

Metamorphosis of the Hermit Crab *Diogenes diogenes* (Herbst) (Decapoda, Anomura) in the Laboratory

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Larval metamorphosis of *D. diogenes* as observed in the laboratory, comprising 3 zoeal and a glaucothoe stage is described. Total duration of the zoeal phase up to the glaucothoe is approximately 21 days at temperatures 24-26°C and salinity about 33‰ of the sea water.

THOUGH larvae of hermit crabs are described in more than 35 species¹ in the genus *Diogenes*, which is represented by about 42 species², laboratory reared larvae are known only in 3 species, viz. *D. pugilator*^{3,4} (1st larva) from British waters; *D. bicristimanus*⁵ (5-zoeal stages and glaucothoe) and *D. avarus*⁶ (4-zoeal stages, glaucothoe and first crab), the latter two being from Indian waters. Gurney⁷ and Menon⁸ refer some of their larvae, collected from plankton, to the genus *Diogenes*.

The present paper deals with the complete zoeal (3) development and the glaucothoe of *Diogenes diogenes* (Herbst), reared in the laboratory.

Materials and Methods

Berried female was obtained from trawlers operating in the Karwar bay, west coast of India. The depths sampled by the otter trawl during this tow varied from 10 to 15 fm. The specimen was maintained alive in aquaria with filtered sea water until the larvae were released.

The adapted rearing technique was the same as one described by Kakati and Sankolli⁹. Freshly hatched *Artemia* nauplii were tried successfully for feeding. The exuviae and dead larvae were preserved in a special preservative¹⁰.

During the experimental period the temperature of sea water ranged from 24° to 26°C and the salinity about 33‰. Duration of stage was determined from time of hatching to first moult and in later stages from one moult to the next. The complete development was carried out in 21 days.

Eggs are oval, violet (when young) turning to pink and later transparent, when about to hatch. In formalin eggs loose colour and become pale. Egg size ranges from 0.58 to 0.67 mm × 0.49 to 0.59 mm.

The following abbreviations are used throughout the paper: A1, antennule; A2, antenna; Md, mandible; Max 1, first maxilla; Max 2, second maxilla; Mxp 1, first maxilliped; Mxp 2, second maxilliped; Mxp 3, third maxilliped; P₁₋₅, pereopods 1-5; and Pl₁₋₅, pleopods 1-5.

