Larval Development of the Hermit Crab *Diogenes planimanus* Henderson (Decapoda, Anomura, Diogenidae) in the Laboratory

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Larval development of *D. planimanus* comprising 3 zoeal and a glaucothoe in addition to the 1st crab instar is described. Total duration of the zoeal stages up to the 1st crab instar is about 21 days at temperature range 25 to 27°C and salinity of about 33‰. Larvae are compared with those of the other species in the genus *Diogenes* wherein laboratory hatched larvae are known. Important generic features of 1st zoeae are summarised based on the hitherto described larvae.

Of the 42 species¹ so far described in the genus *Diogenes* authentic larval information is available in only 5 species, viz. *D. pugilator*²-³, from British waters—1st zoea obtained in the laboratory, remaining stages from plankton; *D. bicristimanus*⁴—5 zoeal stages and a glaucothoe; *D. avarus*⁵—4 zoeal stages, a glaucothoe and a crab instar; *D. diogenes*⁶—3 zoeal stages, a glaucothoe and a crab instar. All the latter 4 species are reared in the laboratory from the Indian waters. However, Gurney⁸ and Menon⁹ refer some of their larvae collected from plankton to the genus *Diogenes*.

The present paper gives an account of the entire larval development of a sandy shore hermit crab, *Diogenes planimanus* Henderson, obtained from laboratory hatchings (comprising three zoeal and a glaucothoe) and a crab instar.

**Materials and Methods**

Two ovigerous females were collected from intertidal sandy shore of Anjadiv Islands, about 8 km from Karwar and kept alive in aquaria with filtered sea water until the larvae hatched. The larvae were mass reared in 1000 ml plastic bowls with 50 larvae per bowl and individually in 25 ml bowls. The rearing technique was same as described by Kakati and Sankolli¹⁰. Freshly hatched *Artemia* nauplii were successfully tried for feeding.

During the experiment the temperature of sea water ranged from 25-27°C and salinity about 33‰.

**Results**

**First zoea**—Carapace length, 0.96 mm; abdomen length, 0.92 mm; duration of the stage, 5-6 days.

Eyes sessile: rostrum smooth, pointed, reaching beyond antennule and antenna (Figs 1 and 2); carapace smooth, postero-lateral margin rounded.

A1 (Fig. 3): Uniramous with 2 aesthetascs and 4 unequal setae terminaly and a long plumose seta subterminally representing the future ventral ramus. A2 (Fig. 4): Scale large, nearly twice as long as endopod, with a sharp, incurved spine terminaly and 10 marginal, plumose setae of which 1st seta (one near the terminal spine) is small and hair-like; endopod with 2 long plumose setae terminaly and a small seta subterminally; peduncle with a strong, stout ventral spine serrated on one side only. Md (Fig. 5): Asymmetrical, cutting edges bear a number of cornaceous, unequal, short teeth. M x 1 (Fig. 6): Coxal endite with 6 plumose setae; basal with 2 serrated teeth; palp 2-segmented with 2 terminal setae. M x 2 (Fig. 7): Both coxal and basal endites bilobed; proximal lobe of coxal with 5 terminal and 2 subterminal setae, the distal with 3 terminal and 1 subterminal setae; basal bears 3 terminal and 2 subterminal on proximal and 3 terminal setae on distal endites respectively; palp (endopod) unsegmented with a distal median notch and bears 4 terminal setae in 2 groups of 2 each; scaphognathite armed with 4 marginal plumose setae. M x p1 (Fig. 8): Basis fairly long with 8 setae as illustrated; endopod 5-segmented, setation being 2, 2, 1, 2 and 4+1 (outer) distalwards, 2nd and 3rd fringed with fine hairs on outer margin; exopod unsegmented with 4 natatory setae terminaly. M x p2 (Fig. 9): Basis with 4 setae; endopod 4-segmented with setation 2, 2, 2 and 4+1 (outer) progressing distalwards; exopod as in M x p1. M x p3 (Fig. 10): A small unsegmented uniramous bud. P1-5: Yet to be developed (in few larvae single pair of buds may be seen). Ab (Figs 1 and 11).
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Figs 1-11—First zoea of D. planimanus [1, entire larva, dorsal view; 2, entire larva, lateral view; 3, A1; 4, A2; 5, Md; 6, M x 1; 7, M x 2; 8, M x p1; 9, M x p2; 10, M x p3; 11, 12]. Figs 12-23—Second zoea of D. planimanus [12, entire larva, dorsal view; 13, entire larva, lateral view; 14, A1; 15, A2; 16, Md; 17, M x 1; 18, M x 2; 19, M x p1; 20, M x p2; 21, M x p3; 22, Pl-4; 23, T]. Figs 24-36—Third zoea of D. planimanus [24, entire larva, dorsal view; 25, entire larva, lateral view; 26, A1; 27, A2; 28, Md; 29, M x 1; 30, M x 2; 31, M x p1; 32, M x p2; 33, M x p3; 34, Pl; 35, Pl1; 36, T and U]. Figs 37-43—Glaucothoe of D. planimanus [37, dorsal view of glaucothoe; 38, lateral view of glaucothoe; 39, A1; 40, A2; 41, Md; 42, M x 1; 43, M x 2]
2): 5-segmented, first 4 segments broader than long, whereas, the 5th longer than broad with a pair of postero-lateral and a pair of medio-dorsal spines. T (Fig. 11): Triangular, as broad as the length of telson and fused 6th abdominal segment, posterior margin convex with a prominent median notch; process formula 7 + 7; 1st a small sharp, articulated spine, 2nd an 'anomuran hair', 3rd to 7th long, plumose setae, 5th process being the longest, 1/2 the telson breadth; posterior margin armed with minute spines between the processes, and fine hairs in the notch.

