

# Redescription of *Ditrichocorycaeus minimus indicus* M. Dahl, 1912 (Copepoda: Cyclopoida, Corycaeidae) from the Adriatic Sea

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*In 1999 the small corycaeid copepod *Ditrichocorycaeus minimus indicus* was recorded for the first time in the Adriatic Sea. Both sexes are characterized by almost equal length and width of the anal somite and presence of the medial ventral hooks on the genital somite. Ventral hooks are prominent in male and minute in female. Detailed description of the species is given on the basis of the material from the middle Adriatic Sea and compared to the existing descriptions.*

## INTRODUCTION

Within the copepod family Corycaeidae, genus *Ditrichocorycaeus* M. Dahl, 1912 is the most speciose (Dahl, 1912; Razouls, 1996; Boxshall and Halsey, 2004). The name and definition of the taxon originates from M. Dahl (Dahl, 1912), who created it as one of the seven subgenera within the genus *Corycaeus* Dana, 1845, but has recently been elevated to generic level (Boxshall and Halsey, 2004). At present, it comprises at least 15 valid species (Boxshall and Halsey, 2004), widely distributed in warm waters of the Indo-Pacific, Atlantic and Mediterranean (Farran, 1911; Wilson, 1942; Sewell, 1947; Davis, 1949; Marques, 1966; Razouls, 1974; Bradford, 1978). Several authors have pointed out the difficulties in the identification of those species, whose small size and high similarity in general appearance led to much taxonomic confusion in the past and frequent descriptions of subspecies (Früchtl, 1924; Klevenhusen, 1933; Tanaka, 1957).

Two species of this genus have been recorded in previous surveys of the Adriatic Sea (Hure and Kršinić, 1998). *Ditrichocorycaeus brehmi* was first reported from the

Gulf of Trieste (Brehm, 1906) and subsequently described as *Corycaeus brehmi* by Steuer (Steuer, 1910). The presence of *Ditrichocorycaeus anglicus* in the Adriatic Sea was reported by Zavodnik (Zavodnik, 1956, 1961).

During the plankton investigations of the offshore middle Adriatic Sea in 1999, a third species was recorded in the area and identified as *Ditrichocorycaeus minimus indicus* M. Dahl, 1912. The small body of recent literature concerning this species might be associated with the difficulties in identification rather than scarcity of its abundance. In this article, we provide morphological analysis and detailed description of both sexes from the middle Adriatic Sea.

## METHOD

Material examined in this study was collected during cruises in May and October 1999 in the middle Adriatic Sea. Sampling was performed with the vertically towed Nansen opening–closing net (200 µm mesh size, 57 cm diameter, 255 cm total length). The samples were preserved in 2.5% formaldehyde solution, previously

buffered with  $\text{CaCO}_3$ . Specimens of *D. minimus indicus* were sorted under the compound microscope, dissected in lactic acid and mounted in lactophenol. Drawings were made with the aid of *camera lucida*, using an OLYMPUS BH-2 microscope with differential interference contrast. Specimens were measured using an ocular micrometer. The descriptive terminology employed largely follows Huys and Boxshall (Huys and Boxshall, 1991).

Type material deposited in the Laboratory of plankton at the Institute of Oceanography and Fisheries, Split, Croatia, derives from the following locations: JP-1 ( $43^\circ 29' 18''\text{N}$ ;  $15^\circ 43' 00''\text{E}$ ), 50–160 m layer (5♀); JP-3 ( $43^\circ 07' 36''\text{N}$ ,  $15^\circ 11' 30''\text{E}$ ), 100–200 m layer (2♀, 2♂), 192–260 m layer (4♂); JP-4 ( $42^\circ 47' 42''\text{N}$ ,  $14^\circ 48' 18''\text{E}$ ) 100–200 m layer (3♀); SG-2 ( $43^\circ 00' 00''\text{N}$ ,  $16^\circ 20' 00''\text{E}$ , 50–100 m layer (2♂); SG-4 ( $42^\circ 22' 00''\text{N}$ ;  $16^\circ 13' 12''\text{E}$ ), 0–50 m layer (3♂), 50–100 m layer (1♂).

Detailed study of *D. minimus indicus* distributional patterns at the same locations is in preparation.

