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Larvae of the Land Crab *Cardisoma carnifex* (Herbst) (Brachyura: Gecarcinidae) Reared in the Laboratory

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Five zoeal stages in addition to a megalopa are observed in the labbratory. The time taken for development from hatching to megalopa is given. The larval stages are illustrated and compared with those of the other known species of this genus.

Crabs of the genus *Cardisoma* are interesting in that they are land forms living in burrows, under roots and fallen logs, at times several kilometers inland but the ovigerous females return to the sea or estuary where the larvae are hatched. After the aquatic phase, which consists of a few zoeal stages and a megalopa, the crab instars emigrate to land. In India, this genus is represented by 2 species[1] and no information on the larval life history is available. In the present study an attempt has been made to rear the larvae of *C. carnifex* in the laboratory from hatching to post-larval stage.

Materials and Methods

Large number of specimens of *C. carnifex* live in burrows around Marine Biological Station at Porto Novo (lat. 11 29′ N; long. 79 46′ E). Berried females migrate from Marine Biological Station to the Vellar estuary during full moon nights to hatch off the larvae and these crabs can be trapped manually with a flashlight from a torch which dazzles them. Ovigerous female was collected from the intertidal region of the estuary on a full moon night and hatching occurred the same night. The method of rearing the larvae was same as given by Mercy *et al.*[2].

Results

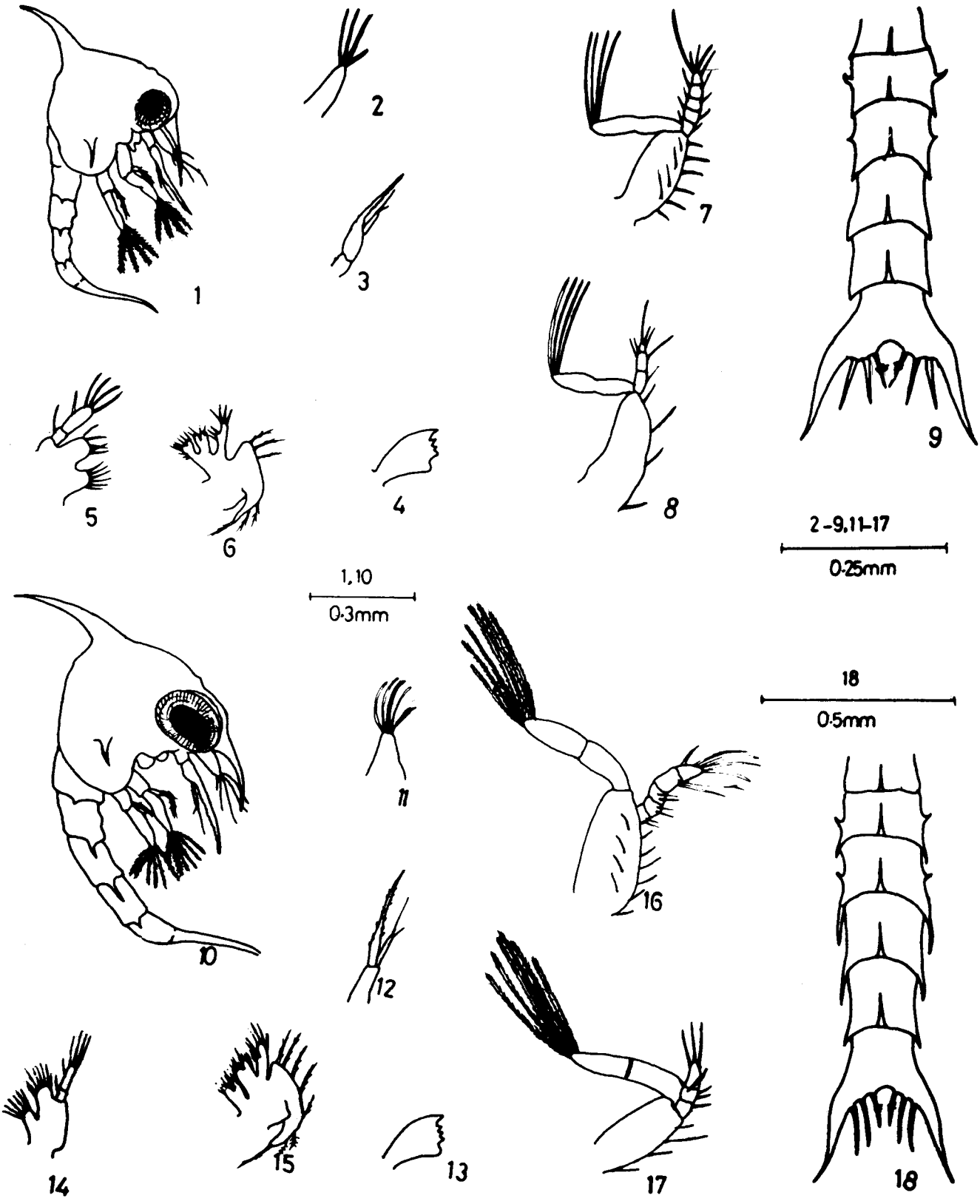
There were 5 zoeal stages and a megalopa under laboratory conditions. Shortest intermoult duration of each zoeal stage is 6,3,4,4 and 5 days respectively for stages I to V.