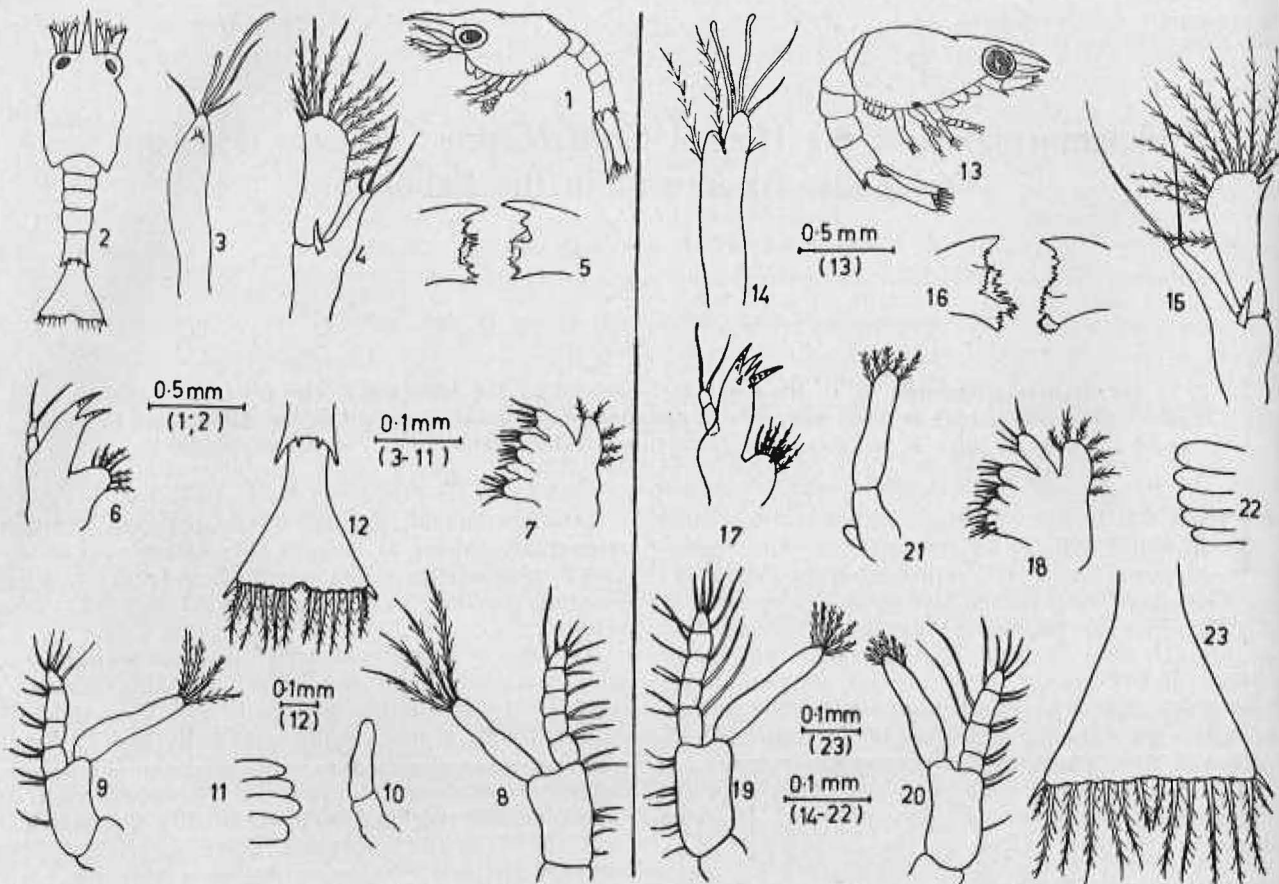
Description of Stages

1st zoea — Carapace length 0.92 mm; abdomen length, 0.92 mm; and duration of the stage, 6-7 days.

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Carapace smooth, postero-lateral margins slightly triangular, almost as long as the abdomen (Figs. 1 and 2; carapace including rostrum); rostrum smooth, pointed, reaching well beyond the A1 and A2; eyes sessile.

A1 (Fig. 3): Uniramous with 2 unequal aesthetascs and 3 setae terminally and 3 fine hairs subterminally. A2 (Fig. 4): Scale large, twice as long as the antennal endopod with a short spine terminally and 11 long plumose setae marginally, the one near the spine being the smallest and hair-like; endopod with 2 long plumose, subequal setae terminally and a small seta subterminally; peduncle bears a strong spine serrated on one side only, distally. Md (Fig. 5): Asymmetrical, cutting edges bear a number of corneous, unequal, pointed teeth. Max 1 (Fig. 6): Coxal endite with 5 plumose and 2 simple setae, basal with 2 serrated teeth; 2-segmented palp bears 2 setae terminally. Max 2 (Fig. 7): Bilobed coxal and basal endites bear 6+1 and 4+3 setae respectively on their proximal and distal endites; unsegmented palp with a median notch and bears 4 setae in 2 groups of 2 each terminally; scaphognathite bears 5 marginal setae, posterior lobe not developed. Mxp 1 (Fig. 8): Basis with 7-8 setae; 5-segmented endopod bears 2, 2, 1, 2 and 4+1 (outer) setae distalwards; exopod unsegmented with 4 natatory setae terminally. Mxp 2 (Fig. 9): Basis with 3 setae; endopod 4-segmented with 2, 2, 2 and 4+1 (outer) setae progressing distally; exopod as in Mxp 1. Mxp 3 (Fig. 10): An uniramous bud. P₁₋₄ (Fig. 11): Four pairs of pereopod buds are clearly visible. Abdomen (Figs. 1 and 2): Five segments are clearly articulated, 6th being fused with the telson; segments 1-4 are broader than long while the 5th longer than broad; 5th segment on its posterior margin bears a pair of lateral spines and a pair of dorsal spines. Telson (Fig. 12): More or less triangular, with the maximum width equals to the length of telson (including the fused 6th abdominal somite); process formula 7+7, the first an articulated spine nearly 1/4th as long as the 5th process, 2nd an 'anomuran' hair as long as the 1st process, 3rd to 7th long, plumose setae, the 5th being the longest, almost as long as the 4th; the posterior margin of telson including the notch with spinules and fine hairs.