## RESULTS

### Taxonomy

Family Corycaeidae Dana, 1852

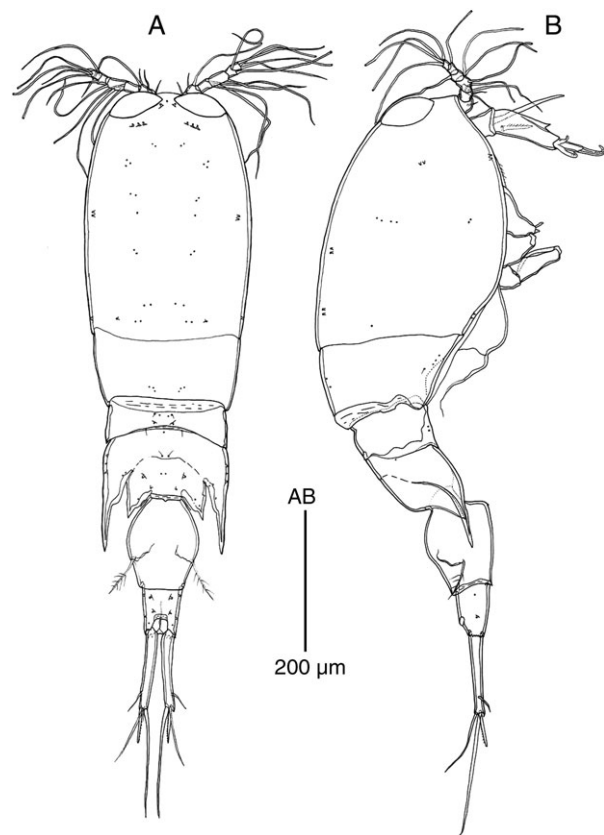
Genus *Ditrichocorycaeus* M. Dahl, 1912

*Ditrichocorycaeus minimus indicus* M. Dahl, 1912

### Description of female

Body cylindrical, tapering posteriorly. Total body length  $864.2\ \mu\text{m}$  ( $868.3 \pm 32.47\ \mu\text{m}$ ,  $n = 11$ ), measured from anterior margin of prosome to posterior margin of caudal rami. Greatest width measured at middle of cephalosome  $232.4\ \mu\text{m}$ . Urosome distinctly narrower than prosome (Fig. 1A).

Prosome five-segmented (Fig. 1A and B), comprising cephalosome and four pedigerous somites. In dorsal view 1.9 times longer than urosome. Frontal part of prosome rounded, bearing two large separate cuticular lenses. Rostral area as figured on Fig. 4A. First pedigerous somite separated from the cephalosome by a faint suture line and slightly wider than the successive somites. Second pedigerous somite distinctly separated from the previous and next somites, posterolaterally ending in small sharp angles. Third and fourth pedigerous somites incompletely separated along the dorsal margin, both posterolaterally projecting into points and extending posteriorly past one-half and one-fifth of the genital somite, respectively.



**Fig. 1.** *D. minimus indicus*, adult female. (A) Habitus dorsal view. (B) Habitus lateral view (swimming legs omitted).

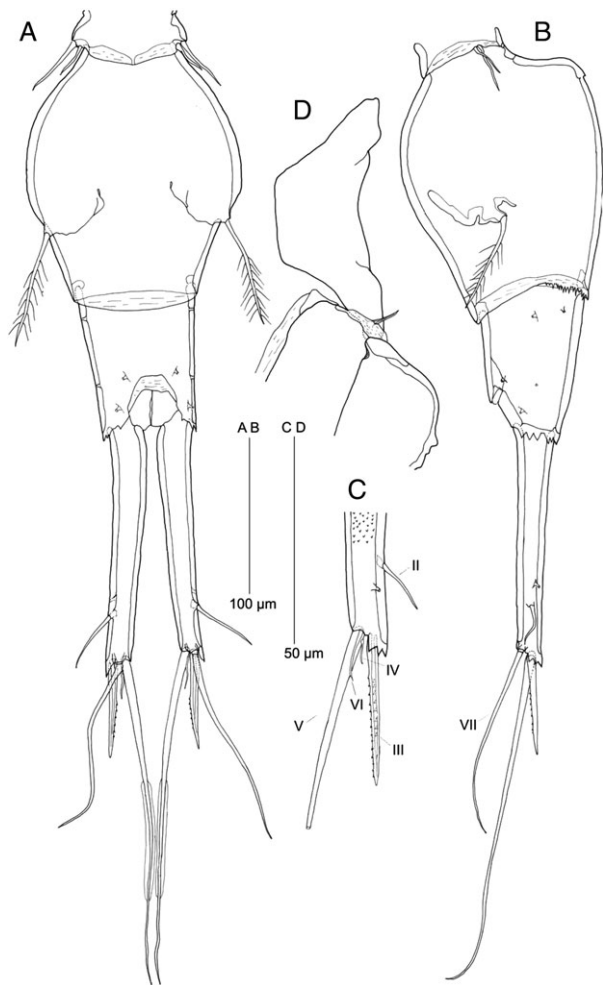
Urosome (Fig. 2A and B) three-segmented, comprising legs 5 bearing somite, genital double somite and anal somite.

