Larvae and Early Postlarvae of a Shrimp, *Metapenaeus burkenroadi*, Reared in the Laboratory

Hiroshi KURATA and Vanitchkul PUSADEE*

Shrimps of the family Penaeidae which support important commercial fisheries in the coastal blackish waters of western parts of Japan has been the subject of several biological studies. KUBO (1949) published a monograph on the taxonomy. YASUDA (1956), MAEKAWA (1961) and IKEMATSU (1963) have contributed much of our knowledges on growth, spawning and migration of various species of penaeid shrimps. Unfortunately, however, none of these works covered the planktonic stage of their life history. This is mainly due to the great difficulties encountered in distinguishing larval stages of various species which occur together in the same general area. Apart from the comprehensive work of HUDINAGA (1942) on *Penaeus japonicus* and of HUDINAGA (1941) on the nauplius stages of two species of *Metapenaeus*, there has been until late 1960's no published descriptions of the larval and early postlarval stages of the penaeid shrimps from Japanese waters. Recently *Penaeus orientalis* (KIM, 1966; OKA, 1967), *Metapenaeus joyneri* (LEE and LEE, 1968) and *Penaeus latisulcatus* (SHOKITA, 1970) have been successfully reared from eggs in the lablоratory in an attempt to develop a mass production method of seed shrimps and their larval stages were briefly described and illustrated. However, our knowledge on this subject is still far inadequate for the identification of plankton samples.

The present paper describes the larvae and early postlarvae of *Metapenaeus burkenroadi* KUBO, a penaeid shrimp of medium size of local importance in Tokyo Bay, Ise Bay, Seto Inland Sea, Sea of Ariake and Nanao Bay. The rearing experiments were done in July, 1968 at the laboratory of Fujinaga Shrimp Institute Foundation at Aio-futajima, Yamaguchi Prefecture. Greatest appreciations are extended to late Dr. Motosaku FUJINAGA and the members of the Institute for their kind cooperations and permission of using facilities of the laboratory. Thanks are also due to Mr. T. YATSUYANAGI and Mr. T. UTSUNOMIYA of the Fishery Seeds Production Center of the Yamaguchi Prefecture for their cooperations in securing mature females.

MATERIALS AND METHODS

All the descriptions and figures, except later juveniles otherwise noted, are taken from specimens reared in the laboratory. The mature females were first removed from the regular commercial hauls of shrimp trawlers working offshore of Suo-Nada and brought to the laboratory. A few probably normal eggs could be obtained by this method. But none of the larvae hatched from these eggs survived beyond the protozoea. The reason may be attributable to the suppress activity of the females from

Recieved: April 1, 1974. Contribution No. 43 from Nansei Regional Fisheries Research Laboratory.
* Marine Fisheries Laboratory, Department of Fisheries, Bankok, Thailand.

which these eggs are spawned. Fortunately, a single fully ripe female was scooped with a hand net on July 9 out of the resorvour pond of the laboratory. This female was quite vigorous and gave a large number of normal eggs at night of the same day it was transferred from the pond to a spawning aquarium. The larvae hatched from these eggs have been reared successfully as far as juvenile stage without any serious mortality.

Spawning took place in a plastic aquarium that contained about 600 liters of aerated sea water. The female was taken out of the aquarium after spawning and preserved for the closer identification. The larvae were then maintained in the same aquarium through metamorphosis until about 15 mm. in total length was reached when the experiment was terminated. Nutrient salts were added to the rearing water as soon as the successful hatching was observed to promote the growth of diatoms, which consisted mainly of *Skeletonema costatum* with admixture of various other species. Brine shrimp eggs were introduced for the post-protozoeal stages.

Average daily temperatures of the rearing water varied between 24.4 and 28.5°C. On fine days the water temperature reached as high as 34.3°C, since the aquarium was placed outdoors in the direct sun. Salinity was 28.51‰ at the beggining but rose to a maximum of 33.24‰ at the end of experiment.

Measurements were taken under a microscope with a micrometer eyepiece. Total length (T. L.) was taken from anterior end of body including rostrum when present to posterior end of telson less terminal spines, and carapace length (C. L.) from tip of rostrum to posterior mid-dorsal margin of carapace.

DESCRIPTION OF STAGES

EGG (Fig. 1, A)

Egg menbrane is spherical, 0.48 mm. in diameter. It is about 2.4 times as large as the diameter of embryonic menbrane, with a wide perivitelline space between the two menbranes. Egg menbrane reflects bright yellow color mixed with a little amount of red in early stages. The reflecting color changes to almost red just before hatching.

NAUPLIUS (Fig. 1, B-H)

Body is pear shaped, a little deeper than wide with a small dorsal protuberance. Antennule is 2/3 or slightly less as long as body. Antenna is as long as or somewhat longer than antennule, exopod being about 1/3 times longer than its endopod. None of the setae on exopod are bifid terminally. Mandible is nearly 1/2 as long as antennule. Body is light brownish yellow as a whole. Tips of appendages are somewhat translucent. There are no distinct chromatophores.

Stage 1. T. L. = 0.27 mm. All the setae on appendages are simple without setules. Hind end of body is roundly convex with a minute spine in the center and a pair of caudal spines. There are no rudiments of appendages posterior to mandible. Antennal exopod has 5 long setae, and endopod ends in 2 long and 1 rudimentary setae.

Stage 2. T.L. = 0.29 mm. Hind end of body is somewhat flattened between caudal spines, which are still 1+1 in number but are now finely plumose. Long setae on appendages are also finely plumose. Rudiments of maxillule and maxilla are faintly seen under the skin. Exopod of antenna has 6 setae.