First zoea—Dorsal spine length = 0.17 mm; rostral spine length = 0.10 mm; carapace length = 0.38 mm and abdomen length = 0.67 mm.

Carapace with rostral, dorsal and a pair of lateral spines, rostral spine longer than antenna but shorter than dorsal spine, carapace longer than dorsal spine, eyes sessile (Fig. 1). A1 (Fig. 2): Uniramous, short, conical with 3 terminal long aesthetascs and a small seta. A2 (Fig. 3): Exopod about half the length of protopodite, with 2 terminal setae, 1 long, 1 short, protopodite tapering gradually to a point, with stiff spines on distal portion. Md (Fig. 4): Without palp and with well developed incisor process, incisor with 4 teeth. Max 1 (Fig. 5): Coxal and basal endites with 6 and 5 setae respectively, endopod 2-segmented, distal segment with 4 terminal and 1 subterminal setae, proximal segment with a single seta. Max 2 (Fig. 6): Coxa and basis bilobed, coxa with 9 spines on proximal and distal segments in total, basis with 2 setae each on proximal and distal segments, endopodite with 4 terminal and 3 subterminal setae, scaphognathite with 3 proximal and 3 distal plumose setae. Mxp 1 (Fig. 7): Basis with 10 setae, endopod 5-segmented, with 2,2,2,2,4 + 1 setae from proximal to distal segments, exopod unsegmented with 4 natatory setae. Mxp 2 (Fig. 8): Basis with 4 setae, endopod 3-segmented, with 1,3,3 setae from proximal to distal segments, exopod unsegmented with 4 natatory setae. Ab (Fig. 9): 5-segmented, segments 2 and 3 each with a pair of dorso-lateral protruberances, segments 2-5 with a pair of short spines in postero-lateral margin, all segments with a median dorsal spine. T: Widely forked with a shallow median notch on posterior margin, inner process formula 3 + 3.

Chromatophores—The brownish black chromatophore pattern is consistent in all the 5 zoeal stages and the pattern noted is: (1) a pair in dorso-lateral surface of cephalothorax between eyes and dorsal spine; (2) a pair in dorso-lateral surface of cephalothorax, caudal to dorsal spine, (3) a pair on ventro-lateral border of cephalothorax, (4) one, dorsal to gut in cephalothorax, (5) one, dorsal to gut in abdominal segments 1-4, (6) a

Abbreviations used: A1, antennule; A2, antenna; Md, mandible; Max 1, maxillule; Max 2, maxilla; Mxp 1, 1st maxilliped; Mxp 2, 2nd maxilliped; Mxp 3, 3rd maxilliped; P_{1-5}, pereiopods 1-5; Pl_{1-5}, pleopods 1-5; Ab, abdomen; T, telson and U, uropod.