Legs 5 bearing somite short and narrow, with legs 5 located ventrolaterally. Each leg reduced to two short setae (Fig. 2A and B).

Genital somite rounded, widest around the middle and 1.2 times longer than wide (Fig. 2A). Minute hook-like projection arising from the anterior ventral margin evident in lateral view (Fig. 2B). Distal margin of the somite ends with fine teeth ventrally, dorsal edge flat. Genital area positioned dorsolaterally, genital apertures paired, hidden behind opercula. Each operculum armed with one long plumose seta. Eggs carried in a single egg sac.

Anal somite (Fig. 2A and B) slightly tapering posteriorly, with large anal opening dorsally, 1.1 times longer than wide at base and 1.8 times shorter than genital somite. Distal margin ends with coarse teeth ventrally and dorsally. Ventral surface covered with minute spinules.

Caudal rami (Fig. 2A–C) cylindrical, 1.1 times shorter than genital somite, 1.7 times longer than anal

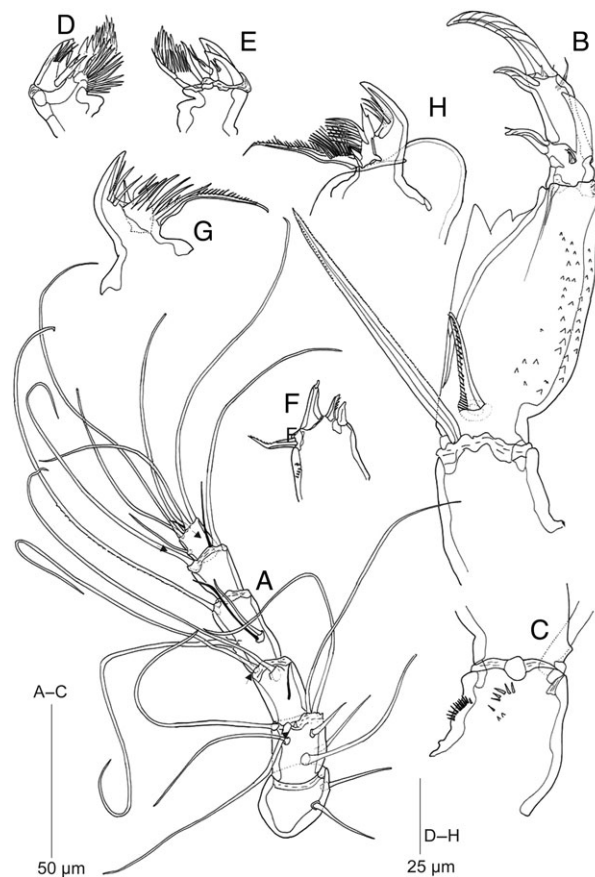


**Fig. 2.** *D. minimus indicus*, adult female. (A) Urosome dorsal view. (B) Urosome lateral view. (C) Caudal ramus ventral view (dorsal seta VII omitted). (D) Vestigial inner coxal seta on leg 3.

somite and approximately seven times longer than wide at base. Rami slightly divergent, ventral surfaces ornamented with minute spinules (Fig. 2C). Each ramus armed with six setae: short anterolateral seta (II), short bidentate posterolateral seta (III), outer terminal seta (IV) reduced and fused with the base of the long inner terminal seta (V), short terminal accessory seta (VI) and dorsal seta located on the small pedestal (VII).

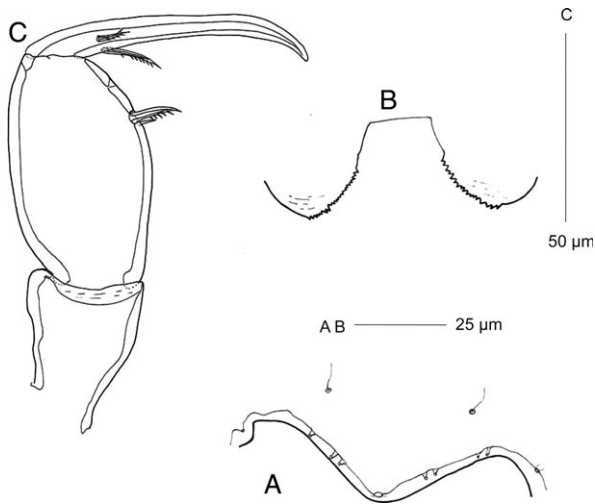
Antennule (Fig. 3A) short, six-segmented. Armature formula: 1-[2] (both short), 2-[8] (2 short), 3-[2+ae], 4-[3+ae] (1 short), 5-[2+ae], 6-[5+(1+ae)] (1 short). Aesthetascs (arrowed on Fig. 3A) short on segments 3 and 6, longer on segments 4 and 5. Segment 4 longest, with a long unidentate seta arising from the inner distal margin.