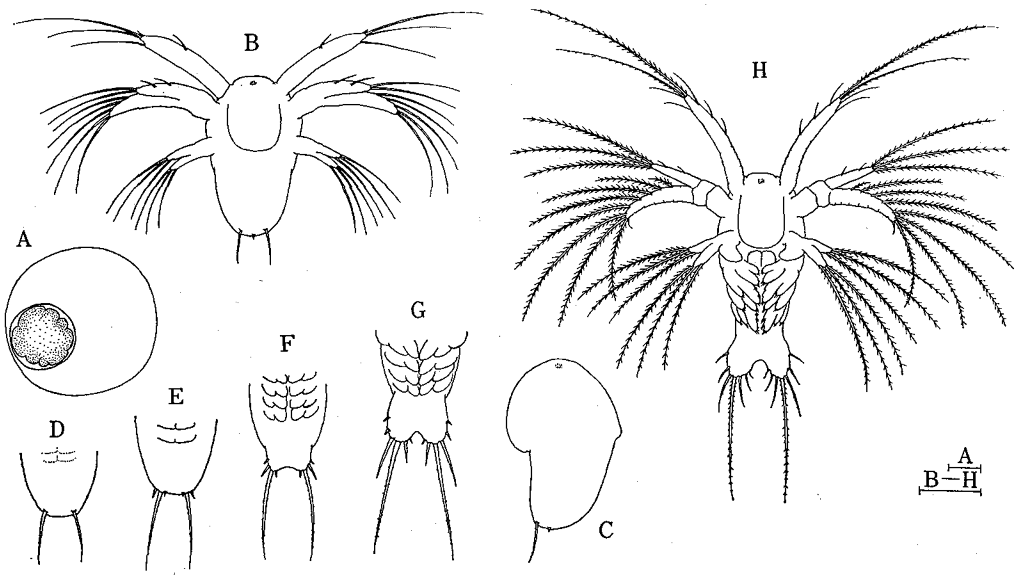

Fig. 1. A, egg. B-H, nauplius: B, stage 1, vetral; C, the same, lateral; D-G, stages 2–5, posterior body, ventral; H, stage 6, ventral. Scales denote 0.1 mm.

Stage 3. T.L.=0.31 mm. There are 3+3 caudal spines. Exopod of antenna has 7 setae. Base of mandible shows a slight swelling.

Stage 4. T.L.=0.33 mm. Posterior part of body is somewhat flattened dorso-ventrally. Hind end concave with 4+4 or 5+5 caudal spines. Antennal exopod has 8 setae, endopod ending in 3 long setae. Rudiments of labium and four pairs of appendages posterior to mandible are seen under skin. Basal swelling of mandible is distinct.

Stage 5. T.L.=0.36 mm. Body is divided into anterior and posterior parts by a shallow, incomplete transverse dorsal furrow. There are 6+6 caudal spines. Segmentation of antennule and antenna is indicated. Antennal exopod has 9 setae. Limb buds are large and free from the body but has no setae.

Stage 6. T.L.=0.42 mm. There are 7+7 caudal spines. Spine 4 is the longest and about 2/3 as long as body. Antennal exopod has 9 or 10 setae. Limb buds are greatly enlarged with rudimentary setae.

ZOEA (Protozoea, Fig. 2)

As has been well known, the first three post-naupliar stages of a penaeid shrimp has structures so markedly different from the rest of the larval stages. This phase has usually been called as protozoea because "it preserved a memory of a pre-decapod ancestry" (GURNEY, 1942). GURNEY regarded it as a distinct phase from the succeeding zoea mainly because it retained an antennal locomotion. Strictly speaking, however, protozoea has setose and functional exopods on the first two pairs of thoracic appendages. These exopods may be used for locomotion in addition to antennae. This fact was ignored by GURNEY. It seems logical to consider that the thoracic propulsion is acquired in the first protozoea. In this sense I agree with WILLIAMSON

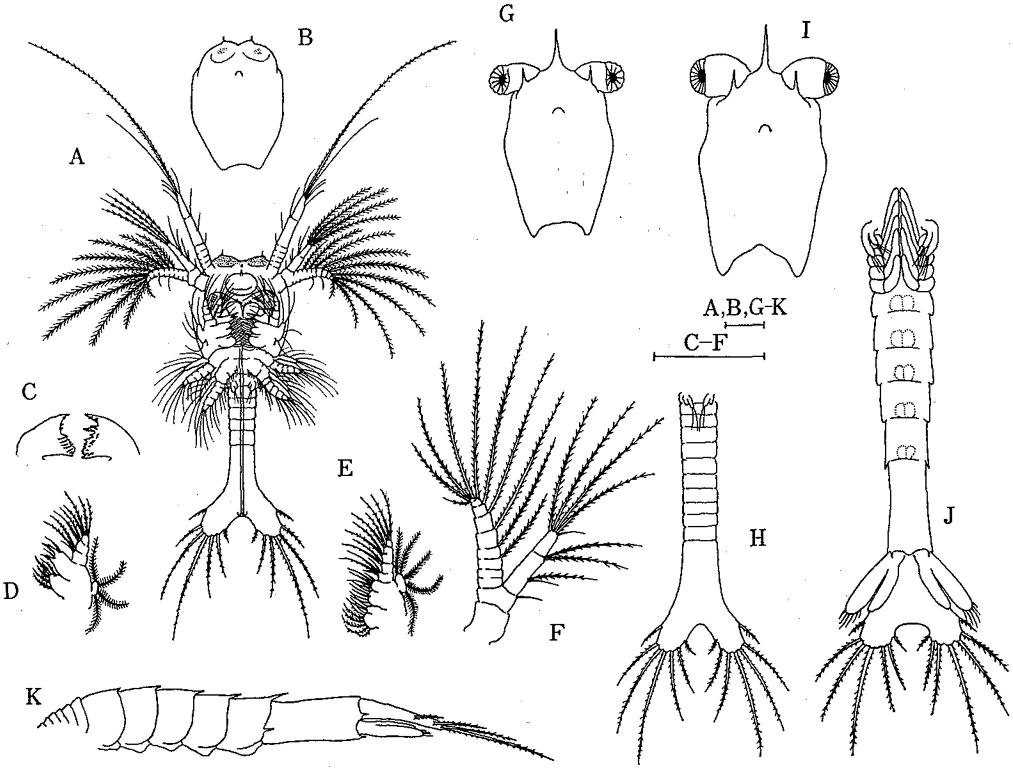

Fig. 2. Protozoeae. A-F, stage 1; A, ventral; B, carapace, dorsal; C, mandible; D, maxillule; E, maxilla; F, antenna. G, H, stage 2: G, carapace, dorsal, H, abdomen, ventral. I-K, stage 3: I, carapace, dorsal; J, abdomen, ventral; K, the same, lateral. Scales denote 0.1 mm.

(1969) to include protozoea within the zoea phase.

Carapace has an inconspicuous dorsal protuberance and smooth ventral margins. Rostrum appears from stage 2, pointed and smooth, and about 1/5 as long as the rest of carapace. A pair of supraorbital spines present from stage 1, but no antennals nor pterygostomians. Eye papilla (frontal organ) is distinct at the fronto-ventral edge of eyestalk. Last 6 thoracic somites are free from carapace. Telson is 2.5 times as wide as its base. Central indentation on the hind margin is moderately wide and deep. The number of telson spines is 7+7 in all stages, all inserted marginally.
Labrum has a distinct spine directing forward on the anterior edge.

