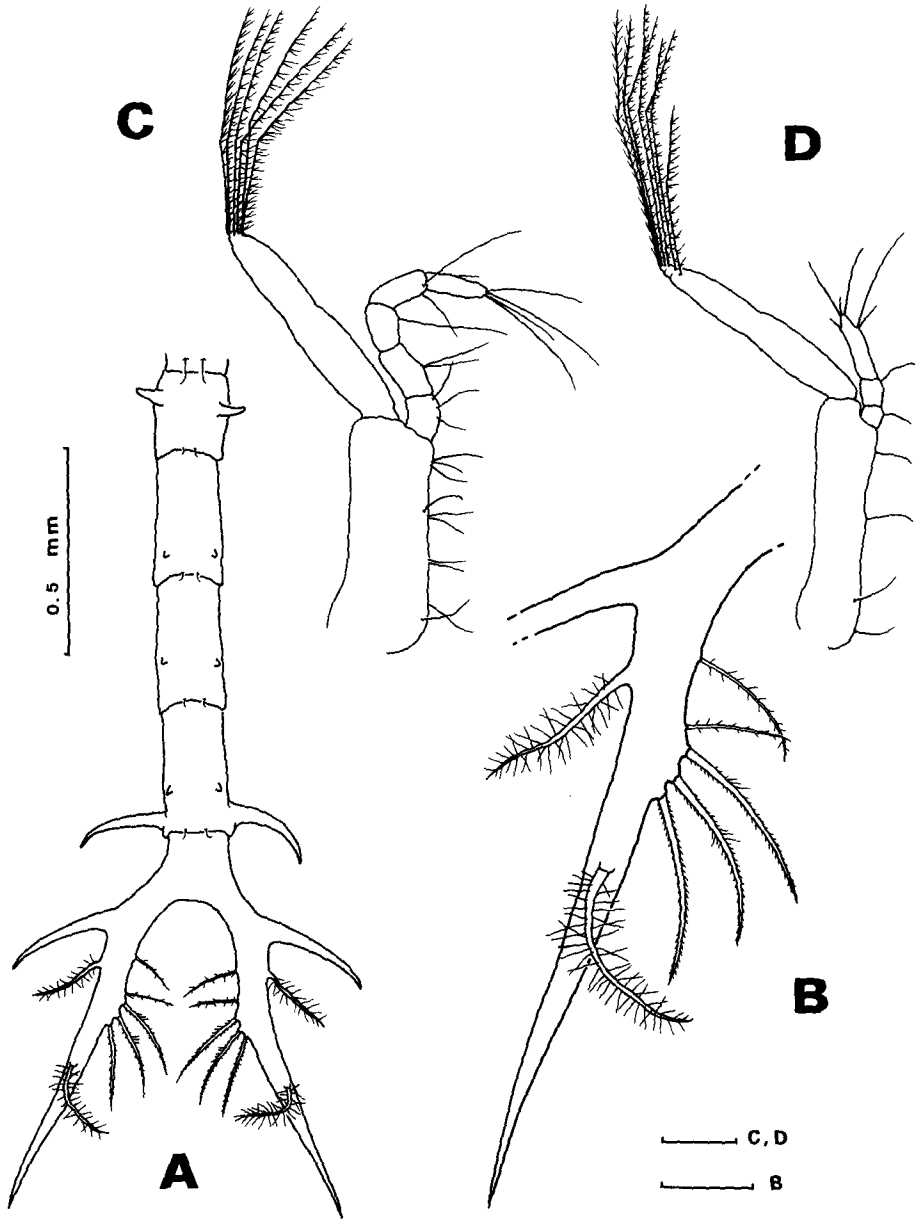

Fig. 7. Xanthid zoea, "*species B*", second zoeal stage. A, abdomen and telson, dorsal view; B, detail of the setation of the telsonal furca (lateral spine partially drawn); C, first maxilliped; D, second maxilliped. Scale bars = 0.1 mm, except for A.

