

NEODIAPTOMUS PRATEEK N. SP., A NEW FRESHWATER COPEPOD FROM ASSAM, INDIA, WITH CRITICAL REVIEW OF GENERIC ASSIGNMENT OF NEODIAPTOMUS SPP. AND A NOTE ON DIAPTOMID SPECIES RICHNESS (CALANOIDA: DIAPTOMIDAE)

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ABSTRACT

Neodiaptomus prateek n. sp. is described based on a plankton sample collected from Deepor Beel, a floodplain lake in the north-eastern, Indian state of Assam, which falls within the key biodiversity area of the Indo-Burma Hotspot. The new species fulfils all the principal criteria of the genus *Neodiaptomus* Kiefer, 1932, as revised by Kiefer (1939). It has, however, a spectacular autapomorphic feature, which is perhaps unparalleled in Diaptomidae as a whole – a massive coxal plate ending in a thumb-like spinulose structure on the caudal surface of the male left P5. The new taxon also has two homoplastic characters that are hitherto unknown within the genus: the female fourth pediger has a prominent mid-dorsal process, and the third endopodal segment of P2-P4 has six instead of seven setae, the proximal outer seta being absent. The affinities of the new species with its congeners are discussed. Furthermore, the generic assignment of all the 13 species of *Neodiaptomus* listed in the latest World Copepoda database (Walter, 2012) is critically reviewed. Of these, five species are recognised as valid, six are relegated to *species inquirendae*, and one each is a *nomen dubium* and a synonym. Two lineage groups are recognised within the genus, one belonging to Southeast Asia and the other mostly confined to India. Surprisingly, the new species was accompanied by a record number of seven other diaptomid species in the same sample; the probable biogeographic and ecological implications of this high species richness are briefly discussed.

KEY WORDS: Assam-gateway, biogeography, Indo-Burma Hotspot, *Neodiaptomus*, species richness

DOI: 10.1163/1937240X-00002195

INTRODUCTION

While attempting a new system of classification of Diaptomidae Baird, 1850, Kiefer (1932a) proposed the genus *Neodiaptomus* with a provisional definition based on only two criteria: 1) endopod of female P5 without terminal setae; and 2) endopod of male P5 very strongly built. Realising that both these criteria are rather trivial, Kiefer himself (1939: 126) revised the generic diagnosis based on his extensive work on the Indian species of *Neodiaptomus*. The revised diagnosis in translation reads thus: “Animals of moderate body size (1.1-1.5 mm, without caudal setae). Female: body relatively plump; antennules extraordinarily long; P5 mostly asymmetrical, right P5 being stouter than left P5, terminal claw with coarse denticles. Male: right P5 coxa produced at inner corner into nearly triangular, pointed or bifid lobe, and endopod flask-shaped with dilated base; left P5 exopod 2-segmented, first segment slender, second one small, roundish, apex having 1 small spherical structure and 1 short seta. Left [*sic*] caudal ramus of male with tooth-like chitinous outgrowth ventro-distally.” Of these generic features, I consider, inter alia, the denticulate terminal claws of female P5 in conjunction with the tooth-like chitinous structure on the male right caudal ramus as being diagnostic to the genus group. In addition, the relatively short genital double-somite of the female seems to be yet another decisive character of

this group. On the whole, Kiefer’s (1932a) diaptomid system still continues to be typological, with no distinct ‘structural gaps’ between several genera (Ranga Reddy, 1987). As a result, several authors including Kiefer himself have to assign certain species to genera rather arbitrarily (Ranga Reddy et al., 2000).

Initially, following Kiefer (1935b, 1939), Ranga Reddy and Subba Reddy (1992) briefly reviewed the taxonomic status of the then known 12 nominal species of *Neodiaptomus* of the Indian subcontinent. After effecting the necessary synonymy, reallocation and suppression of certain species, they recognized as valid only the following four: *N. schmackeri* (Poppe and Richard, 1892), *N. physalipus* Kiefer, 1935, *N. lindbergi* Brehm, 1951, and *N. intermedius* Flössner, 1984. Ranga Reddy (1994), while writing a guide book, further enlarged Kiefer’s (1939) generic diagnosis (see below) only in order to make it consistent with the overall morphological diversity of the 12, then-known, Asian species, but he performed no critical analysis of the interspecific relationships of the species and genera. Subsequently, Ranga Reddy et al. (1998, 2000) studied certain Southeast Asian diaptomid species and carried out further reallocation of the species. According to the latest World Copepoda database on the genus *Neodiaptomus* (Walter, 2012), out of the original 30 nominal species and one nominal subspecies, 13 species are apparently valid (“direct child taxa” of *Neodiaptomus*).

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Clearly, however, all these species do not represent a monophyletic group. Further revisions based on modern morphologic and molecular methods are necessary to put the genus on firm phylogenetic grounds.

This paper describes a new species, *Neodiaptomus prateek*, from Deepor Beel, a floodplain lake in the north-eastern state of Assam, India, and discusses its relationships with its congeners. A critical review is made of the generic assignment and nomenclature of all the 13 putatively valid species of *Neodiaptomus*. Furthermore, as the new species was found co-occurring with seven other diaptomid species in one and the same sample – the highest diaptomid species richness known so far – some biogeographic and ecological notes are provided.

MATERIAL AND METHODS

The description of *N. prateek* is based on specimens sorted from a single large plankton sample collected from a floodplain lake called Deepor Beel, which is located in the north-eastern Indian state of Assam (Fig. 1). The sampling was done for about 20 minutes at dusk time from a rowboat, using a plankton net (diameter 25 cm, mesh size 70 μm). The sample was fixed in the field in about 5% formaldehyde and later preserved in 70% alcohol. The simultaneously taken specimens of the various co-existing diaptomid

copepods were separated by sex, measured for body length. Dissection was carried out in glycerol under a binocular stereomicroscope at a magnification of 90 \times . Drawings were made with the aid of a drawing tube mounted on a Leica DM 2500 Trinocular Research Microscope, equipped with a UCA condenser, IC objective prism and 1-2 \times magnification changer. All the measurements were made with an ocular micrometer and a stage micrometer. Permanent slide preparations were mounted in glycerol, and sealed with paraffin and Araldite. Some digital images were taken with a Leica DC 150 (Cannon S80) camera. The type material was deposited in the Muséum national d'Histoire naturelle, Paris (prefix MNHN) and also in the National Zoological Collections of the Zoological Survey of India, Kolkata.

SYSTEMATICS

Order Calanoida Sars, 1903

Infraorder Neocopepoda Huys and Boxshall, 1991

Diaptomidae Baird, 1850

Diaptominae Baird, 1850

Neodiaptomus Kiefer, 1932a

Partially Emended Diagnosis (from Ranga Reddy, 1994).— Animals of moderate size (1.1-1.5 mm, without caudal setae). Female: antennules long, extending beyond caudal setae. Fifth legs mostly asymmetrical, right leg stouter than left one; third exopod segment reduced or represented

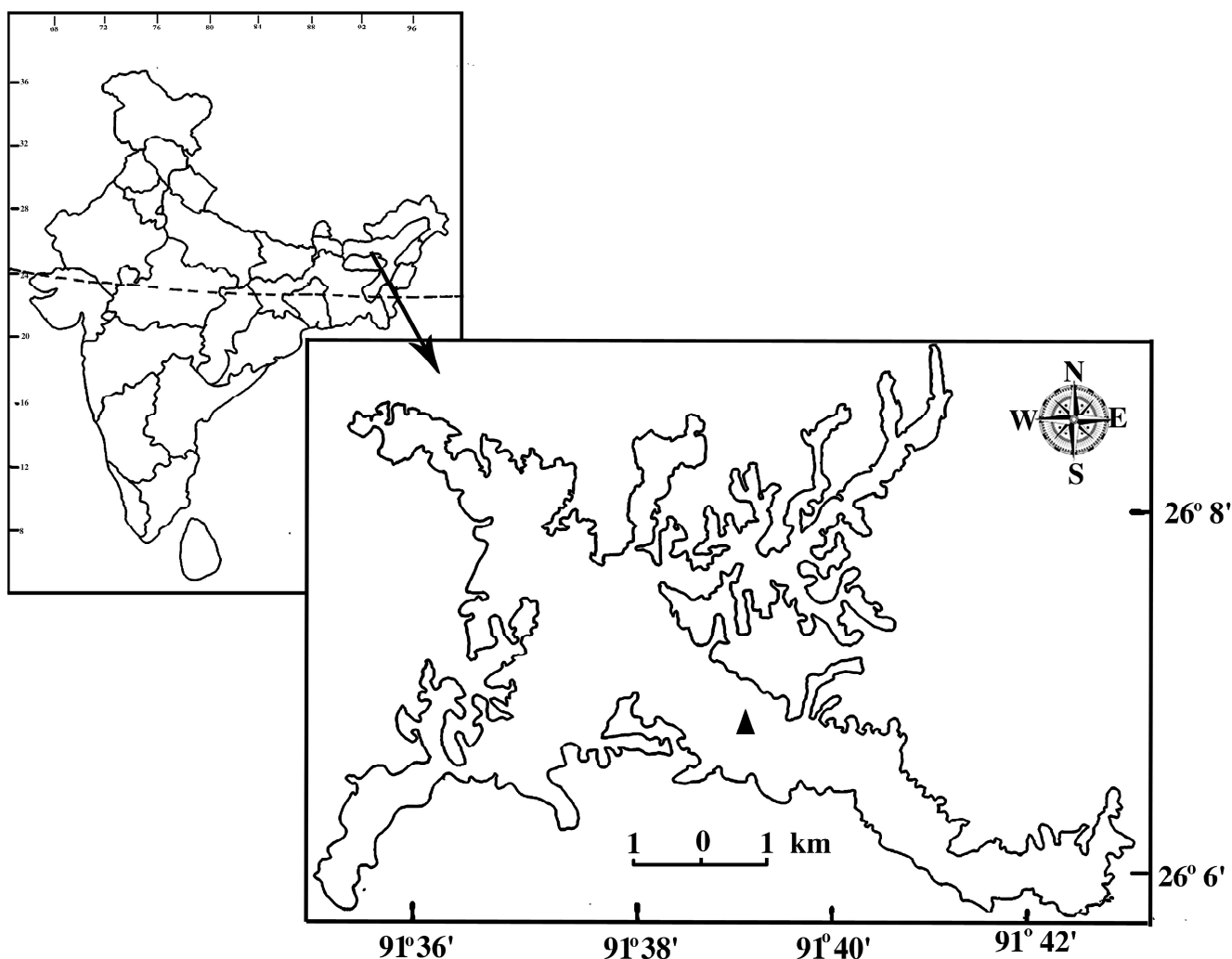


Fig. 1. Map showing the sampling site (▲) at the type locality (Deepor Beel) of *Neodiaptomus prateek* n. sp.

by 2 unequal spines; apex of endopod obliquely cut on inner margin, pointed, with relatively large spinule at disto-medial corner. Male: right antennule with spine on each of segments 10, 11, 13-15; antepenultimate segment with long or sometimes short spinous process. On right leg 5, coxa produced into somewhat triangular, pointed or bifid lobe (intercoxal plate) at distal inner corner; endopod long, 1-segmented, dilated at base and attenuating apically (pyriform); lateral spine inserted generally at the middle of outer margin of second exopod-segment. Second exopod-segment of left leg 5 short, with small thumb-like process and short seta apically. Right caudal ramus with tooth-like chitinous structure at inner ventro-distal corner.