Chromatophores—Chromatophores (Figs 1 and 2) are few and mostly distributed in the cephalothorax as described below: A well branched chromatophore is present at the base of A1 and A2, forming a thick triangle of blood extending up to the rostrum; branched red chromatophores at the base of M × 1, M × p1 and M × p2; light yellow chromatophore on the 5th abdominal somite posteriorly as illustrated.

Second zoea—Carapace length, 1.07 mm; abdomen length, 1.04 mm; duration of the stage, 4-6 days.

This stage is marked by the following changes over the previous stage: Eyes are now movable (Figs 12 and 13).

A1 (Fig. 14): No change over previous stage except for a constriction at the distal end. A2 (Fig. 15): Long hair-like seta of scale of previous stage now longer and plumose; endopod setae reduced to 2 terminal setae. Md (Fig. 16): Slightly enlarged and the serrations increased. M × 1 (Fig. 17): Basal endite now with 4 serrated setae. M × 2 (Fig. 18): Except for the addition of a single marginal seta on scaphognathite no other change. M × p1 (Fig. 19): Exopod with 6 swimming setae; addition of a long, plumose seta each on outer margin of proximal 3 segments of endopod. M × p2 (Fig. 20): Exopod as in M × p1; addition of an outer plumose seta each on proximal 2nd and 3rd segments of endopod. M × p3 (Fig. 21): Exopod functional with 5 natatory setae; endopod unsegmented and bud-like. P1-4 (Fig. 22): Pereiopods developed as 4 pairs of small buds. T (Fig. 23): There is an addition of a pair of small setae near the notch: process formula 8 + 8; 8th process less than half the length of 5th process which continues to remain the longest.

Third zoea—Carapace length, 1.24 mm; abdomen length, 1.20 mm; duration of the stage, 4-6 days.

A1 (Fig. 26): Inner ramus with 2 long plumose setae; outer with 4 aesthetascs and 4 unequal setae terminally, as illustrated; peduncle with 3 long plumose setae. A2 (Fig. 27): Scale with 12 marginal setae; endopod now elongated, 2-segmented, reaching beyond the terminal spine of scale with a short terminal seta; addition of a small spine on the distal margin of basis. Md (Fig. 28): No change except for a rudimentary palp (absent in some). M × 1 (Fig. 29): Setae of coxa increased to 7. M × 2 (Fig. 30): Coxal and basal endites with 4 + 2, 1 + 2, 4 + 1 and 3 setae respectively on their proximal and distal endites; no change in palp; scaphognathite with 10 marginal, plumose setae; posterior lobe well developed but devoid of any setae. M × p1-3 (Figs 31-33): Endopod of M × p3 enlarged; no other change. P1-5: All 5 pairs as well developed buds, 1st (Fig. 34) shows chelate nature, 5th being subchelate. Ab (Figs 24 and 25): 6th segment separated from telson; 3 pairs of uniramous buds developed from 2nd to 4th segments, 1st (Fig. 35) being the longest. U (Fig. 36): Rami unarticulated; outer ramus long with elongated, pointed spine reaching nearly to the base of the postero-lateral margin of telson, with 7 plumose setae marginally; inner ramus small, bud-like without any setae. T (Fig. 36): Process formula reduced to 7 + 7, leaving a gap at the place of 4th process of previous stage; median notch reduced; 4th process the longest (5th of the previous stage).