First maxilliped (Fig. 7C): Basipod with 10 setae along inner margin, arranged as 2, 2, 3, 3. Endopod strongly curved inward, 5-segmented, with 3, 2, 1, 2, 4+1 setae. Exopod with 7 long, terminal setae.

Second maxilliped (Fig. 7D): Basipod with 4 separate setae along inner margin. Endopod short, about 1/2 exopod length, 3-segmented, with 1, 1, 6 setae; exopod with 6 long, terminal setae.

Abdomen (Fig. 7A): Composed of five segments plus the telson; all somites with 2 minute setae postero-dorsally (those of first somite longer, subterminal); prominent lateral knobs on second somite; somites 3–5 each with 2 rudimentary projections dorsally; posterolateral edges of somites 1–4 truncate, unarmed, but those of fifth somite with strong spines, curved downwardly, about 3/4 length of last somite.

Telson (Fig. 7A, B): Bifurcated, divergent posteriorly, posterior margin broadly concave, telson plate about 1/5 length of furcae; furcae long, slender, acutely pointed, each armed laterally with very strong, smooth spine and more posterior plumose seta, both arising from anterior third; similar plumose seta arising dorsally from posterior third; inner borders of furcae each with 5 setae.

Discussion

The zoeas described here are rather rare components of the meroplankton of Tosa Bay, less common than other brachyuran species (Yatsuzuka and Quintana, 1985: 96). The specimens examined (zoeas I-III, and zoea II) probably belong to two xanthid species with previously undescribed larvae. A number of larval descriptions have been published for xanthid crabs from Japanese waters (Aikawa, 1933, 1937; Saba *et al.*, 1978; Fukuda, 1978; Terada, 1980, 1984, 1985), but the present zoeas greatly differ from all of them.

These larvae exhibit the following remarkable morphological features:

Species "A": Very long rostral and dorsal spines (the latter longer); antenna slender, slightly shorter than rostral spine, protopod spinulate apically, exopod minute, armed with 2 terminal setae; maxillule with 6 setae on distal segment of endopod; maxilla with 8 setae on bilobed endopod; first maxilliped with 3 setae on proximal segment of endopod; lateral knobs only on second abdominal somite; abdominal somites 3–5 with 2 posterodorsal stout spines and lateral, outwardly directed spines; the posterolateral spines of the third segment in the zoea I are very small, incipiently produced outward, but are much more prominent in zoea II and zoea III; each furca of telson armed laterally with 2 smooth spines and dorsally with a sparsely setulose seta.

Species "B": Rostral and dorsal spines slender, long (the latter slightly longer); antennal protopod slender, unarmed, exopod minute, armed with 2 setae distally; endopod of maxillule with 6 setae on apical segment; endopod of maxilla with 8 setae; proximal segment of endopod of first maxilliped armed with 3 setae; lateral

knobs only on second abdominal somite; posterodorsal processes on somites 3–5 very rudimentary; prominent lateral spines present only on fifth abdominal somite; each furca of telson armed laterally with smooth prominent spine, a setulose process, and dorsally with a profusely setulose seta.

The combination of zoeal characters listed here corresponds largely to the characters mentioned by Rice (1980), Martin (1984) and Martin *et al.*, (1985) for xanthid larvae. (Additional characters can be observed from the present figures).

At present, there are five groups that accommodate all the known xanthid zoeas. If our assumption that the present zoeas belong to some xanthid species is correct, the zoeas "*species A*" and "*species B*" could be tentatively included with the Group I zoeas (Rice, 1980: 326; Martin, 1984: 221). This is composed of 23 genera (Martin *et al.*, 1985: 100), and the most obvious character is the greatly reduced antennal exopod, less than 1/4 length of protopod (=spinous process), and never armed with more than 2 terminal tetae; this may be sometimes rudimentary, as in our "*species B*" (see Fig. 6D). The zoeas of our species share almost all the characters mentioned by Martin (1984) for this group, except that dorsolateral knobs are present only on the second abdominal segment (see Figs 2A, 7A).