Remarks.—As was mentioned in the Introduction, the genus *Neodiaptomus*, like several other diaptomid genera as they stand today, cannot be considered a monophyletic group (see below). In-depth phylogenetic analysis of these taxa is essential. In the present situation, various workers, sometimes with minor revisions, are following the original generic definitions routinely by adopting a typological attitude. As for the generic criteria of *Neodiaptomus*, none can be singled out as signal synapomorphy of this group; almost all of them are shared with some member(s) of certain other genera.

Type Species.—*Neodiaptomus schmackeri* (Pope and Richard, 1892).

Other species: *N. meggitti* Kiefer, 1932b, *N. lymphatus* (Brehm, 1933), *N. physalipus* Kiefer, 1935b, *N. lindbergi* Brehm, 1951, *N. yangtsekiangensis* Mashiko, 1951, *N. laii* Kiefer, 1974a, *N. intermedius* Flössner, 1984, *N. vietnamensis* Dang and Ho, 1998, *N. madrasensis* Roy, 1999, *N. curvispinosus* Dang and Ho, 2001, *N. songkhramensis* Sanoamuang and Athibai, 2002, and *N. siamensis* Proongkiat and Sanoamuang, 2008.

***Neodiaptomus prateek* n. sp.**
(Figs. 1-10)

Type Locality.—Deepor Beel (26°05'-26°11'N, 91°35'-91°43'E; elevation 42 m), is a Ramsar Site and an important floodplain lake, 10 km southwest of Guwahati town in the northeastern state of Assam (Fig. 1); it is part of the key biodiversity area of the Indo-Burma Hotspot. Essentially, Assam state has temperate climate, with hilly areas usually experiencing subalpine conditions. Deepor Beel is the largest wetland ecosystem of the Brahmaputra River basin in Assam. It has a perennial water-holding area of about 10.1 km², extending up to 40.1 km² during seasonal floods. The depth increases up to 4 m during the rainy season (late June to September) and drops to 1 m during winter (late October to late February). The Government of Assam declared the 10.1 km² area as the 'Deepor Beel Wildlife Sanctuary' in 1989 and also designated it as a 'Bird sanctuary' in view of the regular visit of about 120 seasonal, migratory birds together with the resident ones (Gogoi, 2007). Collector, Y. Ranga Reddy, 4 May 2010.

Material Examined.—Holotype female, dissected on four slides (MNHN-IU-2009-3962); allotype male, dissected on 6 slides (MNHN-IU-2009-3963); 2 male paratypes: paratype-1 dissected on 4 slides (MNHN-IU-2009-3964); paratype-2 partially dissected on 1 slide (MNHN-IU-2009-

3965); all deposited in the National Museum of Natural History, Paris. One male paratype, partially dissected on 1 slide, deposited in the National Zoological collections of the Zoological Survey of India, Kolkata (ZSI C6052/2); 1 male paratype, partially dissected on 1 slide, in the author's collection.

Other localities: none.

Diagnosis.—Female: fourth and fifth pedigerous somites separated by weak septum; fourth pediger with prominent upturned, conical process mid-dorsally; right caudal ramus somewhat shorter than left one, inner margin of both rami hairy; P5 endopod 2/3 as long as inner margin of first exopodal segment, with obliquely truncate and finely spinulose apex; second exopodal segment with short lateral spine, and terminal claw clearly denticulate on inner margin; third exopodal segment small but distinct and armed with 2 unequal spiniform setae. Male: right caudal ramus with moderately large chitinous structure at inner ventro-distal corner; urosomites 2 and 3 with hair-like setae on ventral margin; right antennule with spine or spinous process on each of segments 10, 11, 13-15, and spinous process on antepenultimate segment generally claw-like and longer than next segment; third endopodal segment of P2-P4 with 6 (instead of 7 setae, typically in Diaptomidae), proximal outer seta being absent; right P5 basis rectangular, with hyaline lobe on caudal surface close to inner margin; inner margin with 2 divergent, short chitinous projections; endopod cylindrical, only slightly longer than first exopodal segment; second segment obovate; lateral spine distinctly shorter than its segment, inserted on caudal surface just posterior to midlength of outer margin, and forked at about mid-outer margin; terminal claw slender; left P5 carrying massive coxal plate on posterior surface, plate ending in thumb-like spinulose structure; endopod typically long and 2-segmented.

Description of Adult Female (Holotype).—Total length excluding caudal setae 1600 μm. Body robust, widest at first pedigerous somite (Fig. 5A); prosome and urosome 1210 μm and 390 μm, respectively. Rostrum (Fig. 2C) symmetrical with moderately strong, acutely pointed, paired filaments, delineated from frontal margin of cephalic shield by complete suture, and ornamented with 2 sensilla adjacent to suture. Cephalosome with incomplete suture dorsally (Fig. 5A). Fourth and fifth pedigerous somites separated by weak septum; no dorsal spinules discernible between them under light microscopy. Fourth pediger with prominent, upturned, conical process mid-dorsally (NB: This process appears as a dark spot dorsally (Fig. 2A) when observed with no cover-slip, but as an obliquely right-turned conical structure, as in Fig. 5A, B, under a cover-slip). Fifth pediger with moderately developed, asymmetrical postero-lateral wings; right wing distinctly smaller than left one; both wings with incurved outer margin, somewhat convex inner margin, 1 small postero-lateral hyaline spine and another very similar spine on posterior border close to inner corner; left wing extending beyond level of right wing, both wings barely reaching respective spine on genital double-somite.

Urosome of 3 somites. Genital double-somite about as long as succeeding somites and caudal rami combined, moderately strong, asymmetrical; right proximal region

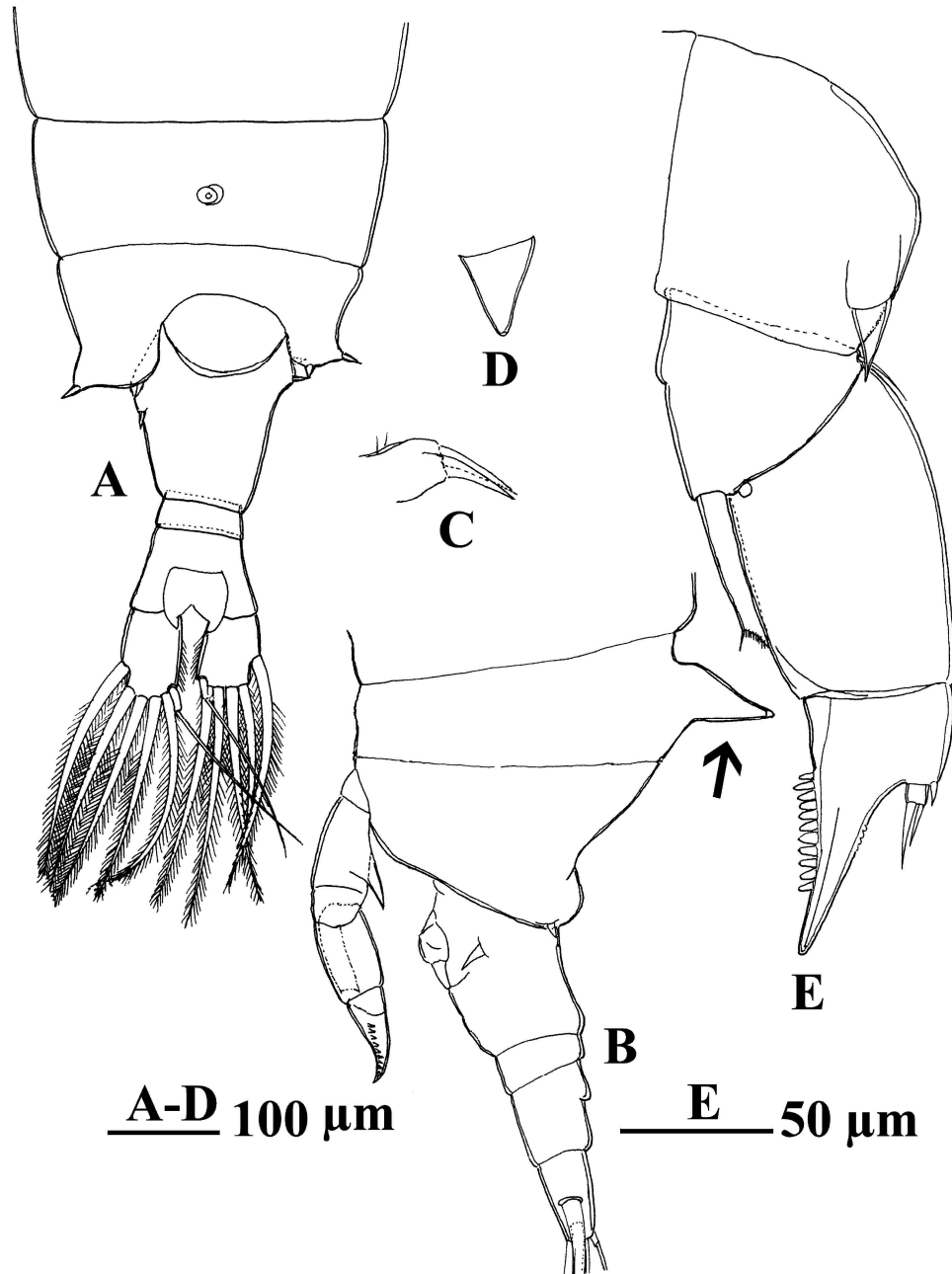


Fig. 2. *Neodiaptomus prateek* n. sp., A-E, holotype female. A, pediger 4, 5, and urosome, dorsal view; B, same, lateral view (arrow points to the mid-dorsal process of fourth pediger); C, rostrum, lateral view; D, mid-dorsal process of pediger 4 (under cover slip); E, P5, posterior view.