Figs. 1 to 12 — First zoea of *D. diogenes* [1 Entire larva (lateral view); 2, entire larva (dorsal view); 3, antennule; 4, antenna; 5, mandible; 6, first maxilla; 7, second maxilla; 8, first maxilliped; 9, second maxilliped; 10, third maxilliped; 11, pereopod buds; and 12, telson]

Figs. 13 to 23 — Second zoea of *D. diogenes* [13, Entire larva (lateral view); 14, antennule; 15, antenna; 16, mandible; 17, first maxilla; 18, second maxilla; 19, first maxilliped; 20, second maxilliped; 21, third maxilliped; 22, pereopod buds; and 23, telson]

IInd zoea — Duration 7-8 days. This stage is marked by the following changes over the previous stage: eyes movable (Fig. 13); inner ramus of A1 (Fig. 14) with a long plumose seta terminally, both rami separated by a median notch; endopod of A2 (Fig. 15) with 2 terminal setae, and peduncle adds a small spine at the outer edge; basal endite of Max 1 (Fig. 17) adds 2 more serrated teeth; scaphognathite and distal lobe of coxal endite of Max 2 (Fig. 18) with 7 and 3 setae respectively; exopods of Mxp 1 and 2 with 6 natatory setae; endopod segments 1 to 3 of Mxp 1, and 2nd and 3rd of Mxp 2 each add a long plumose seta on the outer distal angle; Mxp 3 biramous with a bud-like endopod and a prominent exopod (Fig. 21) which bears 5 natatory setae; addition of the 5th pair of pereopod bud; telson notch disappears (Fig. 23); process formula 8+8.