Glaucothoe—Carapace length, 0.92 mm; abdomen length, 0.87 mm; duration of the stage, 7-8 days.

The larvae of this stage resemble adult in general appearance except for its almost symmetrical, clearly segmented abdomen. Larvae swim for some time after which they settle to the bottom and occupy tiny shells provided in the rearing containers. The glaucothoe were observed to change shells several times before selecting a suitable shell in which they stay for almost a week when they moulted to the first crab instar.

Carapace smooth (Figs 37 and 38); postero-lateral margin rounded, with a well developed cephalic shield as in adult; rostrum pointed, extends up to the ocular scale or slightly beyond; ocular scales minute and simple; eye-stalks stout, longer than broad, reaching beyond the base of antennular peduncle.

A1 (Fig. 39): Peduncle 3-segmented, segments almost of equal length with 2-3 setae; outer ramus 4-segmented with 0, 4, 3 and 2 aesthetascs distally and a single simple seta on distal segment; inner ramus slender, 2-segmented, reaching up to the base of 4th segment of outer ramus, with 4 setae terminally. A2 (Fig. 40): Peduncle 5-segmented, 1st short, 2nd with a reduced scale terminating in a pointed spine, 5th being the longest segment; setation as illustrated; flagellum 7-segmented with 0, 2, 2 + 3, 2, 2 + 3, 2 + 1 and 7 - 8 setae distally. Md (Fig. 41): As in adult, both dorsal and ventral plates well developed, armed with one or two blunt teeth; palp 2-segmented with 9-10 short bristles distally. M × 1 (Fig. 42): Coxal endite with 15-18 short bristle-like setae; basal endite armed with 15-20 short spine-like setae in addition to 2 long setae on the inner distal margin; palp unsegmented with a single terminal seta. M × 2 (Fig. 43): Coxal and basal endites bilobed, the former completely and the latter partially, all the endites carrying tufts of setae as illustrated; palp
slender, reaching up to the distal end of the scaphognathite, devoid of any setae; scaphognathite fringed with about 30 marginal plumose setae. M x p1 (Fig. 44): Flat, as in adult; coxal and basal endites with setation as illustrated; endopod slender, ribbon-like, without setae; exopod with broad basal part and a flagellated distal portion with 3 long plumose setae marginally. M x p2 (Fig. 45): Exopod 2-segmented, with incurved flagellum with 6 setae; endopod reduced, less than half the length of exopod, 5-segmented, with setation, 0, 1, 1, 4-5 and 7-8 distalwards. M x p3 (Fig. 46): Exopod as in M x p2; endopod long, 5-segmented, with setae on all segments more on the distal margin of 3rd to 5th distal segments. P1-5: Unequal, left side pereiopods slightly longer than those of right. P1 (Fig. 47): Chelate, left little larger than the right, fingers long and smooth except for few minute tubercles on the inner margin; merus is the longest segment; carpus with 2 spines on the distal margin; and propodus with a single spine at the base of movable finger; setae scattered all over as illustrated. P2 & P3 (Fig. 48): More or less similar in structure except for the size, left ones are little longer than right; P2 longer than P3; dactylus is the longest segment almost twice as long as propodus, terminating in a spine-like corneous claw; all segments smooth with scattered setae as illustrated. P4 (Fig. 49): Subchelate like in adult, smallest of the pereiopods; propodus short, broad at the base, ending in a pad of corneous granular denticles, forming a subchela with the dactylus; bears 1 or 2 long setae distally; long and short setae are present on all segments as illustrated. P5 (Fig. 50): Minutely chelate, corneous denticles covering the distal part, hide the chelate portion; long setae are present on the inner margin of propodus, carpus and merus. Ab (Figs 37 and 38): Nearly as long as carapace; 6-segmented, all segments broader than long; 3 pairs of pleopods (Figs 51-53) present on segments 2nd to 4th laterally; first pair being the longest, with 8 long plumose setae terminally; endopod represented by a small seta; 3rd pleopod nearly 1/3rd the length of Pl 1, with 3 setae; 5th segment bears 2-3 setae. U (P15) (Fig. 54): Asymmetrical, the left larger than the right as in adult; both rami with corneous granules and setae as illustrated. T (Fig. 54): Nearly as long as broad; posterior margin more or less convex with 3-4 setae in 2 rows dorsally and laterally; posterior margin with 3-4 setae; postero-lateral margins slightly thickened to form a tubercle-like structure.