The morphology of the abdomen and telson seems to be unique. The well-developed dorsal and lateral spines on segmemts 3–5 in "*species A*" in zoea II and III, and very rudimentary dorsal processes on segments 3–5 and prominent lateral spines on the fifth segment in zoea II of "*species B*", as well the armature of the telson in both species, do not correspond to any of the described xanthid zoeal groups.

The present findings indicate that a new larval grouping within the Xanthidae may be needed to accommodate these unusual zoeas. It is also possible that these larvae may belong to a family or subfamily of the Brachyura for which the larvae previously have not been described. According to the key based on zoeal characters presented by Rice (1980: 359), the present species share some larval characters with some members of the family Atelecyclidae, subfamily Acanthocyclinae, based on larval descriptions of *Heterozius rotundrifons* A. Milne Edwards (see Wear, 1968) and of *Corystoides chilensis* Milne Edwards and Lucas (see Boschi and Scelzo, 1970). Similarly, the following larval chracters are shared both by most species of Xanthidae and Acanthocyclinae: a) antennal spinous process long, often longer than carapace; exopod less than 1/4 the length of the spinous process or rudimentary, b) maxillary endopod with at least 6 setae, c) proximal segment of endopod of first maxilliped with 3 setae.

A detailed consideration of characters shows, however, that our "*species A*" and "*species B*" are more closely related to some species of Xanthidae (*sensu lato*) than to the Atelecyclidae. The presence of dorsolateral knobs on the second abdominal segment only, as in *Rhithropanopeus harrisii* (Gould) (see Connolly, 1925), seems to be rather an atypical xanthid character.

Many of the characters of the present zoeas are also shared with those

exhibited in two "*Xanthozoea*" larvae from the Palao Islands, described by Aikawa (1942: 596-599). These are differences of at least specific rank, in the lengths of the carapace spines and in the positioning of the telson processes; the dorsal process on each telson fork is in the form of a prominent plumose seta in Aikawa's "*Xanthozoea 2*" but is reduced in his "*Xanthozoea 3*". Aikawa's "*Xanthozoeas 2* and *3*" and the larvae described here are, however, sufficiently similar to be tentatively assigned to the same genus. Aikawa regarded his larvae as probably belonging to the subfamily Panopaeinae (=Xanthinae), but no genus was suggested. We, too, are unable to suggest a possible genus for the larvae, but the apparent occurrence of two species in the subtropical waters of the Palao Islands and a further two in the temperate waters of Tosa Bay may be useful clues. These or similar zoeas were not mentioned (presumably never collected) by Yatsuzuka and Iwasaki (1980) in their planktonic study of Tosa Bay, and this suggests that the species are rather rare in this area.

Our discussions on the present material are brief compared with those given in Martin (1984) and Martin *et al.*, (1985) on larval morphology of xanthid zoeas and their value in phylogeny of this complex group, but the main objective of the present paper has been to note these atypical larvae.

Summary

Early zoeal stages of two closely related species with remarkable features, especially the morphology of abdomen and telson are described and illustrated in detail from planktonic material collected at Tosa Bay, southern Japan. Zoeal stages I-III of one species tentatively named "*species A*" and zoeal stage II of "*species B*" are regarded here as probably belonging to two species of Xanthidae (*sensu lato*) with previously undescribed larvae. Their larval characteristics are unique and do not correspond to any of the five described xanthid zoeal groups. Similarities with some "*Xanthozoeas*" described by Aikawa (1942) from the Palao Islands and also with zoeas of some Atelecyclidae (subfamily Acanthocyclinae) are discussed.

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References

Aikawa, H. 1933. On larval forms of some Brachyura. Paper II. A note on indeterminable zoeas. Rec. Oceanogr. Wks. Japan **5(2)**: 124-254. Text-figs. 1-61.