slightly dilated proximally and with small, laterally directed, hyaline spine; left sub-proximal region of this somite also dilated and with small, posteriorly-directed spine, close to margin as in Fig. 2A. Second urosomite smallest, partly telescoped into preceding somite. Anal somite as long as left caudal ramus, and widening posteriorly. Caudal rami parallel and asymmetrical, right being somewhat shorter than left ramus; right ramus about as long as wide, left ramus 1.4 times as long as wide; both rami with hairy inner margins. All principal caudal setae with slightly dilated proximal third and with very vague transverse suture (not figured); jointed, weak dorsal, setae about as long as principal setae.

Antennule (Fig. 3A-C): 25-segmented, long, surpassing caudal setae by last 1 or 2 segments (Fig. 5A). Number of setae (s), spines (sp), and aesthetascs of each segment as follows: (1) s + a, (2) 3s + a, (3) s + a, (4) s, (5) s + a, (6) s, (7) s + a, (8) s + sp, (9) 2s + a, (10) s, (11) s, (12) s + sp + a, (13) s, (14) s + a, (15) s, (16) s + a, (17) s, (18) s, (19) s + a, (20) s, (21) s, (22) 2s, (23) 2s, (24) 2s, and (25) 5s + a.

Antenna and oral parts like corresponding appendages as in *Eodiaptomus shihi* Ranga Reddy (see Ranga Reddy, 1992).

Maxilliped (Fig. 4A): 4 moderately strong coxal endites, carrying 1, 2, 3, and 4 setae, respectively. Endopod perpen-

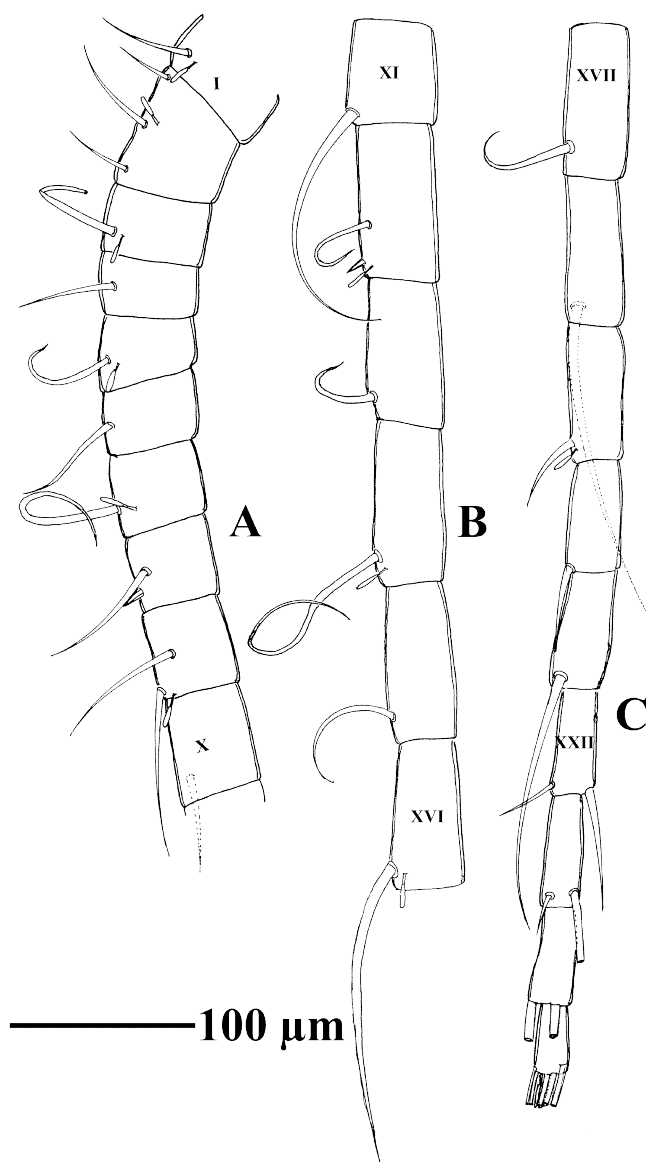


Fig. 3. *Neodiaptomus prateek* n. sp., A-C, left antennule, holotype female. A, segments 1-10; B, segments 11-16; C, segments 17-25.

dicular to coxa and basis. Armature and ornamentation as illustrated.

P1-P4 (Fig. 4B-E): segmentation and armature of P1 typical of Diaptomidae. Third endopodal segment of P2-P4 with only 6 setae, proximal outer seta being absent; second endopodal segment of P2 without Schmeil's organ; otherwise, segmentation and armature as in other diaptomid species (see Discussion).

P5 (Figs. 2E, 5C): both legs symmetrical. Coxal spine on both legs similar in shape and size, moderately strong, conical, acutely pointed. Basis indented on sub-proximal inner margin; sensory seta on outer margin small. First exopodal segment 1.6 times as long at outer margin as wide, cylindrical. Second segment tapering into moderately strong claw, ornamented with 11 coarse denticles on inner margin, denticles on outer margin rudimentary; lateral spine small, about as long as third segment. Third segment small but distinct, squarish, and with 2 unequal, naked

apical spiniform setae; inner seta only slightly longer than outer one and barely reaching midlength of terminal claw. Endopod slender, cylindrical, 0.7 times as long as inner margin; apex obliquely truncate, with transverse row of closely-set fine spinules; 1 spinule at inner corner longer than others.

Description of Adult Male (Allotype).—Total length excluding caudal setae 1350 μ m. Body slenderer than in female. Prosome about 2.2 times as long as urosome. Rostrum (Fig. 6D) asymmetrical with short process on right side of basal part; rostral filaments as in female, but thinner. Fourth and fifth pedigers separated by distinct septum; fourth pediger without any trace of mid-dorsal process. Lateral wings of fifth pediger small and asymmetrical; right wing rounded, with 1 tiny apical spine and 1 lateral, somewhat long and slender spine (or sensillum?); left wing triangular and with 1 apical and 1 inner sensillum-like unequal spines, apical one longer.

Urosome of 5 somites, bent to right side (Figs. 6A, 6B, 8A). Genital somite wider than succeeding somites; right distal corner armed with short, postero-laterally directed spine. Second and third urosomites fringed with long, hair-like setae on ventral margin (Fig. 6B). Fourth urosomite asymmetrical, produced at right distal region into triangular lobe. Right caudal ramus (Figs. 6E-G, 8F) 1.6 times as long as wide, armed with moderately large, conical, pointed chitinous tooth at disto-medial corner of ventral surface. Left caudal ramus twice as long as wide and without any additional armature; both rami with hairy inner margins (Fig. 6C). Caudal setae dilated and weakly jointed at about proximal third; lateral setae unmodified and similar to other setae; dorsal setae somewhat shorter than principal setae.

Antennules: right antennule 22-segmented, geniculate between segments 18 and 19; with spine or spinous process on each of segments 8 and 10-15; spine on segment 13 strong but short, pointed and with accessory hyaline lobe at base of posterior margin; spines on segments 8 and 12 rudimentary, as in female; relative length of spines in decreasing order as follows: $13 > 11 > 15 > 14 > 10 > 12 > 8$; spinous process on antepenultimate segment moderately strong, claw-like, and longer than next segment; apex pointed; outer margin lined with narrow hyaline membrane (Fig. 8C). Left antennule reaching to tips of caudal rami; armature details (Fig. 7A) as in female.

Other cephalic appendages and P1-P4 as in female; third endopodal segment of P2-P4, like in female, without outer proximal seta (Fig. 8E).