First crab instar—This stage shows the typical...
asymmetrical nature of adult. Abdomen coiled, segmentation fainter, left side appendages larger than those of the right; telson well developed and adult-like.

Carapace with well developed cephalic shield and cervical groove, scattered setae all over, groups of plumose setae on lateral and posterolateral angles; eyestalks large, stout, dilated at the base; ophthalmic scales well developed and serrated distally; rostral scale reaches up to the tip of ophthalmic scales, simple with 1 or 2 terminal setae (Figs 55 and 56).

A1 (Fig. 57): Peduncle 3-segmented, as in glaucothoe; inner ramus now 3-segmented with 2, 1 and 7 setae distallywards; outer ramus 5-segmented with 0, 2, 6, 4 and 0 aesthetasces from 1st to 5th segments; 5th bears 2 simple setae terminally. A2 (Fig. 58): As in adult; peduncle slightly longer than antennular peduncle, 5-segmented, 2nd segment bears a spinose acicle reaching up to the half of the penultimate segment; 9-segmented flagellum with setation as illustrated. Md (Fig. 59): As in adult, cup-shaped; palp 3-segmented, distal segment with about 10 setae. M × 1 (Fig. 60): As in glaucothoe and adult. M × 2 (Fig. 61): As in previous stage, but for addition of setae on all endites and scaphognathite. M × p1 (Fig. 62): More like in adult; endopod reduced further; flagellar portion of exopod narrow and distinct but number of plumose setae continues to remain 3; basal and coxal endites setose. M × p2 (Fig. 63): As in previous stage, but for the increase in endopod setae. M × p3 (Fig. 64): As in adult; proximal segment of endopod with a prominent incurved spine-like projection; exopod 3-segmented, with 4-5 long plumose setae, 3 on the ultimate and 1 or 2 on penultimate segments. P1-5: More like setose and spinose than in glaucothoe. P1 (Fig. 65): Fixed and movable fingers of the cheliped with spines wherein were tubercles in the previous stage; addition of a spine on the propodus on the inner margin; long plumose hairs on ischium and merus. P2 and P3: Carpus with a spine on the distal margin; setae as illustrated. P4 (Fig. 66): More like adult, subchelate; corneous granules increase in number. P5 (Fig. 67): As in adult, minutely chelate, with spinose and corneous granules at the base of the chelate portion. Ab: Coiled, asymmetrical as in adult; segmentation is not clear; however, a faint depression with tufts of hairs mark the segmented nature of the body; setae all over the abdomen, more on anterior region; 4 pairs of pleopods present on 2nd to 5th segments (Fig. 68), uniramous, setose on left side, reduced to bud-like ones on the right side; pleopods are shorter than those in the glaucothoe, like in adult, with undulatory margin provided with plumose setae on either side; basipod (peduncle) provided with a single seta. U (Fig. 69): Those of left side larger than right; with a short protopod, bearing a larger outer and a shorter inner ramii, right nearly 2/3rd the left, as in adult; protopod produced into a short lobe; both ramii of each side armed with spines and corneous granules. T (Fig. 69): With prominent spines posteriorly, one on each side and 1 or 2 minute spinules in the centre; resembles adult telson.