Figs. 1 to 9—First zoea of *C. carnifex* [1, Lateral view of larva; 2, antennule; 3, antenna; 4, mandible; 5, maxillule; 6, maxilla; 7, 1st maxilliped; 8, 2nd maxilliped and 9, abdomen]

Figs. 10 to 18—Second zoea of *C. carnifex* [10, Lateral view of larva; 11, antennule; 12, antenna; 13, mandible; 14, maxillule; 15, maxilla; 16, 1st maxilliped; 17, 2nd maxilliped and 18, abdomen]

pair in postero-ventral border of abdominal segments 1-5, from zoeal stage 3 onwards 1-6.

Second zoea—Dorsal spine length = 0.22 mm; rostral spine length = 0.14 mm; carapace length = 0.45 mm and abdomen length = 0.78 mm.

Eyes stalked, 6 natatory setae on exopods of maxillipeds (Fig. 10). A1 (Fig. 11): With 5 aesthetascs. Max 1 (Fig. 14): Coxal and basal endites with 6 and 8 setae respectively. Max 2 (Fig. 15): No change in endopod, coxal and basal endites with 5 spines each in proximal and distal segments, 5 setae in proximal segment of scaphognathite and 3 setae on distal end. Mxp 1 and 2 (Figs. 16 and 17): Exopod 2-segmented, natatory setae increased to 6. Ab (Fig. 18): Postero-lateral spines on segment 2 smaller, spines on segments 3 and 4 bigger, spines on segment 3 larger than other spines and about half the length of segment 4. T: Median notch shallowed, no change in process formula.

Third zoea—Dorsal spine length = 0.33 mm; rostral spine length = 0.25 mm; carapace length = 0.50 mm and abdomen length = 0.88 mm.

Max 1 (Fig. 23): Coxal and basal endites with 6 and 9 setae respectively. Max 2 (Fig. 24): Setation on scaphognathite increased to 15. Mxp 1 and 2 (Figs. 25 and 26): Natatory setae on exopod increased to 8. Ab (Fig. 27): Abdominal segment 6 separated from telson, dorsal spine on segment 6 also developed, postero-lateral margin of segment 6 smooth and rounded. T: Slightly broader than long, inner process formula 4 + 4.

Fourth zoea—Dorsal spine length = 0.43 mm; rostral spine length = 0.37 mm; carapace length = 0.74 mm and abdomen length = 1.08 mm.