Antennule is from 2/3 (in stage 1) to 1/2 (in stage 3) as long as carapace less rostrum, it is composed of 3 segments of which the first is subdivided into 5 segments, except in stage 3 in which it is not subdivided, and nearly as long as the second, the terminal segment is about 3/4 as long as the first and bears 1 long and 2 medium terminal setae in addition to aesthetascs. Antenna is somewhat shorter than antennule. Its endopod is about 4/5 as long as the exopod. Number of setae on the inner edge is 1 at distal end of protopod, 2 each at half way up and distal end of proximal segment. There are 4 long and 1 short setae at tip of distal segment. Exopod bears 10 setae around inner and apical margins and 1 outer seta each on segments 3 and 5.

Mandible has no palp, cutting and grinding portions well diferentiated with several spinous teeth along the cutting edge. Endopod of maxillule is of 3 segments with 3, 2 and 4 setae on the first, second and terminal segment respectively, that of maxilla is of 5 segments of which the third and the fourth partly fused together with 4, 2, 2, 2 and 3 setae. There is a small exopod on both maxillule and maxilla with 4 and 5 long plumose setae respectively.

First two pairs of maxillipeds are well developed. Their endopods are of 4 segments and distinctly longer than respective exopod. Maxilliped 3 is small, biramous and unsegmented in all stages, bearing a few setae from stage 1. The remaining thoracic appendages appear in stage 3 as rudiments.

There are brown color along the nervous system, red on cephalothoracic appendages and yellow green on abdominal appendages.

Stage 1. C.L.=0.36 mm., T.L.=0.81 mm. Eyes are sessile. Supraorbital spine projects as a short, needle like process from just inside of the eye papilla on either side. All the thoracic somites are segmented but all the abdominal somites and telson are fused together. Combined length of abdomen and telson is about 1.3 times the width of telson. Maxilliped 3 is small, slightly divided into two rami with 2 setae on exopod.

Stage 2. C.L.=0.59 mm., T.L.=1.27 mm. Eyes are free from carapace. Abdominal somites 1–5 are segmented. Combined length of somite 6 and telson is about 1.2 times the width of telson.

Stage 3. C.L.=0.66 mm., T.L.=1.69 mm. Abdominal somite 6 is segmented off from telson and as long as or slightly longer than the latter. Telson is somewhat wider than long. Uropod is free but unsegmented with 2 short setae on endopod and several plumose setae on exopod. It is distinctly shorter than telson. There is a dorsomedian spine each on abdominal somites 1–5 in a progressive order of dominance from anterior backward, a pair of lateral spines on somite 5 and 6, and a pair of ventrolateral spines on somite 6. There is an anal spine. First segment of antennule is no longer subdivided. Maxilliped 3 is distinctly biramous with 3–4 setae each on exopod and endopod.

ZOEA (Zoea, Fig. 3)

Carapace now covers all the thoracic somites and is provided with supraorbital, antennal and pterygostomian spines. Antennal spine, though small, remains distinct in all stages while supraorbitals and pterygostomians disappear from stage 5 and 6 respectively. Hepatic spine appears in atage 5. Rostrum is short, straight and smooth reaching behind tip of eye, with a dorsal tooth from stage 5. There is a small dorsal spine on abdominal somites 5 and 6 in all stages. Somite 6 has a pair of ventrolateral spines. No other spines nor carinae are present on abdomen. There is an anal spine. Telson has 7+7 spines in all stages. Spine on labrum is distinct as in protozoea.

Antennule on either side is set widely apart each other at base. First peduncular segment has a ventro-median spine and, from stage 6, a distal outer spine. Antennal exopod is rather broad, it is somewhat wider distally and about 1/4 as wide as long with an apical spine from stage 5. Mandible is as in protozoea except presence of palp appearing in stage 4. Exopod of maxillule still remains in stage 4 but disappears in stage 5, while that of maxilla greatly expands both distally and proximally with an increasing number of plumose setae as the stage proceeds.