Right P5 (Figs. 9A-D, 10A-D): moderately built. Coxa somewhat rectangular and armed with small spine at about distal third on caudal surface, distal inner corner not produced. Basis slightly longer than wide, rectangular in outline; inner margin with 2 small dentate chitinous processes, 1 sub-proximal and oriented anteriorly; the other located at about midlength and oriented posteriorly; 1 hyaline lobe present on caudal plane close to distal chitinous process; 1 oblique chitinous ridge also present on caudal plane, as illustrated; disto-medial corner with narrow, papillate hyaline lobe; short sensory seta at disto-medial corner. First exopodal segment about twice as wide as long and produced into short spinous process at disto-lateral corner; one

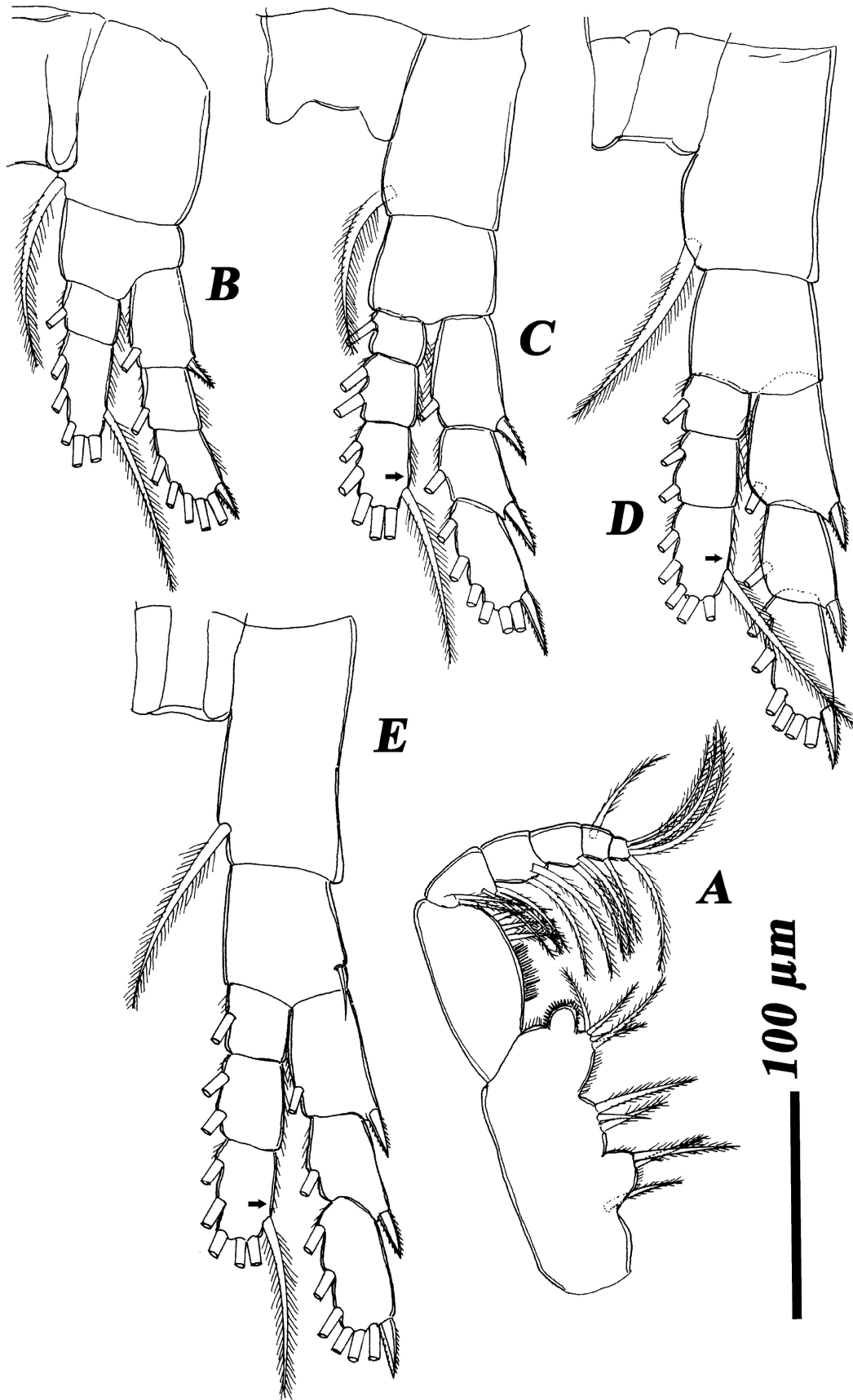


Fig. 4. *Neodiaptomus prateek* n. sp., A-E, holotype female. A, Maxilliped; B, P1; C, P2; D, P3; E, P4.

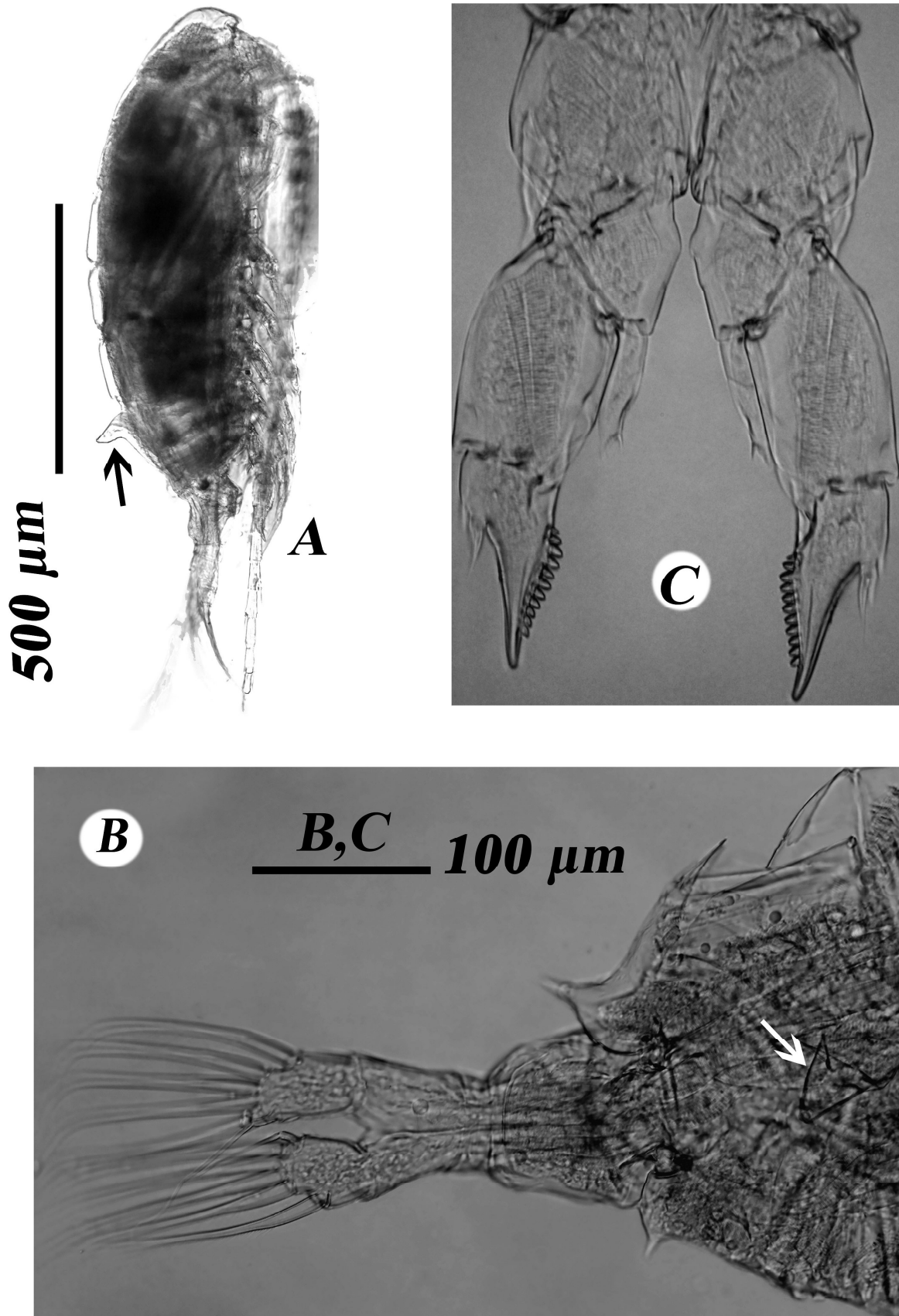


Fig. 5. *Neodiaptomus prateek* n. sp., A-C, holotype female. A, habitus, lateral (arrow points to the mid-dorsal process of fourth pediger); B, pediger 4, 5 and urosome, dorsal (under cover slip; arrow pointing to mid-dorsal process; left margin of pediger 4 damaged); C, P5, posterior view.