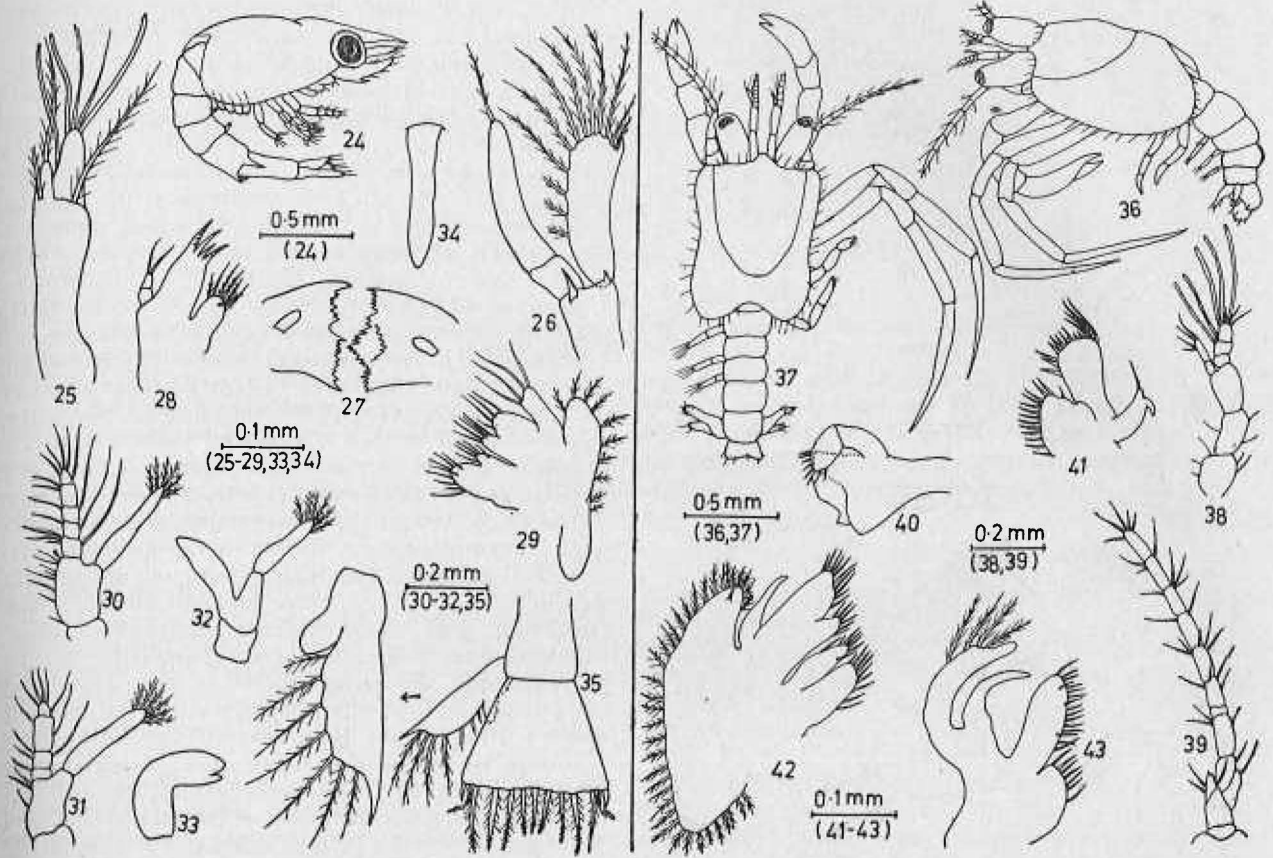
IIIrd zoea — Duration 7-8 days. This stage (Figs. 24-35) is advanced over the previous stage in the following characters: inner ramus of A1 (Fig. 25) partially separated from peduncle with a long plumose seta terminally, outer ramus completely separated from peduncle and with 3 aesthetascs and 2 unequal setae, peduncle with 2 setae; scale of A2 (Fig. 26) with 12 setae and 2-segmented endopod terminates in a seta; Md (Fig. 27) bears a rudimentary palp;

bilobed coxal and basal endites of Max 2 (Fig. 29) with 8, 5, 5 and 4 setae respectively, proximal lobe of scaphognathite developed but without setae, distal lobe bears 10 marginal setae; exopod of Mxp 3 (Fig. 32) with 6 natatory setae; 1st and 5th (Fig. 33) pereopods show chelate and subchelate nature respectively; 6th abdominal segment (Fig. 24) separated from telson; 3 pairs of pleopod buds appear on 2nd to 4th segments, first being the longest; rami of uropods unarticulated, inner being bare, bud-like and the outer elongated terminating in a long unarticulated spine, and 7 long plumose setae; telson process formula 6+1+6.

Glaucothoe — The stage (Figs 36-51) resembles adult in general appearance except for its symmetrical, clearly segmented abdomen and for its free swimming nature.

Appendages such as P 1-5, uropods and telson of left side rather more developed than those of the right side. Reduction in size; reduced rostrum; unequal chelipeds (left the larger); very long P2 and P3 are the characteristic features of this stage.

Carapace smooth, postero-lateral margins rounded, with well marked cephalic shield, typical of adult; rostrum much reduced; eyestalks stout, reaching to 1/2 the length of the last segment of the peduncle of A1; carapace with numerous hairs as illustrated.