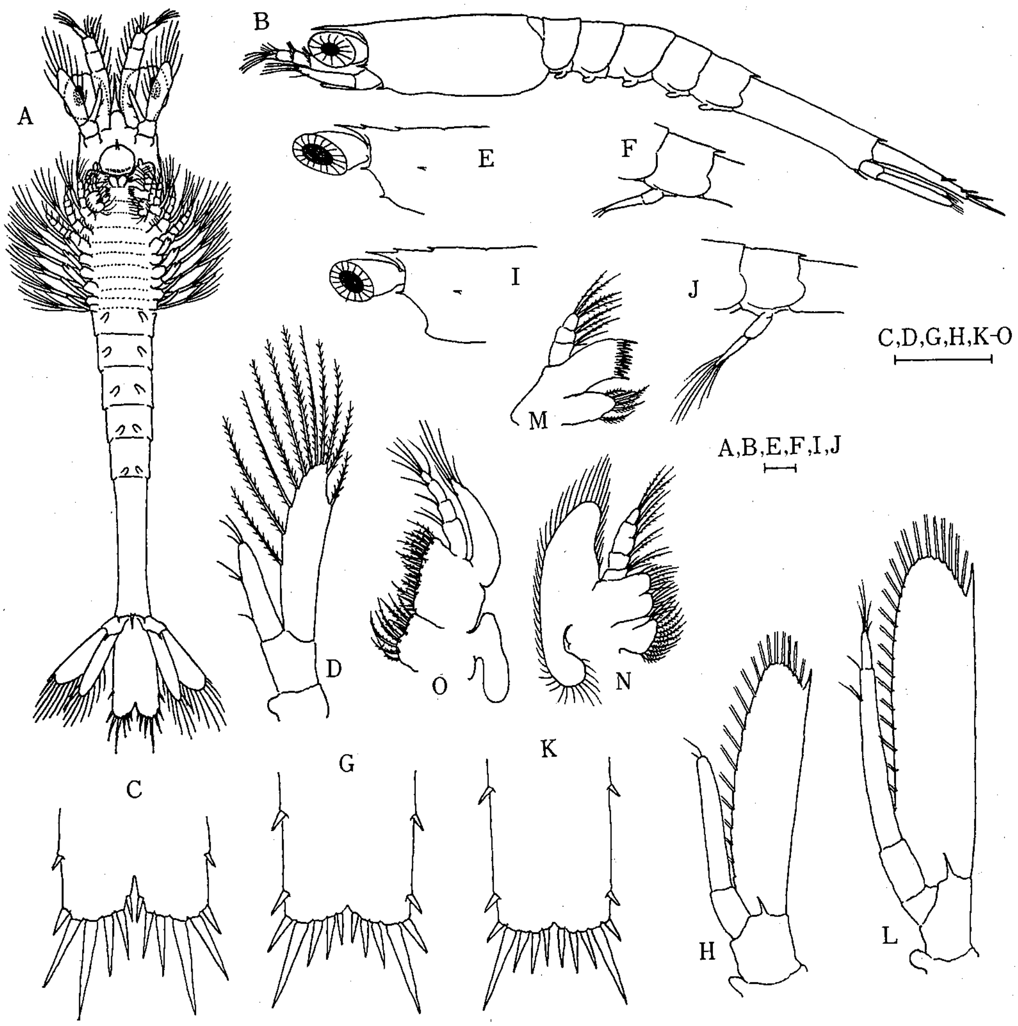

Fig. 3. Zoeae. A-D, stage 4: A, ventral; B, lateral; C, end of telson, dorsal, D, antenna. E-H, stage 5: E, carapace, lateral; F, somite 5 and its pleopod; G, end of telson; H, antenna. I-O, stage 6: I, carapace, lateral; J, somite 5 and its pleopod; K, end of telson, dorsal; L, antenna; M, maxillule; N, maxilla; O, maxilliped 1. Scales denote 0.1 mm.

All the thoracic appendages are biramous and well developed. Protopod of maxilliped 1 is flattened. Maxilliped 3 is longer than the preceeding two pairs. Setation of exopod tends to be limited to terminal margin in maxillipeds 2 and 3 while in maxilliped 1 there is a seta on proximal outer margin. In stage 1 endopod of legs are unsegmented and nearly as long as or slightly longer than their exopods. Pleopods appear in stage 5 and more or less setose in stage 6. There are no endopods of pleopods in all stages.

Stage 4. C.L.=0.71 mm., T.L.=2.13 mm. Rostrum almost reaches tip of eye. It is about 1/4 as long as the rest of carapace. There is an antennal and pterygostomian spines but no hepatics. Supraorbitals are present or absent. Telson is somewhat wider posteriorly, about 1/2 as wide as long and 2/3 as long as somite 6. Spine 2 is terminal. Central indentation on the hind margin is moderately wide and deep ending a little behind the first telson spine. Antennule exceeds eye by its distal 2 segments and flagella. The inner flagellum is very small, the outer with 1 group of aesthetascs. Stylocerite is just indicated and not pointed. Antennal exopod slightly exceeds eye without an apical spine. Endopod is a little more than 1/2 as long as exopod and unsegmented with several remnants of setae. Mandible has a small palp without setae. Endopod of legs are unsegmented, those of legs 1–3 have longitudinal apical furrows indicating developing chelae. Pleopods are very small. There are no gills.

Stage 5. C.L.=0.73 mm., T.L.=2.57 mm. There appears a hepatic spine while supraorbitals disappear. Rostrum becomes considerably shorter in proportion to the rest of carapace, reaching middle of eye with a dorsal tooth. Epigastric spine rarely present. Telson is parallel sided, about 1/3 as wide as long and 3/4 as long as somite 6. Spine 2 moves up to lateral margin. Central indentation on the hind margin becomes inconspicuous ending behind spine 2. Outer flagellum of antennule has 2 groups of aesthetascs. Stylocerite is pointed. Antennal exopod is provided with an apical spine which is exceeded by somewhat acutely rounded tip of blade. Endopod is about 2/3 as long as exopod with a basal joint. Palp of mandible is large with a few setae but unsegmented. Exopod of maxillule disappears. Endopod of legs 1–5 are fully segmented and are distinctly longer than their exopods. Chelae are formed. Pleopods are long and segmented but rarely setose. Maxilliped 1 has a mastigobranch.

Stage 6. C.L.=0.78 mm., T.L.=2.82 mm. There is an epigastric spine. Pterygostomian angle is rounded. Telson is somewhat narrower posteriorly, about 1/3 as wide as long. Central indentation on the hind margin is only slightly indicated. Outer flagellum of antennule is rarely divided into 2 segments, bearing 3 groups of aesthetascs. Inner flagellum is slightly longer than the outer. Antennal endopod is a little shorter than exopod with 1, or sometimes 2, distal joints. Palp of mandible is of 2 segments with many plumose setae. Endopod of legs are by far longer than their exopods. Pleopods are long with several setae. Buds of arthrobranch appear on maxilliped 3 and legs 1–4.

MEGALOPA (Fig. 4)

Megalopa has not usually been recognized in the larval development of a penaeid shrimp. The immediate post-zoeal stage is commonly known as the first post-larva. It has long been known, however, that the so called postlarvae of a first few stages are a member of oceanic plankton (Pearson, 1936), and show strictly pelagic rather than benthic habit in the culture aquaria (Hudinaga, 1942). Thus, the young shrimp of this phase retains larval characters in the mode of life while resembles juvenile in general structures. The equivalent phase in other decapod crustaceans is very distinct in structures and receives special names: *viz, puerulus* in Palinurid lobster, *glaucothoe* in Anomura and *megalopa* in Brachyura. These are regarded as a larva rather than adult (Williamson, 1969). In every instances so far examined in various decapods the stage when the young animals adopt a benthic existence in their respective habitat is toward the end of this phase. Thus puerulus, glaucothoe or megalopae which are brought to the laboratory from their natural habitats usually