———— 1937. Further notes on Brachyuran larvae. *Ibid.*, **9(1)**: 87-162. Text-figs. 1-36.

———— 1942. Systematic studies of the plankton organisms occurring in Iwayama Bay, Palao. VI. On brachyuran larvae from the Palao Islands (South Sea Islands). Palao Trop. Biol. Stn. Studies **2**: 585-611.

Boschi, E.E. and M.A. Scelzo 1970. Desarrollo larval del cangrejo *Corystoides chilensis* Milne Edwards and Lucas en laboratorio (Decapoda, Brachyura, Atelecyclidae). Physis **30**: 113-124.

Connolly, C.J. 1925. The larval stages and megalops of *Rhithropanopeus harrisii* (Gould). Contr. Canad. Biol. Fish., n. ser. **2**: 327-333.

Fukuda, Y. 1978. Preliminary notes on recently obtained larvae of brachyuran Crustacea of the sea around the Aitsu Marine Biological Station. Calanus **6**: 10-16 (In Japanese, with English summary).

Martin, J.W. 1984. Notes and bibliography on the larvae of xanthid crabs, with a key to the known xanthid zoeas of the Western Atlantic and Gulf of Mexico. Bull. Mar. Sci. **34**: 220-239.

Martin, J.W., Truesdale, F.M. and D.L. Felder 1985. Larval development of *Panopeus bermudensis* Benedict and Rathbun, 1891 (Brachyura, Xanthidae) with notes on zoeal characters in xanthid crabs. J. Crust. Biol. **5**: 84-105.

Miyake, S. 1983. Japanese crustacean decapods and stomatopods in color. Vol. II Brachyura (crabs). Hoikusha, Osaka, pp. 1-277. Text-figs. 1-19, Pls. 1-64 (In Japanese).

Quintana, R. 1986. On the megalopa and early crab stages of *Parapilumnus trispinosus* Sakai, 1965 (Decapoda, Brachyura, Xanthidae). Proc. Jap. Soc. Syst. Zool. **34**: 1-17.

Rice, A.L. 1980. Crab zoeal morphology and its bearing on the classification of the Brachyura. Trans. Zool. Soc. London **35**: 271-424.

Saba, M., Takeda, M. and Y. Nakasone 1978. Larval development of *Epixanthus dentatus* (White) (Brachyura, Xanthidae). Bull. Nat. Sci. Mus., Ser. A (Zoology) **4(2)**: 151-161.

Terada, M. 1980. On the zoeal development of *Pilumnus indicus* (De Man) (Brachyura, Xanthidae) in the laboratory. Res. Crust. **10**: 35-44.

———— 1984. Zoeal development of two pilumnid crabs (Crustacea, Decapoda). Proc. Jap. Soc. Syst. Zool. **28**: 29-39.

———— 1985. Early Zoeal development of the crab, *Halimede fragifer* De Haan (Xanthidae, Xanthinae). *Ibid.*, **31**: 30-37.

Wear, R.G. 1968. Life history studies on New Zealand Brachyura 2. Family Xanthidae. Larvae of *Heterozius rotundifrons* A. Milne Edwards, 1867, *Ozius truncatus* H. Milne Edwards, 1834, and *Heteropanopeus* (*Pilumnopeus*) *serratifrons* (Kinahan, 1856). N. Z. J. Mar. Freshw. Res. **2**: 293-332.

Yatsuzuka, K. and N. Iwasaki, 1980. Seasonal occurrence and distribution of the brachyuran zoea in the coast of Tosa Bay. Rep. Usa Mar. Biol. Inst. **2**: 73-99.

————, and R. Quintana, 1985. Ecological studies on the planktonic brachyuran megalopas in the coast of Tosa Bay. Rep. Usa Mar. Biol. Inst. **7**: 87-109.