Antenna (Fig. 3B) uniramous, four-segmented, with coxa and basis fused and bearing three endopodal



**Fig. 3.** *D. minimus indicus*, adult female. (A) antennule (aesthetascs arrowed). (B) Antenna ventral view. (C) Antennal coxobasis dorsal view. (D) Mandible ventral view. (E) Mandible dorsal view. (F) Maxillule. (G) Maxilla dorsal view. (H) maxilla ventral view.

segments. Coxobasis 1.4 times longer than wide, with one powerful bipinnate seta arising from the inner distal margin and reaching over the distal margin of the next segment. Dorsal surface of coxobasis with several spinules medially and laterally (Fig. 3C). First endopodal segment robust, much longer than the successive segments, twice as long as wide, bearing one stout heavily plumose seta above the proximal margin which is 2.7 times shorter than the coxobasal seta. Inner distal margin of the segment ends in two powerful teeth, outer lateral margin and surface randomly ornamented with short teeth. Second endopodal segment short, equal in length and width, bearing three elements: curved spine arising from the outer distal margin, small stout spine located near its base and curved spine arising from the inner margin. Third endopodal segment cylindrical, twice as wide as long and armed with five elements: one stout terminal claw, two vestigial setae fused with its basis, shorter claw arising from the inner margin of the



**Fig. 4.** *D. minimus indicus*, adult female. (A) Rostral area. (B) Labrum. (C) maxilliped.

segment and one thin seta with the filamentous ending.

Labrum (Fig. 4B) bilobed, distal margin with numerous teeth.

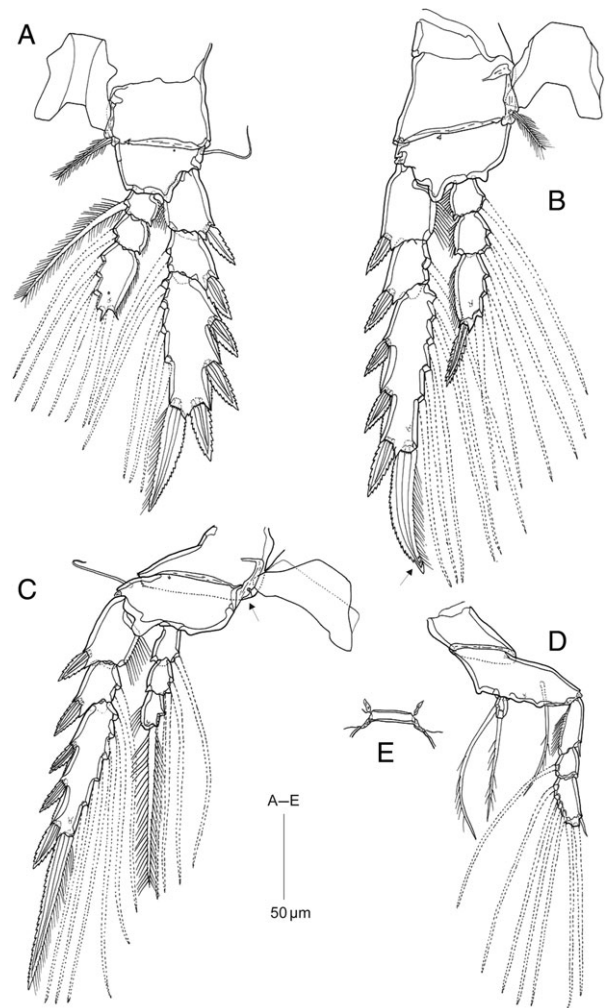
Mandible (Fig. 3D and E) comprising gnathobase with one spine and one blade, separated by the bifid process. Spine robust, bicuspid, with spiniform processes on both dorsal and ventral sides. Blade pectinate on top, surrounded by a row of spinules around the base.