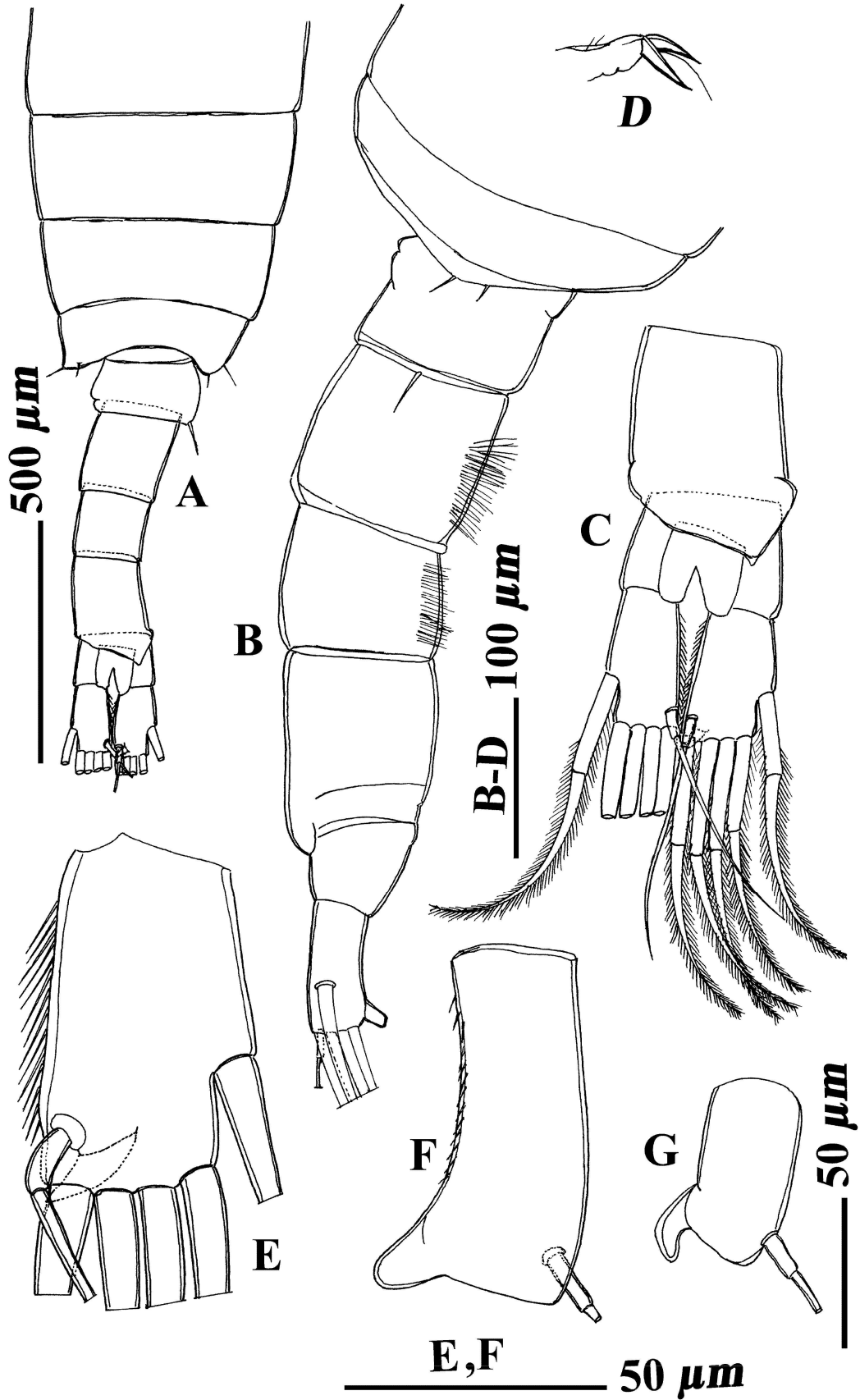


Fig. 6. *Neodiptomus prateek* n. sp., A-F, allotype male; G, paratype male. A, pedigers 2-5 and urosome, dorsal; B, pedigers 4, 5 and urosome, lateral; C, urosomites 4, 5 and caudal rami, dorsal view; D, rostrum, lateral view; E, right caudal ramus, dorsal; F, G, same, lateral view.

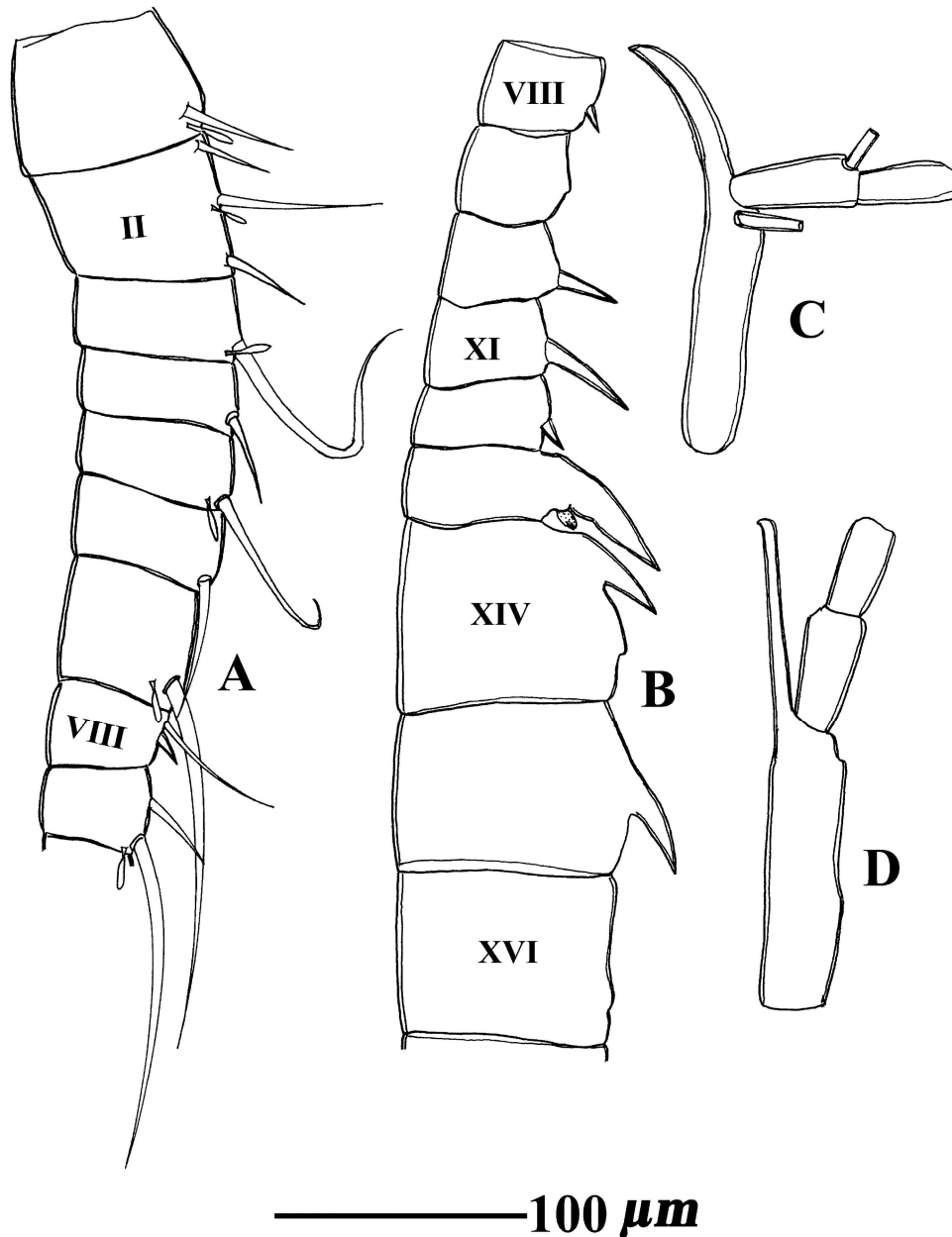


Fig. 7. *Neodiaptomus prateek* n. sp., A-C, allotype male; D, paratype male. A, left antennule, segments 1-9; B, right antennule, segments 8-16; C, D, right antennule, spinous process on antepenultimate segment.

narrow, crescentic hyaline lobe present at disto-medial corner; this lobe appearing as papillate structure in lateral view (Fig. 9D). Second exopodal segment ovate, lateral spine slender, about half as long as this segment, straight, inserted on caudal surface just posterior to midlength of outer margin; terminal claw slender, doubly curved, as long as rest of appendage; proximal one-fifth or so straight, without any bulge at sub-proximal outer angle and also without spinules on inner margin; beyond this point, terminal claw gradually bending inward and tapering to blunt point on recurved terminal region and with fine spinules on inner margin except for short distance proximally and distally. Endopod distinct from base, 1-segmented, cylindrical, slightly longer than first exopodal segment; apex flat and with transverse row

of fine spinules; 1 spinule relatively strong on either distal angle.

Left P5 (Figs. 9A, E-G, 10A, D): very slender and reaching to proximal third or so of second exopodal segment of right P5. Coxa sub-rectangular, carrying 2 structures: 1) small hyaline spine at disto-lateral corner, and 2) massive, plate-like structure arching over proximal region of basis of left P5, as shown in Figs. 9A, 10D; this plate ending in small but distinct lobe appearing differently in different views: in posterior view, triangular, with transverse folds on outer margin (Figs. 9A, 10D); in lateral-internal view (Fig. 9F), a spinulose structure as in Fig. 9D-F. Basis quadrate, inner margin convex and outer margin straight; short sensory seta present at disto-medial corner. First exopodal segment

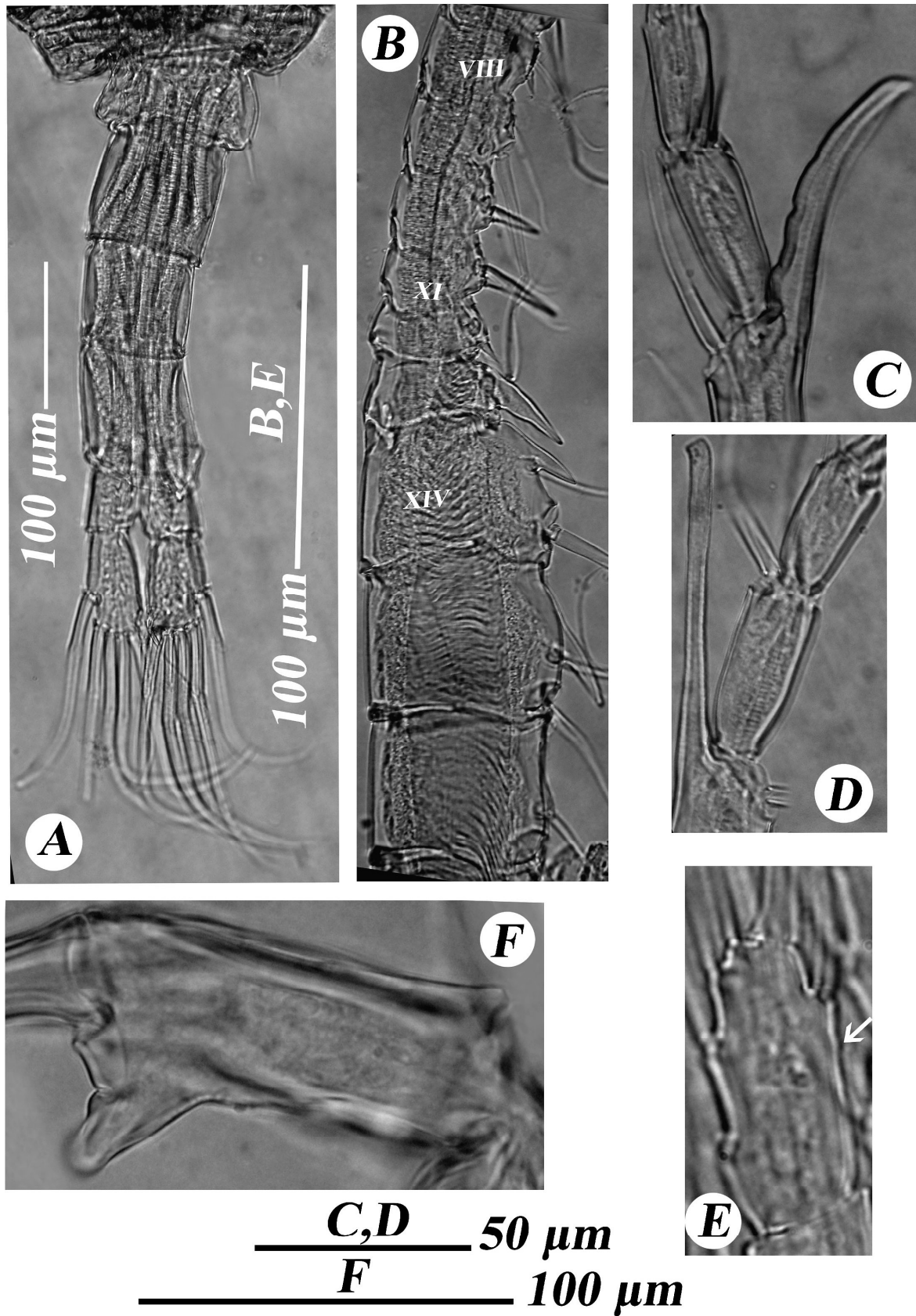


Fig. 8. *Neodiaptomus prateek* n. sp., A-C, E, F, allotype male; D, paratype male. A, pediger 5 and urosome, dorsal; B, right antennule, segments 8-16; C, D, same, spinous process on antepenultimate segment; E, third endopodal segment of P3 (arrow indicates the absence of proximal outer seta); F, right caudal ramus, lateral view.