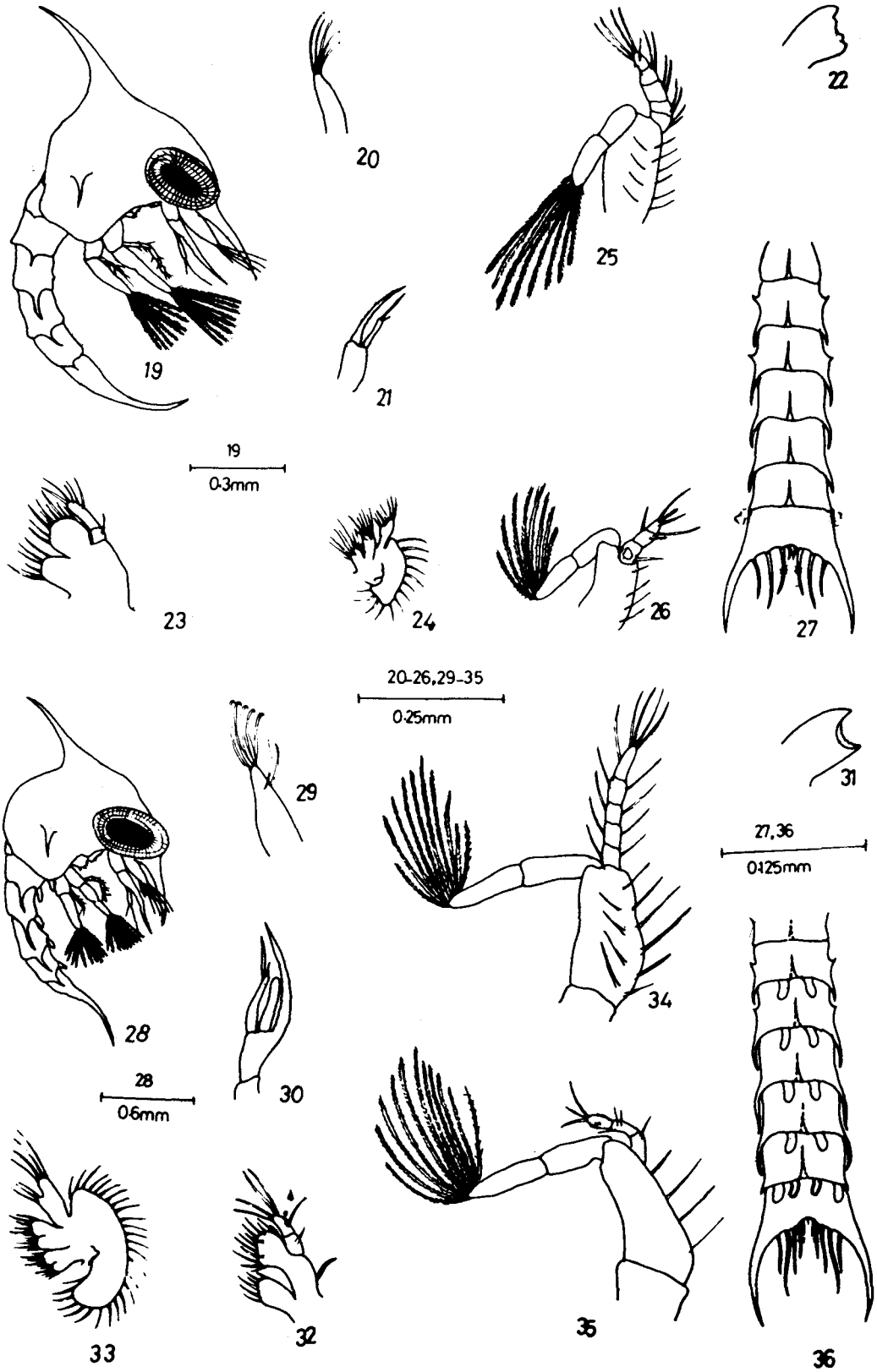
Other thoracic appendages developed in the form of buds. A1 (Fig. 29): With 5 terminal and 2 subterminal aesthetascs. A2 (Fig. 30): Endopod bud developed, equals exopod in length, more than $\frac{1}{2}$ the length of protopodite. Max 1 (Fig. 32): Coxal and basal endites with 6 and 12 setae respectively. Max 2 (Fig. 33): Coxal and basal endites with 10 and 11 setae in total on both segments respectively, scaphognathite now with 27 setae. Mxp 1 (Fig. 34): Natatory setae increased to 10 on exopod. Mxp 2 (Fig. 35): Natatory setae increased to 11. Mxp 3: Developed as a bud. Ab (Fig. 36): 5 pairs of uniramous pleopod buds developed from segments 2-6, segment 6 with a pair of small uropod buds, 6 pairs of postero-lateral spines on segments, spines on segments 1,2 and 6 smaller than rest. T: Slightly broader than long, median notch completely shallowed, telson process formula 5 + 5.

Fifth zoea—Dorsal spine length = 0.60 mm; rostral spine length = 0.48 mm; carapace length = 0.90 mm and abdomen length = 1.54 mm.