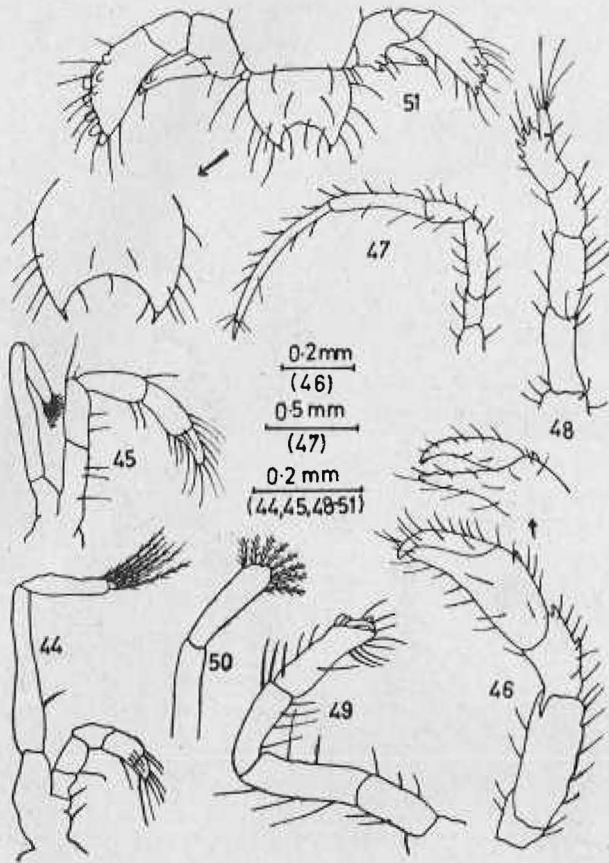


Figs. 24 to 35—Third zoea of *D. diogenes* [24, Entire larva (lateral); 25, antennule; 26, antenna; 27, mandible; 28, first maxilla; 29, second maxilla; 30, first maxilliped; 31, second maxilliped; 32, third maxilliped; 33, 5th pereopod; 34, pleopod; and 35, telson + uropod]

Figs. 36 to 43 — Glaucothoe of *D. diogenes* [36, Lateral view; 37, dorsal view; 38, antennule; 39, antenna; 40, mandible; 41, first maxilla; 42, second maxilla; and 43, first maxilliped]

A1 (Fig. 38): Peduncles, 3-segmented, segments almost of equal length with setation as illustrated; outer ramus 3-segmented with 2 and 3 aesthetascs on the inner distal angle of the 2nd and 3rd segments distalwards, and 3 small setae terminally; inner ramus slender, 2-segmented, reaching to the base of the 3rd segment of the outer ramus, with 4 setae terminally. A2 (Fig. 39): Peduncle 5-segmented, 1st short, 2nd with reduced, serrated scale, 3rd partly covered by the 2nd, 5th being the longest; flagellum 7-segmented with setae as illustrated. Md (Fig. 40): Typically like adult with dorsal and ventral plates well developed; 2-segmented palp armed with about 9 bristles distally. Max 1 (Fig. 41): Coxal and basal endites armed with setae as illustrated; palp bilobed with a single terminal seta on the proximal lobe. Max 2 (Fig. 42): Coxal endite divided into 2 unequal lobes; basal endite partially bilobed; all endites carrying tufts of setae as in adult; endopod slender, reduced and without any setae; scaphognathite fringed with about 38 marginal setae and a single simple seta on the distal lobe slightly below the marginal ones. Mxp 1 (Fig. 43): Coxal and basal endites with setation as illustrated; endopod slender, ribbon-like, without setae; exopod with broad basal part and a flagellar distal part with 4 long plumose setae

on the outer distal margin. Mxp 2 (Fig. 44): Endopod reduced, nearly half the exopod, 5-segmented (segmentation at the base is not very clear) with setose dactylus and distal part of propodus; exopod with incurved flagellum typically of adult, with 6 long plumose setae. Mxp 3 (Fig. 45): Endopod long reaching well beyond the exopod, 5-segmented with setae as illustrated, thicker on the distal 2 segments; exopod with 5 long plumose setae. P1-5: Unequal, left slightly longer than those of right. P1 (Fig. 46) chelate, fingers long and smooth, crossing at the tip; merus being the longest segment; few spines and setae are present as illustrated. P2 and 3 (Fig. 47) more or less similar except for the size, P2 slightly longer than P3; dactylus is the longest segment, nearly twice as long as propodus and 1/4th the carpus; merus nearly 1 1/2 the carpus; segments smooth except for the setation. P4 (Fig. 48) subchelate; smallest of all the pereopods; propodus ending in a broad pad of corneous spines forming a subchela with the dactylus; dactylus elongated, with tufts of setae as shown in figure. P5 (Fig. 49) corneous granules cover the distal part so as to hide the minutely chelate nature of the pereopod, long setae cover the segments. Abdomen (Figs. 36 and 37): 6-segmented, all segments broader than long, 3 pairs of pleopods