Maxillule (Fig. 3F) reduced, bearing four articulated spinous elements.

Maxilla (Fig. 3G and H) two-segmented, with large unarmed syncoxa and small basis ending in curved claw distally and bearing two additional spinous elements.

Maxilliped (Fig. 4C) three-segmented. Syncoxa unarmed, 1.3 times longer than wide. Basis oval, with two elements arising from the inner palmar margin: short pinnate seta and tiny transparent seta near its base. Endopod drawn out and incorporated into strong claw, bearing two pinnate setae above the proximal margin.

Swimming legs 1–3 (Fig. 5A–C) each with coxa, basis and three-segmented rami. Intercoxal sclerites large, unornamented. Legs 1 and 2 coxae each with plumose inner coxal seta, leg 3 with vestigial seta in that place (Fig. 2D and arrowed in Fig. 5C). Distal outer coxal margin with several small teeth in legs 1–3. Bases with (legs 1 and 3) or without (leg 2) bare outer basal seta. Endopods distinctly shorter than exopods. Segments of both rami short and stout in leg 1, longer and more slender in legs 2 and 3. Exopod longest in leg



**Fig. 5.** *D. minimus indicus*, adult female. (A) Leg 1. (B) Leg 2. (C) Leg 3 (vestigial inner coxal seta arrowed). (D) Leg 4. (E) Intercoxal sclerite of leg 4 (setulation on most exopodal and endopodal setae omitted).

2. First exopodal segments with setules along the inner margin. Exopodal outer spines biserrate, terminal spines with serrate outer and pinnate inner margin. Terminal spine of third exopodal spine in leg 2 slightly curved inward, with several small teeth near the tip medially (Fig. 5B). Outer margins of endopodal segments with setules in legs 1 and 2, bare in first and second endopodal segments of leg 3. Terminal seta in third endopodal segment of leg 2 spiniform (Fig. 5B).

Leg 4 (Fig. 5D) with transversally prolonged protopod. Intercoxal sclerite narrow, almost rectangular in shape (Fig. 5E). Coxa unarmed, basis with outer basal seta arising from the posterior surface. Exopod well developed, three-segmented, with setules along the inner margin of the first segment. Endopod reduced to



Table I: Armature formula for swimming legs of *D. minimus indicus*

♀ ♂	Coxa	Basis	Exopod		Endopod			
Leg 1	0-1	1-0	1-0	1-1	III, I, 4	0-1	0-1	0, 2, 3
Leg 2	0-1	0-0	1-0	1-1	III, I, 5	0-1	0-2	0, 1, 3
Leg 3	0-1	1-0	1-0	1-1	III, I, 5	0-1	0-2	0, 1, 1
Leg 4	0-0	1-0	1-0	0-1	I, 6	-	-	0, 1, 1

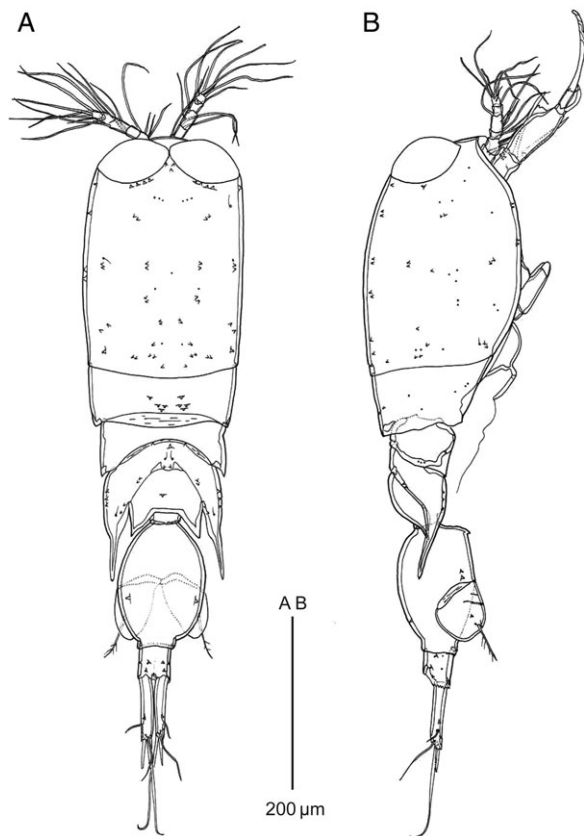


Fig. 6. *D. minimus indicus*, adult male. (A) Habitus dorsal view. (B) Habitus lateral view (swimming legs omitted).

a knob-like segment, with a long plumose terminal seta and one slightly longer plumose seta arising from the inner margin.