Buds of developing thoracic appendages increased in length, 1st pair of pereiopods chelate in nature. A1 (Fig. 38): Aesthetascs arranged in 3 tiers as 1,1,8. A2 (Fig. 39): Endopod increased in size, longer than exopod and about $\frac{3}{4}$ the length of protopodite. Md (Fig. 40): Unsegmented, unarmed, palp developed. Max 1 (Fig. 41): Setation on coxal and basal endites increased to 10 and 14 respectively. Max 2 (Fig. 42): Coxal and basal endites with 14 and 15 setae in total respectively on proximal and distal lobes, scaphognathite with 37 plumose setae. Mxp 1 (Fig. 43): Natatory setae on exopod increased to 11. Mxp 2 (Fig. 44): Natatory setae on exopod increased to 14. Mxp 3: Developed as 3 unarmed lobes. Ab (Fig. 45): 5 pairs of uniramous pleopod buds increased in size, postero-lateral spines on segments 3-5 touch base of succeeding spines, postero-lateral spines of segment 6 also increased in size, about $\frac{1}{2}$ the length of uropod bud. T: As long as broad, process formula 5 + 1 + 5.

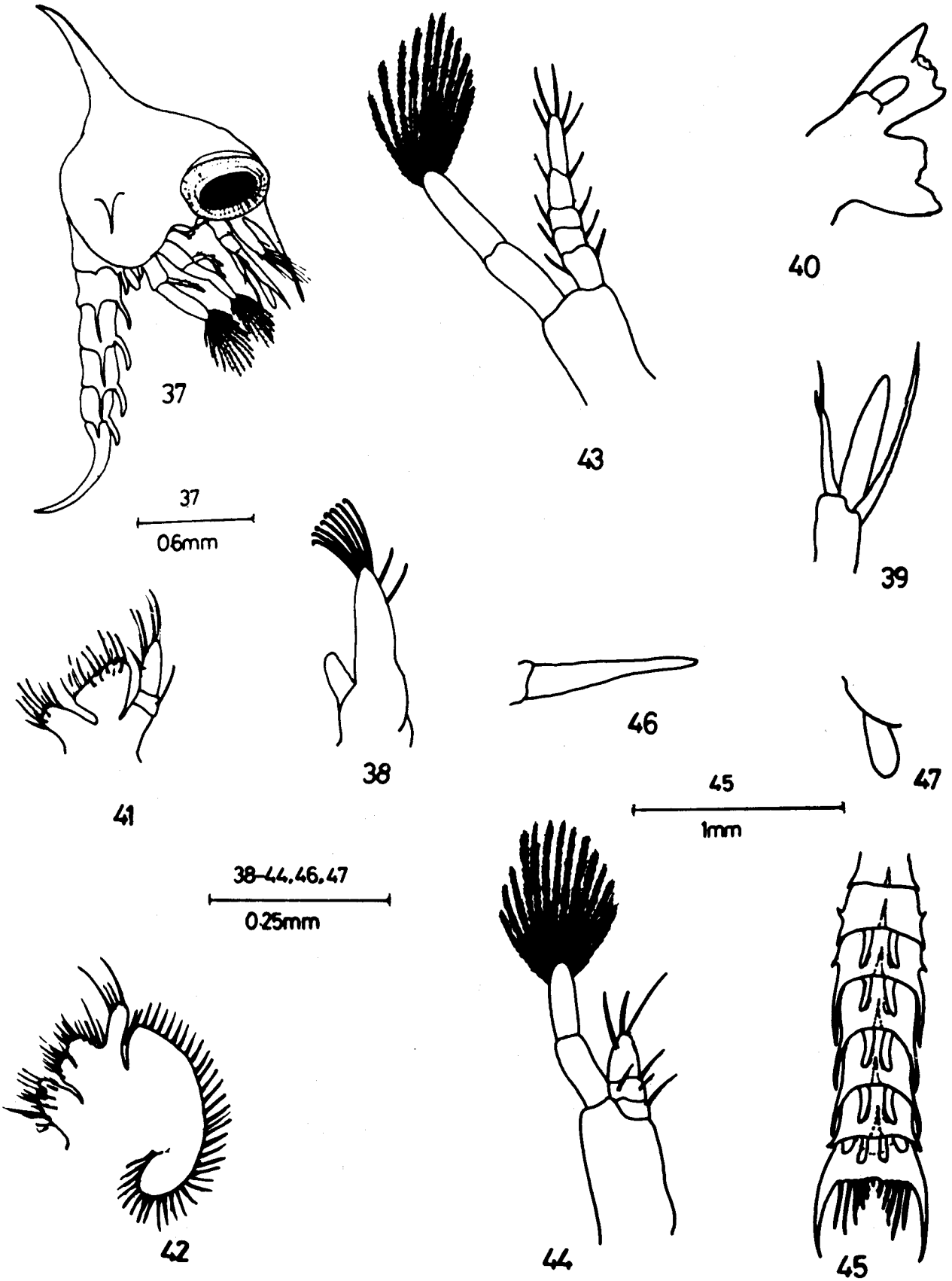
Megalopa—Carapace length = 0.88 mm; abdomen length = 1.02 mm and total length = 1.88 mm.