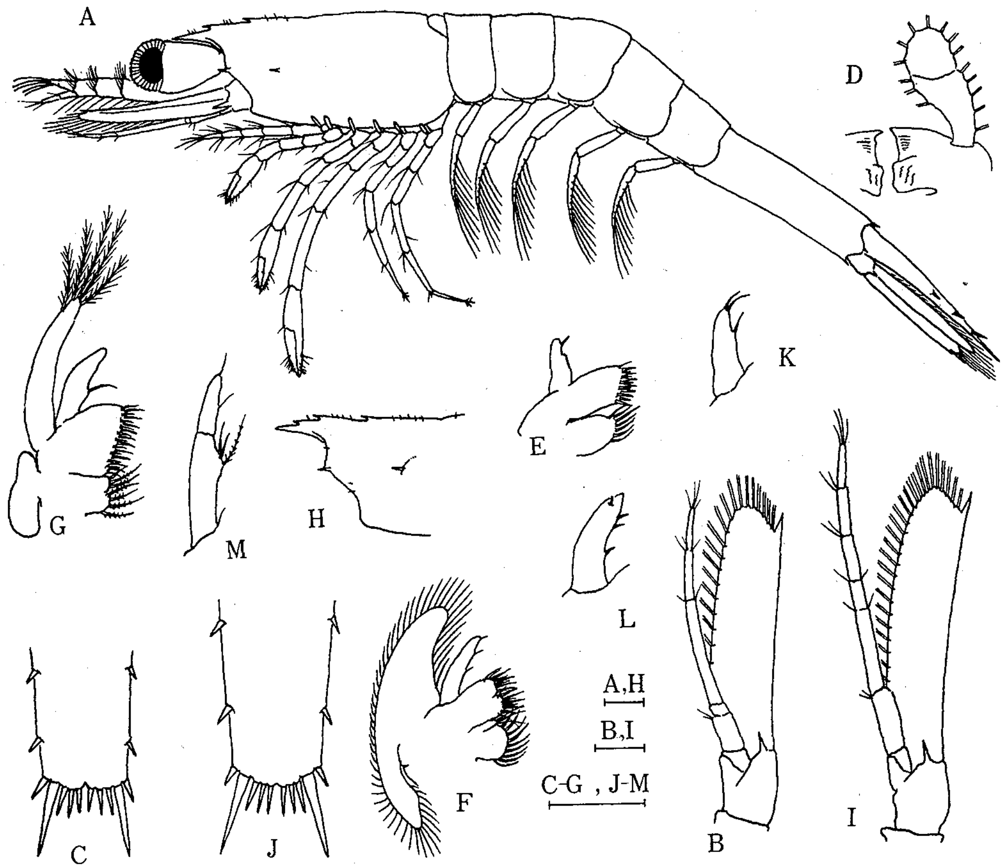

Fig. 4. Megalopae. A-G, stage 1: A, lateral; B, antenna; C, end of telson; D, mandible; E, maxillule; F, maxilla; G, maxilliped 1. H-M, stage 2: H, carapace, lateral; I, antenna; J,end of telson; K, endopod of maxillule; L, endopod of maxilla; M, endopod of maxilliped 1. Scales denote 0.1 mm.

molt into natant young stage in a few days. I would like to adopt the name "megalopa" after WILLIAMSON (1969) to denote this phase of transition in the normal development of a penaeid shrimp even if there are no major morphological distinctions from subsequent juvenile.

Megalopa of *M. burkenroadi* may be characterized as a phase when the degeneration of larval structures and the construction of the adult structures occurring at the same time. Within the larval structures which degenerate are included the spines on the first antennular peduncle, on labrum, on abdominal somite 5, on uropod peduncle and in front of the anus. Adult structures which develop are the gills and epipods among others. A temporary degeneration of certain of the mouth parts is also observed. This is a common phenomenon prevailing among the larvae of the transitional phase of most, if not all, decapod crustaceans.

It is true that the post-zoeal change in structures is so gradual that the distinction between megalopa and subsequent juvenile phase is not very clear from morphological evidences alone. Thus, by habit rather than by structures megalopa may well be defined. Number of stages in megalopa, accordingly, is by no means certain. However, when it is admitted that the stage when the shrimp transfer from planktonic to benthic existence is toward the end of megalopa, the size and structures of the minimum size group of shrimp found on the intertidal mud flat where *M. burkenroadi* is believed to adopt benthic existence for the first time in its life history will give a valuable information to define the end of megalopa and the commencement of juvenile phase. Extensive surveys were made during summers of 1970–72 on the intertidal areas of the Seto Inland Sea and a number of *Metapenaeus* juveniles were collected. They were sorted into 3 species: *M. joyneri, M. ensis* and *M. burkenroadi,* commonly found in this water. The minimum size of *M. burkenroadi* were 1.08 mm. in carapace length or 3.5 mm. in total length. The size and the structures of this specimen is quite comparable to those of the second post-zoeal stage reared in the laboratory. PERASON (1939) states that *Penaeus setiferus* "normally passes the first and part of the second postlarval stage at sea prior to adopting a demersal habitat in shallow, muddy estuarine bays and rivers." MENON (1951), studying on the life history of *Metapenaeus dobsoni* in Indian waters, found that the postlarva older than the first stage were absent from plankton and presumed that "they go down soon after the moult into the second stage and adopt the bottom living habit." In our sample of *M. burkenroadi* taken from intertidal mud flats the minimum size group was represented by a very few specimen while many specimen were found belonging to the immediate larger size group, 1.3–1.6 mm. in carapace length. The size range and structures of this group agree well with those of the third post-zoeal stage reared in the laboratory. There is, therefore, considerable justifications for supporting that the first two post-zoeal stages may be regarded as megalopa in *M. burkenroadi.*

Rostrum is short, hardly reaching cornea of eye with 1–3 dorsal teeth plus epigastric. The first dorsal tooth is almost level with the postrior corner of the eyesocket. Carapace has an antennal and a hepatic spine, its margins are otherwise smooth without carinae nor grooves. There is a stout spine between the leg 4, directing forward. Hind margin of abdominal somite 5 indented in the center for the reception of dorsal carina of somite 6 with a minute vestige of dorso-median spine in stage 1 and, in some specimens, also in stage 2. Somite 6 is more or less longer than telson with a dorsal carina extending almost its entire length and ending postriorly in an acute spine. Telson slightly tapers with 7+7 spines. The spines 1 and 2 are on the lateral edge and spine 4 is by far the longest of all. Hind margin is roundly convex with or without a small central indentation. There remains an anal spine, the ventro-terminal spine on uropod peduncle and a mid-ventral spine on the first peduncular segment of antennule. Prosartema is absent. Antennal scale is almost parallel sided with an apical spine ending behind tip of blade, the later reaching the tip of antennular peduncle or only slightly beyond it. The labral spine becomes blunt and inconspicuous. Mandible is robust but smooth without spinous teeth along masticatory edges. It looks more suitable for grinding than for cutting. Palp of 2 segments becomes enlarged and fringed with many setae. Endopod of maxillule, maxilla and maxilliped 1 become unsegmented with a few rudimentary setae in stage 1, that of maxillule having no setae on proximal outer margin. Endopod of maxilliped 2 distinctly bent on itself with many strong spines and setae along its inner, morphologically outer, margin.

Endopods of maxilliped 3 and legs 1–5 become quite firm and rigid, chelae and claws being fully formed. Vestiges of exopod without setae remain on maxillipeds 2 and 3 and legs 1–5. They begin to develop again from stage 2 except those of legs 4 and 5. Leg 1 usually has a basial spine but ischial spine of leg 1 and basial spines on legs 2 and 3 are somewhat irregular in appearence. Leg 5 is about 1/5 longer than leg 4. There are no epipod on any of the thoracic appendages. Pleopods have no endopods. Arrangement of gills is shown in Table 1. They are budlike and simple in stage 1 and begin to foliate from stage 2.

Table 1. Arrangement of gills in the megalopa.