Armature formula for swimming legs as in Table I.

### Description of male

Body more slender than in female. Total body length 742.6  $\mu\text{m}$  ( $727.2 \pm 19.13 \mu\text{m}$ ,  $n = 13$ ), measured from anterior margin of prosome to posterior margin of

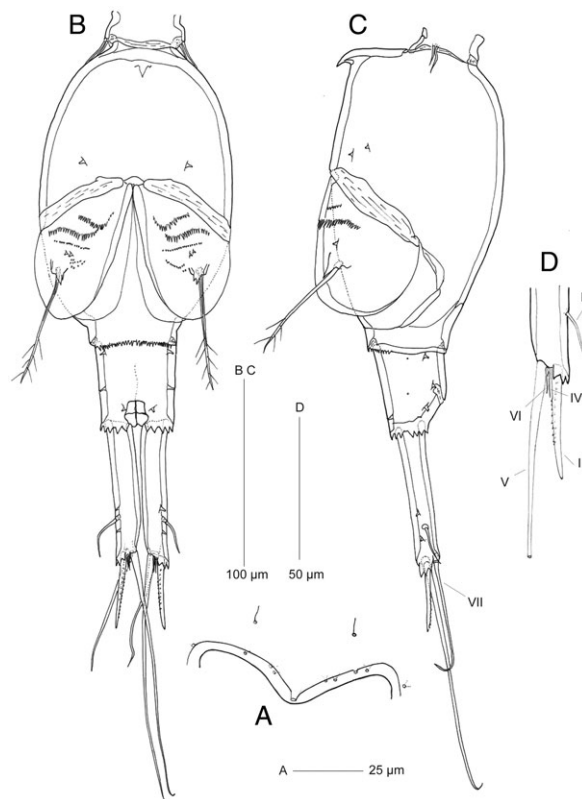


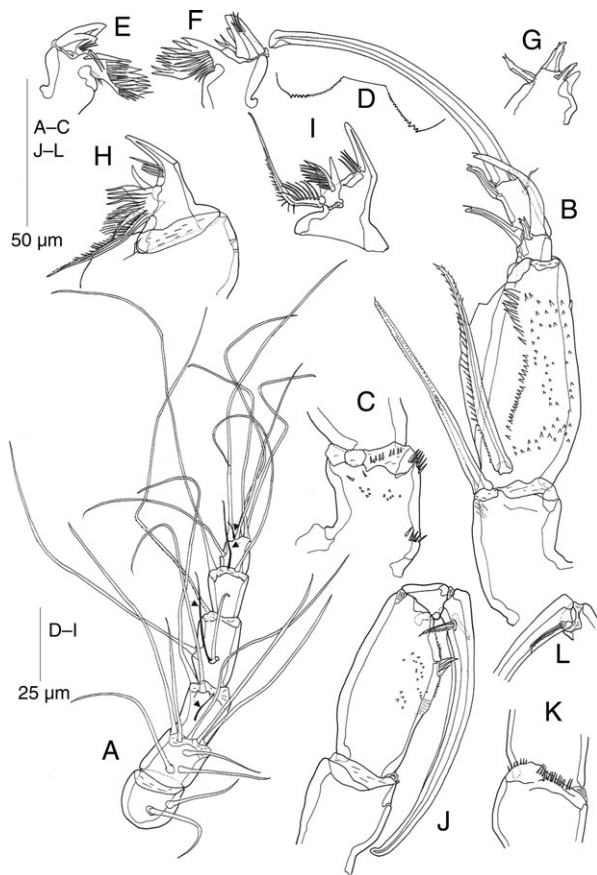
Fig. 7. *D. minimus indicus*, adult male. (A) Rostral area. (B) Urosome ventral view. (C) Urosome lateral view. (D) Caudal ramus ventral view (dorsal seta VII omitted).

caudal rami. Greatest width measured at middle of cephalosome 189.5  $\mu\text{m}$ .

Prosome (Fig. 6A and B) in dorsal view 1.6 times longer than urosome. Frontal part filled with two large almost contiguous cuticular lenses. Rostral area as figured on Fig. 7A. Third and fourth pedigerous somites completely separated along the dorsal margin, both posterolaterally projecting into points and extending posteriorly past one-third and one-eighth of the genital somite, respectively. Urosome segmentation and legs 5 as in female (Fig. 7B and C).