Rostral spine highly reduced and terminates as a single ventrally depressed median process, numerous hairs on carapace and thoracic appendages (Fig. 48). A1 (Fig. 49): Biramous, peduncle 3-segmented, inner ramus unsegmented with 2 terminal setae, outer ramus 4-segmented, segments 1-3 with 6 long aesthetascs each, segment 4 with 2 terminal setae. A2 (Fig. 50): Flagellum 9-segmented, all segments except segments 4,6 and 7 with a pair of setae at its distal end, segments 4 and 6 without setae, segment 7 with 3 long and 2 short setae. Md (Fig. 51): With 2-segmented palp, proximal segment with a single seta and distal segment with 10 setae, palp bends inside cutting edge. Max 1 (Fig. 52): Coxa with 5 setae laterally and 4 setae terminally, basis with 13 setae, palp 2-segmented, 2 setae on proximal segment and 4 setae on distal segment terminally. Max 2 (Fig. 53): Coxa with 19 setae in total, basis with 15 setae in total, endopod with 2 terminal, 2 subterminal and 2 middle setae, scaphognathite greatly enlarged and with about 60 setae. Mxp 1 (Fig. 54): Bilobed, protopod with 7 and 12 setae respectively on proximal and distal segments, endopod long with 8 setae, exopod 2-segmented, 5 terminal setae on distal segment, epipod with 9 setae. Mxp 2 (Fig. 55): Endopod 3-segmented, with 1,4,7 setae from proximal to distal segments, exopod 2-segmented, 5 apical setae on distal segment. Mxp 3 (Fig. 56): Endopod 5-segmented with 7,5,5,7,6 setae respectively from proximal to distal segments, exopod 2-segmented with 5 apical setae on its distal segment, epipod comparatively longer than 1st maxilliped, with 14 setae. P 1-5 (Figs. 57-61): First pair of pereiopods equal, chelate, fingers with 4 teeth along cutting edges, ischial spine present, propodus longest segment, palm shorter than fingers, dactylus of 2nd leg longer than