Appendage	Podobranch	Arthrobranch	Pleurobranch
Maxilliped 1	m	0	0
2	1	1	0
3	0	2	0
Leg 1	0	2	0
2	0	2	0
3	0	2	0
4	0	1	0
5	0	0	0

Stage 1. C.L.=0.81—0.92 mm., T.L.=2.8—3.2 mm. Rostrum has 1 dorsal tooth plus epigastric. Telson is 3/4 as long as somite 6. The hind margin is slightly convex with a minute indentation in the center. Both inner and outer flagella of antennule are of 2 segments. The antennal flagellum is nearly as long as or a little shorter than the scale with 2 distal joints. The scale is almost parallel sided and about 1/4 as wide as long.

Stage 2. C.L.=0.95—1.04 mm., T.L.=3.3—3.6 mm. Rostrum has 2 or sometimes 3 dorsal teeth plus epigastric. Telson is about 4/5 as long as somite 6. Hind margin of telson distinctly convex without central indentation nor median spinous process. The antennal flagellum, with 4–5 distal joints, is longer than scale by its terminal joint. Endopod of maxillule has 1 subterminal and 2 terminal spinous setae, that of maxilla 3 inner and 1 subterminal outer spines which are all very small. Endopod of maxilliped 1 is of 2 segments with 3 subterminal inner spines on proximal segment, and 1 inner and 1 terminal setae on distal segment. Exopods of maxillipeds are more or less developed with several setae and that of leg 5 is still rudimentary in all specimens examined, while those of legs 1–4 are somewhat irregular in development. Presence of basial spines on legs 1–3 is also inconsistent. No ischial spine is observed on leg 1.

JUVENILE (Figs. 5 and 6)

In early stages of juvenile certain of the larval structures of minor importance may still be retained, while on the other hand adult structures a not yet fully formed. It should be supposed that the reconstruction of structures is still going on for a while after the adoption of benthic existence. The stages of juvenile phase may be defined somewhat arbitrarily according to the size and morphological characteristics.

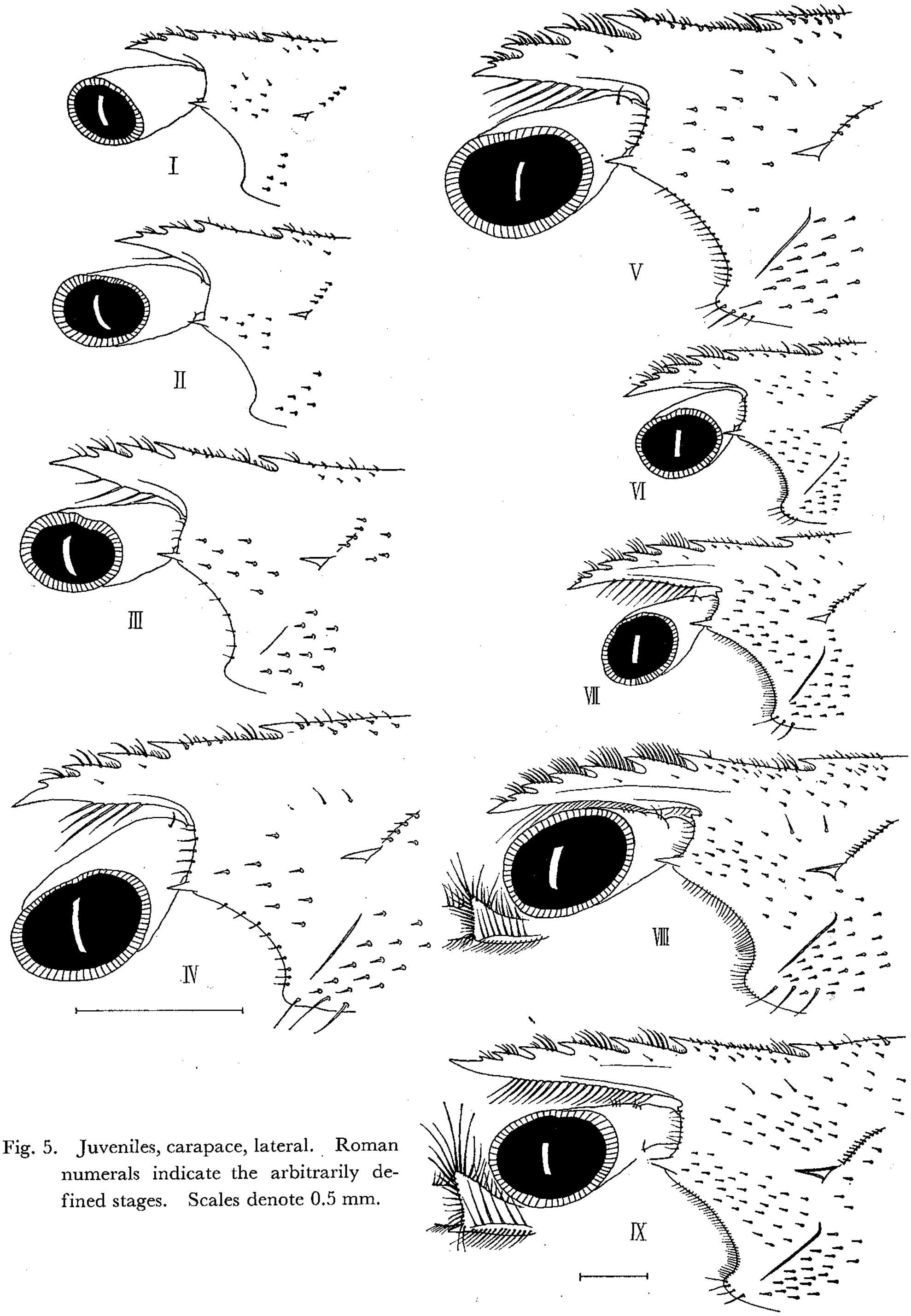

Fig. 5. Juveniles, carapace, lateral. Roman numerals indicate the arbitrarily defined stages. Scales denote 0.5 mm.