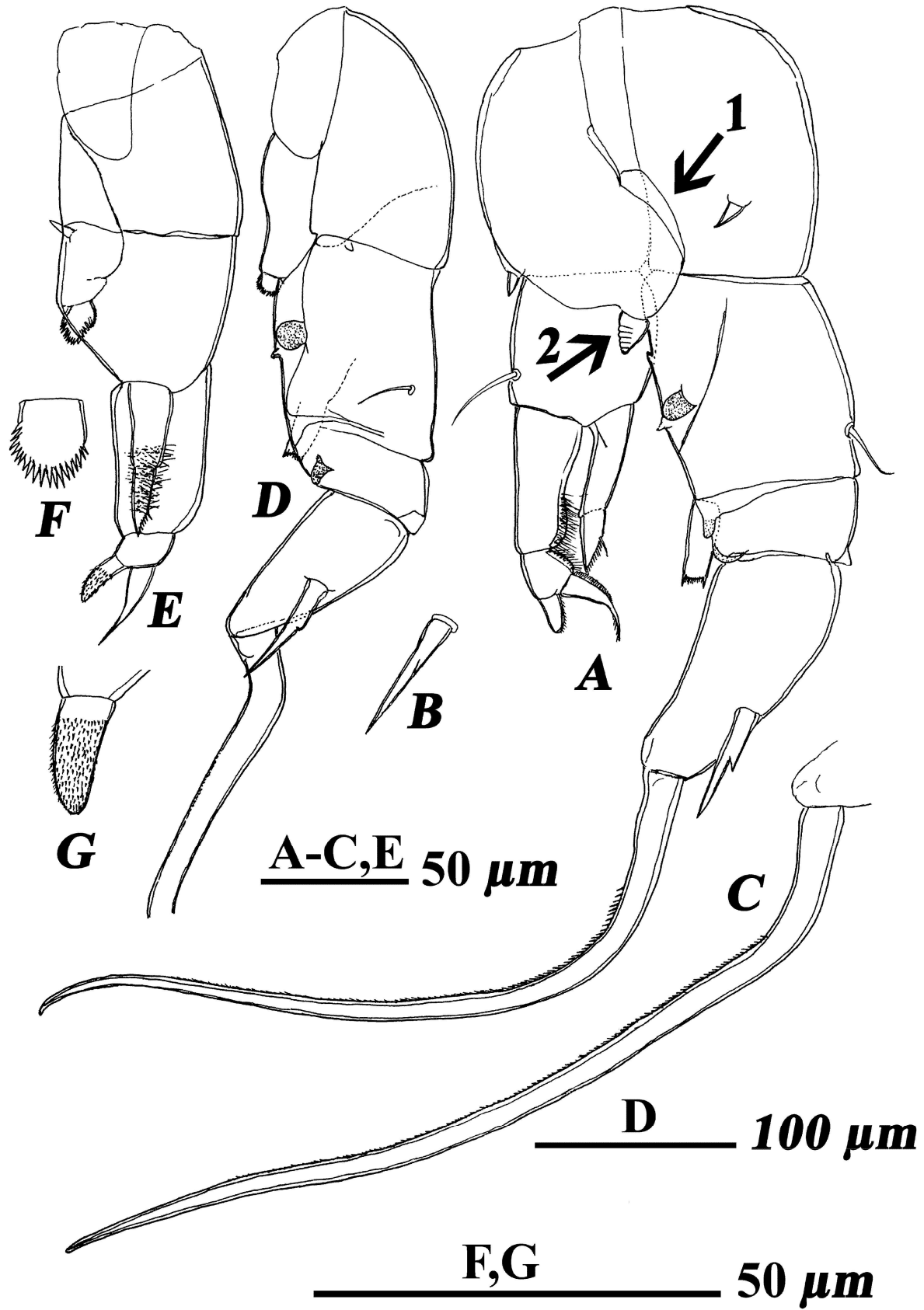


Fig. 9. *Neodiaptomus prateek* n. sp., A-G paratype male. A, P5, posterior view (arrows pointing to coxal plate and its terminal structure); B, right P5, lateral spine of second exopodal segment; C, right P5, terminal claw; D, right P5, lateral-internal view (coxal plate of left P5 also shown); E, left P5, lateral view; F, same, terminal structure of coxal plate, lateral-internal view; G, same, terminal thumb, lateral-internal view.

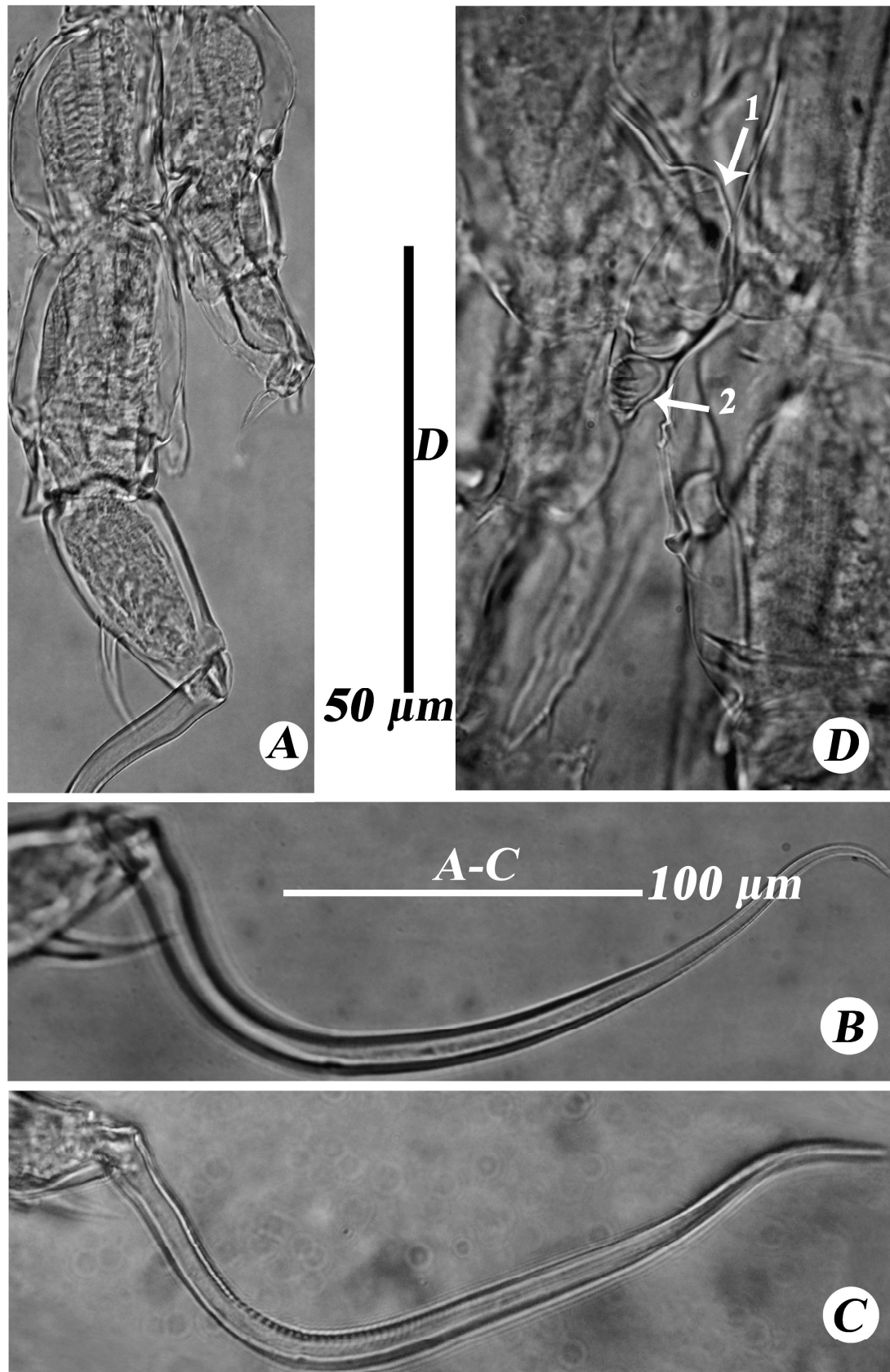


Fig. 10. *Neodiaptomus prateek* n. sp. A, B, allotype male; C, D, paratype male. A, P5, anterior view; B, right P5, second exopodal segment (in part) and terminal claw, anterior view; C, same, terminal claw; D, P5, posterior view, showing inner proximal details of both legs (arrow 1 points to coxal plate of left P5 and arrow 2 points to its terminal structure; hyaline lobe and chitinous projecting of basis of right P5 and endopod of left P5 are also visible).

slender, over twice as long as wide, with hairy lobe at disto-medial corner. Second segment small, obovate, outer margin nearly straight, inner margin inflated and fringed with hairs. Apical process short, thumb-like, and lined with finely serrulate hyaline lamella on inner margin; in lateral view (Fig. 9G), thumb studded with fine denticles on entire surface except for short distance proximally. Seta modified, with proximal two-thirds thickened and distal end drawn out into unipinnate setiform structure. Endopod elongate, extending to base of modified seta, divided into 2 unequal segments by vague septum, distal segment shorter, conical, pointed, with 1 row of fine spinules on obliquely truncate inner apical margin; 1 strong sub-apical spinule.