Genital somite oval, widest around the middle and 1.5 times longer than wide (Fig. 7B). Ventral hook arising from the anterior ventral margin prominent in lateral view (Fig. 7C). Distal margin of the segment with array of fine teeth ventrally; dorsal edge flat. Genital area positioned midventrally, genital openings paired, covered with flaps derived from sixth legs. Each flap medially bearing a long sparsely plumose seta with bidentate cover at the base. Medial surface above the setae ornamented with several rows of unequal teeth.

Anal somite (Fig. 7B and C) squarish, equal in length and width, with large anal opening dorsally, 3.7 times



**Fig. 8.** *D. minimus indicus*, adult male. (A) Antennule (aesthetascs arrowed). (B) Antenna ventral view. (C) Antennal coxobasis dorsal view. (D) Labrum. (E) Mandible dorsal view. (F) Mandible ventral view. (G) Maxillule. (H) Maxilla dorsal view. (I) Maxilla ventral view. (J) Maxilliped ventral view. (K) Dorsal view of maxilliped syncoxa. (L) Detail of maxilliped terminal claw.

shorter than the genital somite. Distal margin ends with coarse teeth ventrally and dorsally. Both surfaces unornamented, with several large tubular pores.

Caudal rami (Fig. 7B–D) parallel, cylindrical in shape, 1.7 times longer than anal somite and approximately five times longer than wide at the base. Armature of the rami similar to female's.

Antennule (Fig. 8A) with segmentation and armature similar to female's.

Antenna (Fig. 8B and C) sexually dimorphic, four-segmented, with coxa and basis fused and bearing three endopodal segments. Coxobasis 1.3 times longer than wide, with a powerful bipinnate seta arising from the inner distal margin and reaching over the distal margin of the next segment. Dorsal surface of coxobasis with several tufts of short spinules near the inner margin and random small teeth located medially (Fig. 8C). First endopodal segment much longer than the successive segments, almost twice as long as wide and bearing one

heavily plumose seta above the ventral proximal margin, equal in length to long coxobasal seta. Inner distal margin ends in two teeth, the outer sharp, the inner blunt. Outer lateral margin and its surface randomly covered with small teeth. Vertical array of coarse teeth gradually increasing in length towards the distal end of the segment located midventrally. Second endopodal segment short, 1.2 times wider than long, bearing three elements: powerful claw-like spine arising from the outer distal margin, small stout spine located near its base and shorter curved spine arising from the inner margin. Third endopodal segment cylindrical, 1.4 times wider than long, slightly swollen at base and armed with six elements: one terminal claw much longer than in female, almost equal in length to all endopodal segments combined, three vestigial setae fused with its basis, smaller curved spine arising from the inner margin of the segment and one thin seta with the filamentous ending arising from the outer margin.

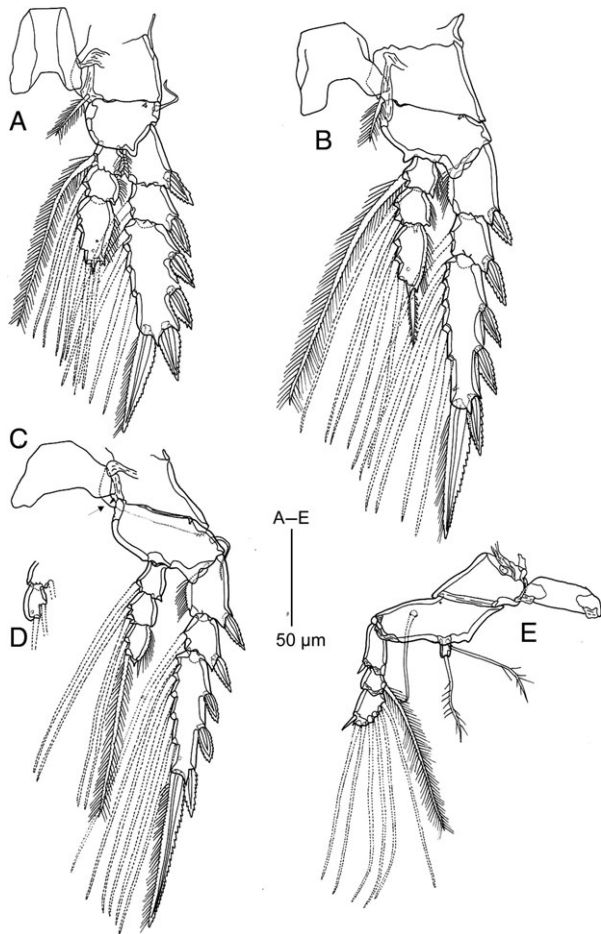
Mouth parts similar to those of the female, as figured on Fig. 8D (labrum), E and F (mandible), G (maxillule) and H and I (maxilla).