Rostrum is almost straight. It is shorter than eye and about 1/4 or 1/3 as long as the rest of carapace in early stages, but becomes longer than eye and about 2/5 as long as the rest of carapace from stage 7. Dorsal teeth deminish in size from posterior forward, and the first is almost level or slightly anterior to the postrior corner of eyesocket (Fig. 5). Hepatic carina may be seen faintly from stage 3 and becomes distinct from stage 4. It runs obliquely down from under the base of the hepatic spine right toward the pterygostomian corner. It bends anteriorly near its posterior upper end, but the rest of its length is almost straight. Cervical carina is also distinct from stage 4, straight and almost as prominent as but a little shorter than hepatic carina, accompanied by a row of spinules, and almost parallel to the straight part of hepatic carina. Abdominal somite 5 may still retain a vestige of median dorsal spine at the hind end in stage 1. Dorsal carina becomes distinct from stage 3. Somite 6 is nearly as long as or slightly longer than telson. Telson gradually assumes adult structures (Fig. 6). The hind end between spine 4 gradually protrudes into a triangular process and the telson eventually becomes cuneiform as a whole. Spines 5–7 are always nearly of the same length and disappear in stage 6 in which spine 4 is still by far the longest and not exceeded by the central process. Examinations of wild specimens showed that certain of the telson spines may be retained until the carapace length reaches 7 mm (25mm. in T.L.). Small vestige of anal spine may be retained until stage 3, and that of ventro-terminal spine of uropod peduncle until stage 4. Prosartema begins to develop from stage 5 while the vestige of midventral spine on the first peduncular segment may be retained until stage 6. Antennal scale is more or less wider proximally, extending forward slightly beyond the tip of antennular peduncle.

Mouth parts gradually assume adult structures at each molt. From stage 2 endopod of maxillule has a proximal outgrowth fringed with setae, and that of maxilla has a lamellar expansion on the outer edge at about halfway up. Endopod of maxilliped 1 is of 2 segments in stage 1, 3 segments in stage 2, and 4 segments and becomes longer than its exopod from stage 5.

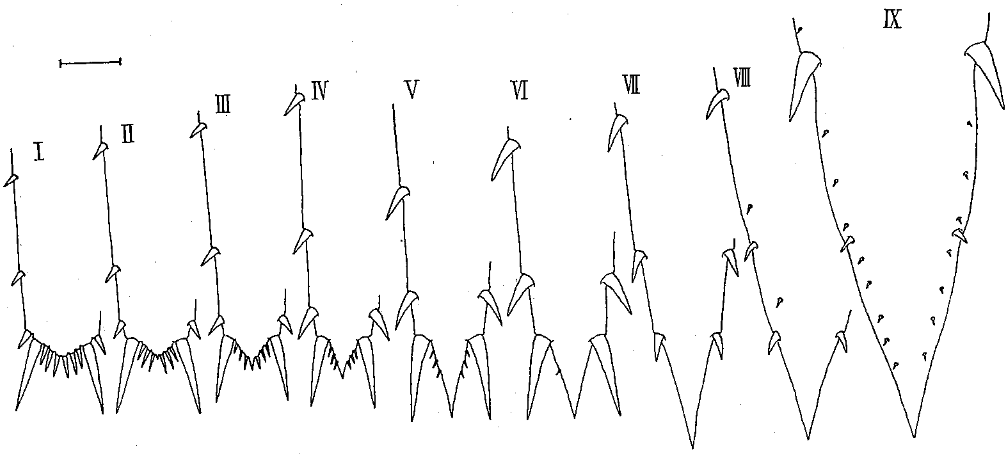

Fig. 6. Juveniles, telson, dorsal. Setae are not shown. Roman numerals indicate the arbitrarily defined stages. Scale denotes 0.1 mm.

Presence of basial and ischial spines on leg 1 and basial spines on legs 2 and 3 is still irregular in early stages but from stage 3 all of these spines are distinct in all specimens examined. Maxillipeds 1–3 and legs 1-5 bear short but setose exopods. Exopods of legs 4 and 5 are usually smaller and less setose than in the preceeding legs and may be rudimentary in an early few stages. Exopod of leg 5, which will eventually be lost in the adult, becomes longer and even setose keeping pace with that of leg 4 during at least early juvenile stages. It is retained as late as stage 8.

Endopods of pleopods 1–5 appear at the same time in stage 5 and those of pleopods 3–5 become setose from stage 6.

Rudiments of epipod appear on maxilliped 2 and legs 1–3 in stage 1 and grow rapidly as the stage proceeds. Epipod of maxilliped 2 is earlier in development than those of posterior limbs, and setose from stage 2, while those of legs 1–3 become setose from stage 3. All but one gills are distinct from stage 4 and more or less foliate from stage 6. An arthrobranch of radial structure at the base of maxilliped 1 is late in appearence. The minimum juvenile in which it is distinct is 16 mm. in total length.

Approximate ranges of carapace length and certain of the distinguishing characters of arbitrarily defined juvenile stage are summarized in Table 2.

Table 2. Approximate ranges of size and certain of the distinguishing characters for juvenile stages.

Stage	Approx. C. L., mm.	No. of segment of antennular flagella		No. of dorsal spine on rostrum less epigastric	Length of antennal flagellum/scale
		Inner	Outer		
1	1.1–1.3	2	3	2–3	1.2
2	1.3–1.6	2	3	3	1.3
3	1.7–1.9	2–3	3	3	1.4
4	1.9–2.3	3	3	4	1.8
5	2.4–2.7	3–4	5–6	4	1.8–2.0
6	2.8–3.5	5	6–7	5	2.0–2.5
7	3.8–4.2	8	9	5	2.8–3.2
8	4.6–5.0	9	10	6	4.5
9	5.4–6.0	9	11	6–7	5.0

Chronology of Larval Development

In this study the eggs were spawned at night of July 19 and hatched the following about noon. The protozoea was first noted in the early morning of July 22. The number of days after spawning when the indicated stages were first noted are listed in Table 3.

Discussion

In *Metapenaeus stebbingi* and *M. dobsoni* Gurney (1927) and Menon (1951) found only 3 naupliar stages based on the samples taken from plankton. However, 6 naupliar stages were usually found in *M. ensis* and *M. burkenroadi* (Hudinaga, 1941) and

Table 3. Chronology of larval development in *M. burkenroadi*

Stage		Date	No. of days after spawning
Zoea (Protozoea)	1	7/22	3
	2	7/23	4
	3	7/24	5
Zoea (Zoea)	4	7/26	7
	5	7/27	8
	6	7/29	10
Megalopa	1	8/ 2	14
	2	8/ 6	18

M. joyneri (LEE and LEE, 1968) when they were reared from eggs in the laboratory. In other genera of penaeid shrimps also 5–6 naupliar stages were usually observed as in *Penaeus* (PEARSON, 1939; HUDINAGA, 1942; DOBKIN, 1961; KIM, 1966; SHOKITA, 1970), in *Trachypenaeus* (PEARSON, 1939) in *Xiphopenaeus* (RENFRO and COOK, 1962; KURATA, 1970) and in *Sicyonia* (PEARSON, 1939; COOK and MURPHY, 1965).