Discussion

Laboratory hatched larvae in the genus Diogenes are known in 5 species. MacDonald et al. described 4 zoal stages and a glaucothoe in D. pugilator from British water. However, they mention the possibility of a 5th zoal stage, as their 4th zoal lacks pleopod buds and mandibular palp. They obtained the 1st zoal in the laboratory, remaining stages being collected from plankton. Pike and Williamson further remark, '4 is the normal number of zoal stages for this species in Mediterranean and Indian waters for D. pugilator. Sarojini and Nagbhushnam recorded 5 zoal stages and a glaucothoe for D. bicornistatus, reared in the laboratory, from the east coast of India. Sankolli and Shenoy gave an account of D. avarus comprising 4 zoal, a glaucothoe and a first crab instar obtained in the laboratory. Nayak and Kakati described 3 zoal and a glaucothoe stage for D. diogenes and Shenoy and Sankolli reared D. miles recording 3 zoal and a glaucothoe stage (abstract only), the latter 3 from the west coast of India.

Thus, of these 5 species only Diogenes diogenes, D. miles and the present species pass through 3 zoal stages before a glaucothoe. Hence comparison is possible among only 3 species. As the information on D. miles is yet to be published, the comparison of stages of the present species is made with only D. diogenes.

The first zoa of the present species differs from Diogenes diogenes in the following: A1 bears 2 aesthetascs and 4 unequal setae in addition to a subterminal plumose seta in the former as against 2 aesthetascs, 2 unequal setae terminally and 3 fine hairs subterminally in addition to a subterminal plumose seta in D. diogenes erroneously mentioned earlier as terminal). Scale of A2 with 10 marginal setae in D. planimanus whereas in D. diogenes 11; terminal spine short in the latter whereas longer and incurred in the former. Coxal endite of M × 1 with 7 and 6 setae respectively in D. diogenes and D. planimanus. Setation of M × 2 in D. diogenes is coxal, 6 + 1, basal, 4 + 3 and scaphognathite, 5 setae as against 7 + 3, 5 + 3 and 4 respectively in D. planimanus. Pereiopod buds absent or only one pair in D. planimanus whereas 4 pairs in D. diogenes (in D. miles also pereiopod buds are observed). Posterior margin of telson convex in the present species whereas almost straight in D. diogenes.

The larvae of present species differs from other larvae described hitherto in having —2 postero-dorsal spines on 5th abdominal segment whereas in D. miles,
D. avarus only 1 and in D. bicristimanus and D. pugilator mid-dorsal spines present on 3rd, 4th and 5th abdominal somites (in D. pugilator absent in some larvae).

On the basis of description of the larvae, generic features of the 1st zoea in the genus may be summarised as under: Rostrum smooth and pointed; carapace smooth; a pair of postero-lateral spines on 5th abdominal somite; telson with a pointed spine as 1st process; dorsal spine(s) on the abdominal somites; antennal scale with a terminal spine, peduncle with a prominent spine serrated mostly on one side.

The 2nd zoea of the present species differs from Diogenes diogenes in: scale of A2 with 10 plumose setae; peduncle with one spine; scaphognathite of M × 2 with 5 plumose setae; 4 pairs of pereiopod buds in D. planimanus as against scale of A2 with 11 plumose setae, peduncle with 2 spines; scaphognathite of M × 2 with 7 plumose setae; 5 pairs of pereiopod buds in D. diogenes.

The outer ramus of A1 in the 3rd zoea of D. planimanus with 4 aesthetascs and 4 unequal setae terminally, peduncle with 3 plumose setae; M × 2 with 6, 3, 5 and 3 setae on coxal and basal endites; exopod of M × p 3 with 5 natatory setae; telson process formula 7 + 7 whereas in D. diogenes, outer ramus of A1 with 3 aesthetascs and 2 unequal setae terminally, peduncle with 2 plumose setae; M × 2 with 8, 5, 5 and 4 setae on coxal and basal endites; exopod of M × p 3 with 6 setae; telson process formula 6 + 1 + 6.

The glaucothoe of the present species may be differentiated from those of D. diogenes and D. avarus in having 9 aesthetascs on 4-segmented outer ramus of A1; 3rd pleopod with 3 plumose setae and other variations in number of setae on appendages.

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