Figs. 44 to 51 — Glaucothoe of *D. diogenes* [44, Second maxilliped; 45, third maxilliped; 46, cheliped; 47, second pereopod; 48, 4th pereopod; 49, 5th pereopod; 50, pleopod; and 51, telson + uropod]

(Fig. 50) on 2nd to 4th segments; first two pleopods with 8 plumose setae each terminally while the 3rd with only 6 setae, the 3rd pleopod nearly half as long as the first one, all being uniramous. *Uropods* (Fig. 51): Asymmetrical, left the larger, much like adult, rami with corneous granules and setae as shown in the figure. *Telson* (Fig. 51): Posterior margin convex with 3 setae (2 dorsal and 1 dorso-medial) and spines at the postero-lateral angles, 4 setae laterally on each side.

Discussion

Though Gurney⁷ and Menon⁸ describe larvae of the genus *Diogenes*, the authentic information available is only in 3 species, viz. *D. pugilator*³, *D. bicristimanus*⁵ and *D. avarus*⁶. The present larvae, therefore, are compared with those of these 3 species hitherto described.

MacDonald *et al.*³ describe 4 zoeal stages for British species of *D. pugilator* and mention about the possible 5th zoea before the glaucothoe since their 4th zoea lack pleopod buds and mandibular palp. However, Pike and Williamson⁸ further state that 4 is a normal number of zoeal stages for this species in Mediterranean and Indian waters. *D. bicristimanus* and *D. avarus* possess respectively 5 and 4 stages while in the present material only 3 stages are recorded.

The 1st zoea of the present species may be differentiated from remaining 3 species as follows.

In *D. bicristimanus* and *D. pugilator* mid-dorsal spine present on 3rd, 4th and 5th abdominal somites (in *D. pugilator* absent in some) and in *D. avarus* only on 5th, whereas in *D. diogenes* 2 dorsal spines in addition to 2 strong lateral spines on 5th segment common to all species.

Al in *D. bicristimanus*, *D. pugilator* and *D. avarus* bear 3+2; 3+2 and 2+3 aesthetascs and simple setae respectively in addition to a long plumose seta which represents the inner ramus, while in the present species A1 bears 2 aesthetascs, 3 plumose setae terminally and 3 hair-like setae in place of the long plumose seta of other species.

Scale of A2 in *D. pugilator*, *D. bicristimanus* and *D. avarus* with 10, 9 and 10 setae respectively whereas in *D. diogenes* there are 11 setae in addition to a spine common to all species. Pereiopod buds lack in *D. pugilator* and *D. bicristimanus* whereas 3 pairs are noted in *D. avarus* and 4 pairs in the present species.

The third zoea of the present species is advanced over larvae of other 3 species in the following: (i) Antennal endopod 2-segmented; (ii) mandible palp developed as bud; (iii) three pairs of pleopod buds developed; (iv) telson process formula 6+1+6.

Information regarding the glaucothoe of *D. pugilator* and *D. bicristimanus* is very little for comparison. However, glaucothoe of the present species differs from *D. avarus* in the following:

Rostral scale absent in the present species whereas well developed in *D. avarus*. Second and 3rd segments of the outer ramus of antennule with 2 and 3 aesthetascs in the former whereas 3 and 4 in the latter. Mandibular palp, 2- and 3-segmented respectively in *D. diogenes* and *D. avarus*. Unsegmented palp of Max 1, bilobed with single seta in the present species while simple with a long seta and a hair distally and a plumose seta proximally in *D. avarus*. Exopods of first maxillipeds bear 4 and 3 setae respectively in *D. diogenes* and *D. avarus*. Chelipeds in the present species with few spines while absent in *D. avarus*; telson in the former with 2 prominent spines whereas in the latter these spines absent.

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