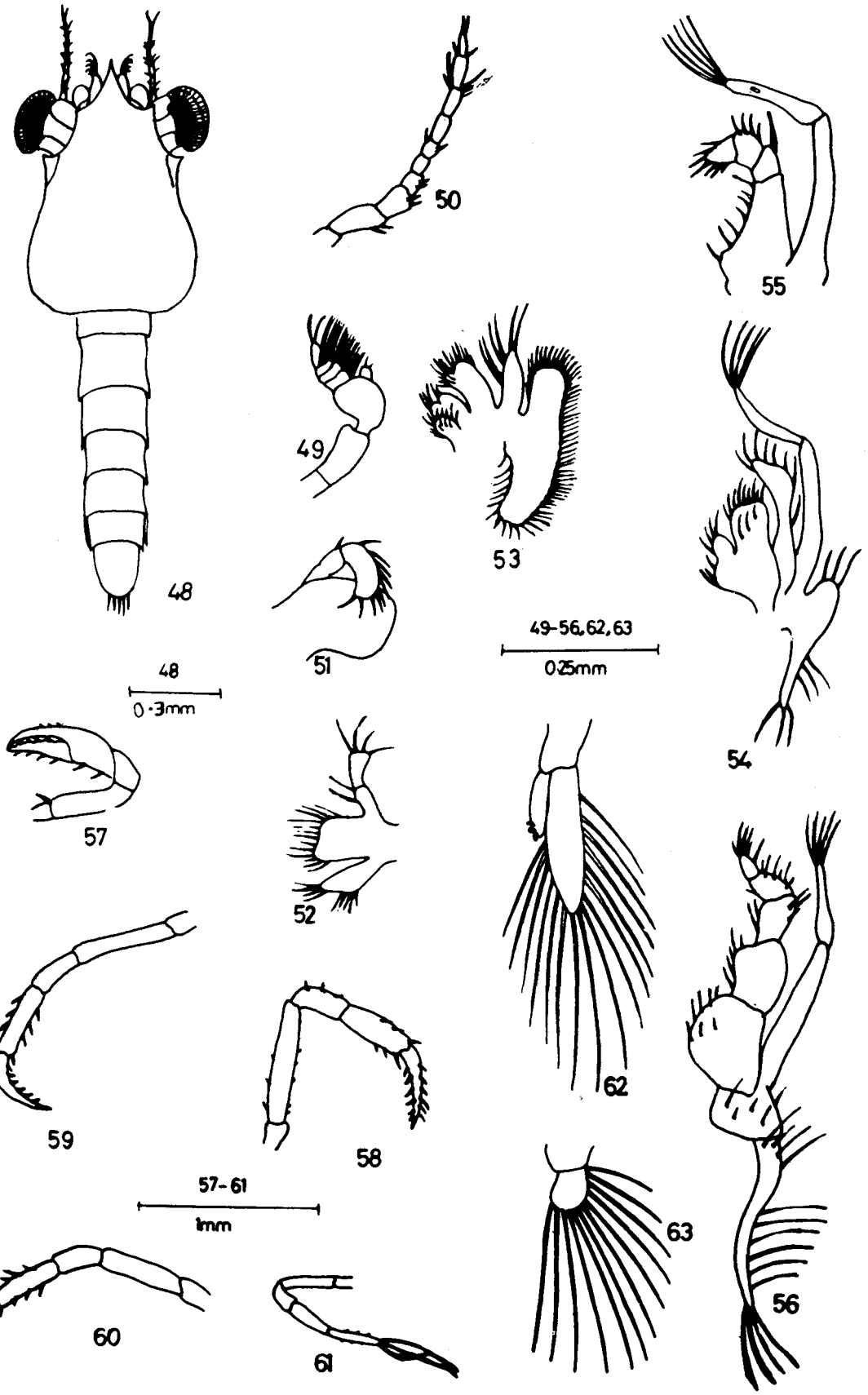


Figs. 19 to 27—Third zoea of *C. carnifex* [19, Lateral view of larva; 20, antennule; 21, antenna; 22, mandible; 23, maxillule; 24, maxilla; 25, 1st maxilliped; 26, 2nd maxilliped and 27, abdomen]

Figs. 28 to 36—Fourth zoea of *C. carnifex* [28, Lateral view of larva; 29, antennule; 30, antenna; 31, mandible; 32, maxillule; 33, maxilla; 34 1st maxilliped; 35, 2nd maxilliped and 36, abdomen]



Figs. 37 to 47 – Fifth zoea of *C. carnifex* [37, Lateral view of larva; 38, antennule; 39, antenna; 40, mandible; 41, maxillule; 42, maxilla; 43, 1st maxilliped; 44, 2nd maxilliped; 45, abdomen; 46, pleopod and 47, uropod]