Variation.—Body length of male paratypes ranging from 1300 to 1500 μm , mean 1380 μm ($N = 4$). Chitinous tooth at disto-medial corner of ventral surface of right caudal ramus of males varying in shape and size (Figs. 6F, 6G, 8F). In one male paratype, spinous process on antepenultimate segment of male right antennule very slender, rod-like, almost as long as next 2 segments, apex produced into pointed beak; hyaline lamella on inner margin greatly reduced (Figs. 7D, 8D).

Etymology.—The new species is named for my grandson, Prateek Cheedepudi. The name is proposed here as a noun in the nominative singular standing in apposition to the generic name.

DISCUSSION

Interspecies Relations

Neodiptomus prateek is assigned to the genus because it fulfils almost all the generic criteria set by Kiefer (1939) (see Introduction) except for the absence of any lobe at the disto-medial corner of the male right P5 coxa. On the other hand, the male left P5 coxa is produced into an enormous plate-like lobe, ending in a thumb-like spinulose structure – an outstanding feature within the family as a whole. In the female, the genital double-somite is relatively short, and the terminal claws of P5 with denticulate margins. In the male, urosomites 2 and 3 have hair-like setae on the ventral margin; the right caudal ramus is armed with a chitinous tooth at the disto-medial corner of the ventral surface; the spinous process of the antepenultimate segment is somewhat claw-like and at least as long as the next segment; and the left P5 endopod is long and 2-segmented. It is to be noted that the above constellation of the probable synapomorphies of the genus can be seen without exception only in the type species (*N. schmackeri*), in all the three Indian endemics (*N. physalipus*, *N. lindbergi* and *N. intermedius*), and in the predominantly Southeast Asian *N. meggitti*. I am of the opinion that these five species constitute a distinct lineage group within the genus *Neodiptomus*. On the other hand, six of the other eight species (*N. lymphatus*, *N. yangtsekiangensis*, *N. laii*, *N. curvispinosus*, *N. songkhranensis* and *N. siamensis*) form another lineage (see below) by sharing, inter alia, the following principal characters: in the female, the genital double-somite is elongate vs. short; and the terminal claws of P5 are ornamented with spinules vs. denticles; in the male, urosomites 2 and 3 are without vs. with hair-like setae

on the ventral margin; the right caudal ramus lacks vs. is armed with a definite chitinous tooth at the disto-medial corner of the ventral surface; the spinous process of the antepenultimate segment is generally rod- or claw-like vs. comb-like and shorter than vs. as long as or longer the next segment (exception: *N. yangtsekiangensis* shows the latter condition); and the left P5 endopod is generally short vs. always long.

Amongst its congeners, *N. prateek* has a somewhat closer morphological kinship with *N. meggitti* as evident from a combination of characters. For example, in the female, the caudal rami are asymmetrical, the right ramus being smaller than the left one, and the inner margin of P5 basis is indented, though the indentation is more prominent in *N. meggitti*. In the male, the chitinous tooth on the right caudal ramus is similar in size and form; the right P5 basis has a chitinous ridge and hyaline lobe; and the left P5 has an elongate first exopodal segment and endopod. Further, a very close biogeographic affinity exists between the two species. Neither of them occurs on the Indian Peninsula. The new species has been found near the “Assam gateway” (see Species Richness), which has somewhat closely intertwined geological history with Myanmar, Malaysia, and the South Andaman Islands from where *N. meggitti* has heretofore been reported (Ranga Reddy, 2000). The new species must have evolved from *N. meggitti* or from an ancestor common to both species. The two species, however, differ from each other in several respects. For example, in the female, the new species has a mid-dorsal process on the fourth pediger, which is absent in *N. meggitti*; the urosome has three somites vs. two somites; P5 endopod is obliquely truncate vs. simply pointed. In the male, the left P5 coxa has a massive plate, which is absent in *N. meggitti*; on the right P5, the size and insertion of the lateral spine on the second exopodal segment, and the form of the end claw as well as the endopod are distinctly different in the two taxa.

The new species stands out in the genus by virtue of the features as indicated in the following paragraphs.

First, the female has a mid-dorsal process on the fourth pediger. Overall, this is a rare structure among diaptomid copepods, having so far been reported only in the females of a few species of *Sinodiptomus*, *Tropodiptomus*, or *Mastigodiptomus*. None of the Indian species except the new species is known to possess this character. Surprisingly, three of the 61 females of *Heliodiptomus cinctus* (Gurney, 1907) that coexisted with the new species show the above character, but not as prominently. In the species in which it occurs commonly, it is reportedly variable within and between populations (see Wilson and Yeatman, 1959; Wilson, 1953; Bowman, 1986, and others), but nothing is known about its ecological/physiological significance. According to Kikuchi (1928), it is quite “insignificant” in the winter forms. So, it would be instructive to investigate the influence of temperature and food availability on the degree of development of the mid-dorsal process.

Second, the male left P5 has, on its caudal surface, an enormous coxal plate, ending in a thumb-like spinulose structure, whereas the right P5 coxa is unproduced. Generally, in this genus it is the male right P5 coxa that is produced at its inner corner into a lobe (“intercoxal plate”),

the size and shape of which are species-specific despite the fact it is subject to some degree of variation (see Ranga Reddy, 2000). Also, this lobe is not unique to *Neodiptomus* species alone, but also occurs in certain species of several other genera, e.g. *Phyllodiptomus* Kiefer, 1936b, *Heliodiptomus* Kiefer, 1932a, *Eodiaptomus* Kiefer, 1932a, *Eudiaptomus* Kiefer, 1932a, etc. But what obtains in the new species is something spectacular in Diaptomidae, as already underscored.

Generally, the third endopodal segment of P2-P4 of both sexes in most diaptomids bears a full complement of seven (2 outer + 2 apical + 3 inner) setae. On the contrary, the new species has only six setae, the proximal outer seta being absent. I have so far noticed this apparent homoplasy only in the following species: the Indian *Heliodiptomus contortus* (Gurney, 1907), *Allodiptomus raoi* Kiefer, 1936a, and *Eodiaptomus shihi* Ranga Reddy, 1992, the Australian *Eodiaptomus lumholtzi* (Sars, 1889), and the Japanese *Eodiaptomus japonicus* (Burckhardt, 1913). In fact, the armature details of P1-P4 are not known for most diaptomid species, though, occasionally, interesting modifications can be witnessed. For example, all the outer spines of exopodal segments of P2-P4 are enlarged and spatulate in the species of *Megadiptomus* Kiefer, 1936c (see Ranga Reddy, 1990), the outer spine of first exopodal segment of P1 is extraordinarily long in *Arctodiptomus* (*Rhabodiptomus*) *michaeli* Ranga Reddy, Balkhi, and Yousuf, 1999 (see Ranga Reddy et al., 1999), and the third inner seta of the third exopodal segment of P4 is very long with modified setules in *Tropodiptomus orientalis* (Brady, 1886) (Ranga Reddy, unpublished).

The lateral spine on the second exopodal segment of the male right P5 is distinctly shorter than its segment and forked at about its mid-outer margin, and inserted on the posterior plane slightly posterior to midlength of the same segment. It is to be noted here that the Southeast Asian *N. yangtsekiangensis* has even shorter and more slender lateral spine, but this species belongs to a different lineage (see below).

Critical Review of Generic Assignment and Nomenclature of *Neodiptomus*

N. schmackeri.—This is now an easily recognizable and relatively widespread species in Asia (see Ranga Reddy, 1994). The incompletely characterized *Neodiptomus strigilipes* (Gurney, 1907) and *Neodiptomus handeli* (Brehm, 1921) were, for a long time, mistakenly considered to be closely allied to *N. schmackeri* in the “*schmackeri*-group of species” (see Rajendran, 1971), but they were eventually synonymized with *N. schmackeri* (Bhattacharya et al., 1990; Ranga Reddy and Subba Reddy, 1992). This species truly typifies Kiefer's (1939) generic definition.

N. meggitti.—A rare species but well documented by Kiefer (1932b), this has a restricted distribution in Asia (see above). By possessing a proximally dilated terminal claw on the male right P5, inter alia, this species displays a close similarity to the Indian *N. physalipus* and *N. intermedius* (Ranga Reddy, 2000).

N. lymphatus.—This Indonesian species was dealt with rather incompletely by Brehm (1933), and no better is its subsequent treatment by Lai (1986). Although Kiefer (1939)

arbitrarily assigned this species to the genus *Neodiptomus*, its position is highly questionable because it does not fulfill any of the prominent generic characters. Hence, this anomalous species is relegated to a *species inquirenda*.

N. physalipus, *N. lindbergi* and *N. intermedius*.—These Indian endemics are well characterized (Kiefer, 1935b; Brehm, 1951; Flössner, 1984; Ranga Reddy and Subba Reddy, 1992), and truly valid species.

N. yangtsekiangensis.—Known so far from China (Wuhan), Vietnam, and Thailand (Dussart and Defaye, 2002), this species no doubt has at least two principal neodiptomid characters: in the male, the right caudal ramus has a chitinous tooth, and the right antennule has an elongate spinous process on the antepenultimate segment. However, the absence of denticles on the female P5 end claws, the short, unsegmented male left P5 endopod, the elongate female genital double-somite, the strongly asymmetrical wings of the female fifth pediger together with its dorsal spinules render it anomalous within *Neodiptomus*. Pending further analysis of its generic affiliation, I prefer to treat it as a *species inquirenda*.