The setation along the inner edge of antennal endopod has successfully been used by COOK (1967) as a distinguishing character of protozoeae of different penaeid genera. In this respect protozoea of *M. burkenroadi,* having 1+2+2 setae, agrees with that of *Parapenaeus,* from which it is different in comparatively longer antennule and wider telson. The same setation has also been observed in *M. enesis* protozoea (KURATA and PUSADEE, in preparation). This character, therefore, may be considered as generic for *Metapenaeus* protozoeae. MENON (1961), however, reported a different setation in the protozoea of *M. dobsoni* from Indian waters. His materials were obtained only from plankton and the setation was 0+2+2, which agrees with that of *Trachypenaeus* protozoea according to the COOK's key. *T. curvirostris* (STIMPSON) is reported by RACEK and DALL (1965) to be rather common in the waters from which MENON obtained his materials. LEE and LEE (1968) was successful in rearing *M. joyneri* larvae from eggs spawned from known females in the laboratory. Unfortunately, however, this character was not referred to and the illustrations are inadequate in their paper.

Zoea of *M. burkenroadi* agrees well with that of *M. dobsoni* described by MENON (1961) in general structures with the exception of the number of telson spines in stage 1. It is 8+8 in *M. dobsoni,* while 7+7 in *M. burkenroadi.* The number of these spines in *M. dobsoni* is reported to decrease to 7+7 in stage 2 and 3, while in *M. burkenroadi* it does not change through zoea phase. It seems rather unusual for the penaeid zoeae that the number of telson spines decrease in stage 2, though the reverse may sometimes be observed as in *Xiphopenaeus kroyeri* (KURATA, 1970).

SUMMARY

Larval and early postlarval stages of *Metapenaeus burkenroadi* KUBO reared from

eggs spawned in the laboratory are described and illustrated. Megalopa phase was established in the normal development of a penaeid shrimp. This is a transitional phase between planktonic zoea and benthic juvenile during which reconstructions of various body parts occurs, and the bottom living habit is adopted toward the end.

Six stages in the nauplius, six stages in the zoea including protozoea and 2 stages in the megalopa were recognized. The larvae developed to megalopa stage 2 in 18 days at temperatures of 24.4–28.5°C and salinities of 28.51–33.24‰ in the laboratory.

REFERENCES

1) COOK, H. L., 1965: A generic key to the protozoean, mysis and post-larval stages of the littoral Penaeidae of the northern Gulf of Mexico. *U. S. Fish. Wildl. Serv., Fish. Bull.* **65** (2), 437–447.

2) COOK, H. L. and M. A. MURPHY, 1965: Early developmental stages of the rock shrimp, *Sicyonia brevirostris* Stimpson, reared in the laboratory. *Tul. Stud. Zool.* **12** (4), 109–127.

3) DOBKIN, S., 1961: Early developmental stages of pink shrimp, *Penaeus duorarum* from Florida waters. *U. S. Fish Wildl. Serv., Fish. Bull.* **61**, 321–346.

4) GURNEY, R., 1927: Zoological results of the Cambridge Expedition to the Suez Canal. XV, Report on the larvae of the Crustacea Decapoda. *Trans. Zool. Soc. Lond.* **22** (2), 231–286.

5) GURNEY, R., 1942: Larvae of decapod Crustacea. Ray Soc. London.

6) HUDINAGA, M., 1942: Nauplius stages of *Metapenaeus monoceros* and *M. affinis*. *Suisan Gakkaiho,* **8**, 282–287 (In Japanese).

7) HUDINAGA, M., 1942: Reproduction, development and rearing of *Penaeus japonicus* Bate. *Jap. Jour. Zool.* **10**, 305–393.

8) IKEMATSU, W., 1963: Ecological studies on the fauna of Macrura and Mysidacea in the Ariake Sea. *Bull. Seikai Reg. Fish. Res. Lab.* **30**, 1–124 (In Japanese wits English Summary).

9) KIM, K. D., 1966: Studies on the development of *Penaeus orientalis* Kishinouye. *POK Culture Farm, Chung Chong Nando, Korea,* 7 pp.

10) KUBO, I., 1949: Studies on the penaeids of Japanese and its adjacent waters. *Jour. Tokyo Coll. Fish.* **36**, 1–467.

11) KURATA, H., 1970: Larvae of decapod Crustacea of Georgia. In Studies on the Life Histories of decapod Crustacea of Georgia. Part III, 122–274, 105 pl, Marine Institute, University of Georgia.

12) LEE, B. D. and T. Y. LEE, 1968: Larval development of the penaeidean shrimp, *Metapenaeus joyneri* (Miers). *Publ. Haewundae Mar. Lab.* **1**, 1–18.

13) MAEKAWA, K., 1961: Studies on the management and improvement of fisheries in the Seto Inland Sea with special reference to coastal waters of Yamaguchi Prefecture. *Res. Rept. Yamaguchi Pref. Inland Sea Fish. Exp. Station* **11** (1), 1–483. (In Japanese)

14) MENON, M. K., 1951: The life history and bionomics of an Indian penaeid prawn *Metapenaeus dobsoni* Miers. *Proc. IPFC* **3** (III), 80–93.

15) OKA, M., 1967: Studies on *Penaeus orientalis* Kishinouye. V. Fertilization and development. *Bull. Fac. Fish. Nagasaki Univ.* **23**, 71–87.

16) PEARSON, J., 1939: The early life history of some American Penaeidae, chiefly commercial shrimp *Penaeus setiferus* (Linn.). *Bull. U. S. Bur. Fish.* **49** (30), 1–73.

17) RACEK, A. A. and W. DALL, 1965: Littoral Penaeidae (Crustacea Decapoda) from Northern Australia, New Guinea and adjacent waters. *Verh. Akad. Wet. Amst.* (b) **56**, 1–116.

18) RENFRO, W. C. and H. L. COOK, 1963: Early developmental stages of the seabob, *Xiphopenaeus kroyeri* (Heller). *U. S. Fish Wildl. Serv., Fish Bull.* **63** (1), 165–177.

19) SHOKITA, S., 1970: A note on the development of eggs and larvae of *Penaeus latisulcatus* Kishinouye reared in an aquarium, *Biol. Mag. Okinawa* **6** (8), 34–36.

20) WILLIAMSON, D. I., 1969: Names of larvae in Decapoda and Euphausiacea. *Crustaceana* **16** (2), 210–213.
21) YASUDA, J., 1956: Ecological studies on the shrimps in the coastal bays. II. Bionomics by species. *Bull. Naikai Reg. Fish. Res. Lab.* **9**, 1–81. (In Japanese)