Maxilliped (Fig. 8J) sexually dimorphic, three-segmented. Syncoxa equal in length and width, with two separate arrays of spinules along the distal dorsal margin (Fig. 8K). Basis elongate, almost twice as long as wide, bearing two small setae on the inner palmar margin. Palmar surface around them covered with spinules. Endopod small and squarish, with terminal claw longer than in female. The claw equals in length to syncoxa and basis combined and proximally bears two pinnate setae (Fig. 8J and L).

Swimming legs 1–4 (Fig. 9A–E) in segmentation and armature similar to female's (Table I). Terminal spine of third exopodal segment in leg 2 straight (Fig. 9B).

## DISCUSSION

This copepod belongs to the genus *Ditrichocorycaeus* M. Dahl, 1912 which accommodates small corycaeid species characterized by the possession of two setae on the leg 4 endopod (Dahl, 1912). It is readily distinguished from the congeners present in the Adriatic Sea by the smaller size and proportions of the urosomites. The combination of almost equal length and width of the anal segment and the possession of ventral hooks on genital somites of both sexes are consistent with the description of *D. minimus indicus* M. Dahl, 1912. In her formidable monograph of the family Corycaeidae M. Dahl, (Dahl, 1912) established this subspecies on the basis of two female specimen from the Indian Ocean, indicating that they differed from *D. minimus minimus*



**Fig. 9.** *D. minimus indicus*, adult male. (A) Leg 1, (B) Leg 2. (C) Leg 3 (vestigial inner coxal seta arrowed). (D) Detail of the left leg 3 terminal endopodal segment. (E) Leg 4 (setulation on most exopodal and endopodal setae omitted).

F. Dahl, 1894, among others, by the slightly divergent instead of parallel caudal rami and the presence of minute protrusion on the ventral edge of genital somite. Farran (Farran, 1936) described two similar female specimens from the Pacific Ocean. Lakkis and Zeidane (Lakkis and Zeidane, 1987) gave short descriptions of both sexes of *D. minimus indicus* on the basis of the specimens from the eastern Mediterranean. Klevenhusen (Klevenhusen, 1933) also described a form of *D. minimus* with a ventral hook in both sexes from the Atlantic Ocean. However, his drawings and the short description indicate the possession of the well-developed ventral hook in female instead of a minute protrusion which characterizes *D. minimus indicus* M. Dahl, 1912.

General characteristics of *D. minimus indicus* females from the Adriatic Sea are in good agreement with the original description. However, Adriatic specimens are longer than 750  $\mu\text{m}$ , as measured by M. Dahl (Dahl, 1912). Apart from the fact that only two individuals

were measured in the original description, the observed difference might also be influenced by the recent measurement technique which calculates the total body length as the sum of the individual body somite lengths and takes into consideration the telescoping of body segments (Böttger-Schnack and Huys, 2001).

In the Adriatic material majority of the recorded females showed slightly divergent caudal rami, but few specimen with parallel caudal rami and ventral hooks on the genital somite were also observed. Again, since both earlier descriptions (Dahl, 1912; Farran, 1936) were made on the basis of two specimen, it is uncertain if some variability regarding this character occurred in the population. In the eastern Mediterranean specimens divergent caudal rami was also regarded as an important distinguishing characteristic of *D. minimus indicus* and no variability in the population was mentioned (Lakkis and Zeidane, 1987).

General morphology of *D. minimus indicus* males from the Adriatic Sea is in good agreement with the description offered by Lakkis and Zeidane (Lakkis and Zeidane, 1987), but some differences concerning body segmentation and comparative lengths of the urosomites are noticed. Lakkis and Zeidane (Lakkis and Zeidane, 1987) drew their males and females with the first pedigerous somite incompletely separated from the cephalosome, while in the Adriatic *D. minimus indicus* specimens there is a faint suture line defining the somite boundary from the cephalosome in both sexes. In addition, the male anal somite is slightly longer than one-half of the caudal rami length observed in the eastern Mediterranean specimens.

The presence of the vestigial inner coxal seta in the third pair of swimming legs in both sexes has not previously been reported, either in *Ditrichocorycaeus* or corycaeids in general. During this investigation a similar rudimentary coxal seta has also been observed in the third pair of swimming legs in both sexes of *D. anglicus* and *D. brehmi* from the Adriatic Sea (Vidjak, 2004).

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