Figs. 48 to 63 Megalopa of *C. carnifex* [48, Dorsal view of megalopa; 49, antennule; 50, antenna; 51, mandible; 52, maxillule; 53, maxilla; 54, 1st maxilliped; 55, 2nd maxilliped; 56, 3rd maxilliped; 57, cheliped; 58, 2nd leg; 59, 3rd leg; 60, 4th leg; 61, 5th leg; 62, pleopod and 63, uropod]

Table 1 – Distinguishing Characters Between Larval Stages of *C. carnifex* and *C. guanhumi*

Stage	Character	*C. carnifex*	*C. guanhumi*
Zoea 1-5	Dorsal spine in abdomen	Present in all segments	Absent
	Endopod of maxilla	With 4 terminal & 3 subterminal setae	With 3 terminal & 2 subterminal setae
Zoea 1	Exopod of antenna	About $\frac{1}{2}$ of protopodite	About 3 4 of protopodite
Zoea 2	Basal endite of maxillule	With 8 setae	With 6 setae
	Exopod of maxillipeds	2-segmented	Unsegmented
Zoea 3	Basal endite of maxillule	With 9 setae	With 7 setae
Zoea 4	Endopod of antenna	Equals exopod. $> \frac{1}{2}$ of protopodite	Shorter than exopod. $< \frac{1}{2}$ of protopodite
	Natatory setae on exopod of I maxilliped	10	9
	Natatory setae on exopod of II maxilliped	11	10
Zoea 5	Endopod of antenna	Shorter than protopodite	Equals protopodite
	Natatory setae on exopod of I maxilliped	11	10
	Natatory setae on exopod of II maxilliped	14	12
Megalopa	Telson	Longer than broad	Broader than long
	Spine on caudal margin	5	6

propodus, ischial and meral segments smooth, carpal, propodal and dactyl segments with few spines, dactylus of 3rd and 4th legs equal in length to propodus, propodus and dactylus with spines, propodal spine on distal end prominent in legs 2-4, merus longest segment in legs 2-4, dactylus of 5th leg longer than propodus, meral segment equal to dactylus, 3 long aesthetascs in distal end of dactylus. Ab: Postero-lateral border of segment 1 smooth, spines on segments 2-4 small, spines on segment 5 covers the whole length of segment 6, segment 6 without spines, 4 pairs of biramous pleopods on segments 2-5 and a pair of uniramous pleopods on segment 6, no setae on protopod, exopod with 16 setae, endopod of biramous pleopods with 3 microscopic hooks. T: Longer than broad, posterior margin rounded and with 5 stiff spines. U (Fig. 63): Uniramous, exopod with 12 setae, protopod without seta.

Chromatophore pattern in megalopa: (1) a pair in rostrum (2) one on each eyestalk dorsally (3) a pair in anterior margin of cephalothorax posterior to eyestalk (4) a pair in dorso-lateral margin of cephalothorax (5) a pair in posterior margin of cephalothorax (6) dorsal to gut in abdominal segments 1 - 3, extending into cephalothorax (7) postero-lateral borders of abdominal segments 1 - 6.

Discussion

Costlow and Bookhout[3] reared *C. guanhumi* in the laboratory and described 5 zoeal stages and a megalopa. After separating the larvae of *C. guanhumi* from the larvae of grapsids and xanthids, they commented that the extent to which the zoea of *C. guanhumi* could be separated from other more closely related species depends on additional descriptions of their larvae. The present study on the larval development of *C. carnifex* also showed 5 zoeal stages in addition to a megalopa. The characters by which the larvae of these two species could be separated from each other are summarised in Table 1.

Presence of dorsal spines on abdominal segments in *C. carnifex* as reported here and their absence in *C. guanhumi*[3] can be of taxonomical significance and it indicates that this genus is not homogenous and probably polyphyletic in origin. Further the dorsal spines directed anteriorly instead of posteriorly (which is normal) is interesting.

Information on the larval stages of crabs belonging to the family Gecarcinidae is very limited[3] and additional descriptions of larvae of more species of crabs will throw light on intergeneric and interspecific relationships and will also facilitate formulating the generic characteristics.

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