N. laii.—Much like *N. lymphatus*, this Malaysian taxon is obviously incongruous within *Neodiptomus*, as borne out by the following features: in the female, the genital double-somite is elongate and the terminal claws of P5 lack denticles; in the male, the right caudal ramus lacks a chitinous tooth and the right P5 has no coxal lobe at the proximal inner corner, the lateral spine of the second exopodal segment of the same appendage is extremely proximal in position, etc. Kiefer (1974a) placed this species in *Neodiptomus*, stating that a detailed report on this genus was in preparation, but the report never appeared (Defaye, personal communication). Hence it is advisable to treat it a *species inquirenda*.

N. vietnamensis.—A perusal of the original account of this species leaves no doubt that it is synonymous with *Mongolodiptomus botulifer* (Kiefer, 1974b). Ranga Reddy et al. (1998) studied the latter species in detail under the name *Neodiptomus botulifer* Kiefer, 1974b, based on samples collected from diverse habitats in Thailand. While providing an amended delimitation of *Mongolodiptomus* against *Neodiptomus* and *Allodiptomus*, Ranga Reddy et al. (2000) transferred *N. botulifer* to *Mongolodiptomus*. Following the Principle of Priority (ICZN, 2000; Art. 23.3), *N. vietnamensis* is relegated here as a junior synonym of *M. botulifer*.

N. madrasensis.—While claiming to have first described this species in his 1978 unpublished and inaccessible Ph.D. thesis, Roy (1999: 297) published for the first time the diagnosis of this species but without any drawings! Unfortunately, the available diagnosis of this species is so incomplete that it cannot serve to identify the species. So, *N. madrasensis* shall be treated as a *nomen dubium*.

N. curvispinosus.—This Vietnamese species is very inadequately characterized based on a single male specimen; the female is still unknown. The right caudal ramus of this species lacks any chitinous tooth at the ventro-distal corner, but there is a “denticulate projection” near the base of what

looks like the dorsal surface of the ramus. This character along with the diminutive comb-like process on the antepenultimate segment of the right antennule does not justify the inclusion of this species in *Neodiaptomus*. In these circumstances, it is only appropriate to treat this as a *species inquirenda*.

N. songkhramensis and *N. siamensis*.—Both these of Thai species are very well characterised, but their position within the genus *Neodiaptomus* is untenable for the following reasons: in the female, the genital double-somite is distinctly longer than the rest of the urosome; the antennules are short, extending only up to the proximal 2/3 of genital double-somite; and the P5 lacks denticles on the terminal claws. In the male, urosomites 2 and 3 have no hair-like ventral setae; the right caudal ramus has no definite tooth at the ventro-distal corner, but only has a vague projection near the base of the second inner seta on the ventral surface; and the right antennule has a short comb instead of an elongate spinous process on the antepenultimate segment. Hence both species are treated as *species inquirendae*.

The foregoing analysis shows that of the 13 species of *Neodiaptomus* listed as validly assigned to this genus in the World Copepoda database, only five species, viz., *N. schmackeri*, *N. meggitti*, *N. physalipus*, *N. lindbergi* and *N. intermedius* are valid for the reasons already given. While *N. madrasensis* is a *nomen dubium*, *N. vietnamensis* is reduced here to a junior synonym of *M. botulifer*. All the remaining species are treated as *species inquirendae* pending the taxonomic revision of *Neodiaptomus*.

The present scenario suggests two discrete lineage groups within the genus – the valid species versus the *species inquirendae*. These two groups are well-knit and distinctive not only in their salient morphologic features, as already pointed out, but in their overall biogeographic affinities as well. While all the *species inquirendae* without exception are Southeast Asian, *N. physalipus*, *N. lindbergi*, and *N. intermedius* are strictly Indian endemics, *N. schmackeri* is common to India and Southeast Asia, and nearly so is *N. meggitti*. Given the fact that diaptomid systematics is presently in a state of flux, with most genera awaiting revision, it is only appropriate at this juncture not to propose any reallocation or establishment of a new genus/subgenus for the *species inquirendae*.

Species Richness

Neodiaptomu prateek was found co-existing simultaneously with four species of the genus *Heliodiaptomus* Kiefer, 1932a: *H. cinctus* (Gurney, 1907), *H. contortus* (Gurney, 1907), *H. viduus* (Gurney, 1916), and *H. elegans* Kiefer, 1935a, two species of the genus *Neodiaptomus*: *N. schmackeri* and *N. meggitti*, and one sole representative of the genus *Tropodiaptomus*: *T. orientalis* (Brady, 1886). Numerically, *H. contortus* was the most dominant species, followed by *H. cinctus*, whereas the other species were represented almost as strays. Both *H. contortus* and *H. cinctus* are almost of the same body size whereas *H. viduus* is the largest-bodied species in the consortium (Table 1).

Such a 'momentary composition' (Pennak, 1957) of eight diaptomid species in any water body has not yet been reported in the world (W. T. Reid, H. J. Dumont, D. Defaye and E. N. Santos-Silva, pers. commun.). Pennak (1957), while studying the species composition of limnetic zooplankton communities of 27 lakes in Colorado, found one or two copepod species in each. Sanoamuang (1999) investigated the species composition and distribution of freshwater calanoids and cyclopoids of various types of freshwater bodies of Thailand and reported 2-3 species, sometimes up to five diaptomid species per water body. Santos-Silva (pers. communication) from Brazil says he has found one sample with 6 diaptomid species, and 13 species in a year-round sampling of a habitat. In my own studies of the peninsular India, spread over a 30-year period, the great majority of the zooplankton communities contained 1-3, or, rarely, 4-5 diaptomid species.

The above-mentioned, intriguing multiple species consortium cannot be glossed over as a fortuitous happening. One must consider the concomitant situation concerning the biodiversity of certain other groups of this habitat, its biogeographic position, and the apparent ecological scenario. As has been mentioned, the wetland ecosystem of Deepor Beel belongs to the key biodiversity area of the Indo-Burma Hotspot, which is centred on the Indochinese Peninsula, and comprises Cambodia, Laos PDR, Myanmar (Burma), Thailand and Vietnam, plus parts of southern China and north-eastern India (Tordoff et al., 2012). High species richness in two other groups of the zooplankton community of Deepor Beel has already been reported in year-round studies, e.g., 51 species of micro-crustaceans with a qualitative dominance of cladocerans (Sharma and Sharma, 2009) and 134

Table 1. Co-occurrence of diaptomid species in a sample of Deepor Beel and their relative numerical abundance sex-wise. * Some specimens were lost accidentally before the final count.

Name of species	No. of specimens in the sample (body length range and mean in μm)		♀:♂ ratio
	♂	♀	
<i>Neodiaptomus prateek</i> n. sp.	4 (1300-1500; 1380, N = 4)	1 (1600)	0.25:1
<i>Neodiaptomus schmackeri</i>	8*	4 (1450-1530; 1470, N = 4)	0.5:1
<i>Neodiaptomus meggitti</i>	3 (1448-1500; 1480, N = 3)	1 (1700)	0.3:1
<i>Heliodiaptomus contortus</i>	36 (1100-1280; 1190, N = 6)	136 (1280-1480; 1380, N = 30)	3.8:1
<i>Heliodiaptomus cinctus</i>	20 (1100-1250; 1160, N = 15)	61 (1250-1450; 1360, N = 32)	3:1
<i>Heliodiaptomus viduus</i>	3 (1800-1970; 1540, N = 3)	6 (1950-2270; 2040, N = 6)	2:1
<i>Heliodiaptomus elegans</i>	2 (1240-1300; 1270, N = 2)	4 (1500-1550; 1500, N = 4)	2:1
<i>Tropodiaptomus orientalis</i>	4 (1440-1560; 1470, N = 4)	7 (1700-1800; 1760, N = 6)	1.75:1

species including several new records of Rotifera (Sharma and Sharma, 2011). Unfortunately, the diaptomid species richness of this habitat, and, in fact, of the whole of northeast India, has received but little attention.

During its tectonic evolution, the Indian plate in its northward drift eventually docked against Asian plate ca. 55–65 Ma. Mani (1974) underscores, inter alia, the subsequent formation of the Assam-gateway at the north-eastern corner as “the most important phase in the biogeographic evolution of India.” This vital biogeographic corridor facilitated extensive interchanges between the Indian and Asian biota, thus changing the modern biotic composition of the epigeic ecosystems of India into one of “predominantly oriental” nature. In stark contrast to the epigeic biota, the hypogean biota of peninsular India has retained its original Gondwanan heritage intact in spite of dramatic climatic changes and Late Cretaceous volcanism (Mani, 1974; Ranga Reddy, 2011). The geographical location of Deepor Beel right at the threshold of the Assam-gateway – a rendezvous, as it were, for the Southeast Asian and Indian biota – appears to be the overriding historical factor enabling long-term species dispersal for this extraordinary species consortium. This is evidenced by the nature of the species involved and their overall biogeographic affinities. Of the four species of *Heliodiaptomus*, *H. cinctus* and *H. contortus* are believed to be Indian endemics, whereas *H. viduus* is widespread in India and Southeast Asia, and *H. elegans* is a typical Southeast Asian element (Ranga Reddy and Dumont, 1999). Similarly, while *N. schmackeri* and *T. orientalis* are widespread, *N. meggitti* is predominantly Southeast Asian. Away from the northeastern region, it is hard to expect a similar species constellation anywhere on the Indian subcontinent. It appears that the new species described here must have originated in South-east Asia.

In addition to the historical factors paving way for the subsequent long-term species dispersal, habitat heterogeneity, high primary productivity, and reduced predation pressure as well as environmental stress, niche diversification of the species, shallow depth of the water body, climatic factors (Deepor Beel is located within the world’s rainiest belt), etc., must have also been involved in favouring such a high species richness (see Wilson, 1990). This rare event brings to mind the classical “The paradox of the plankton” by Hutchinson (1961), a ‘fundamental and ever-green question’ in plankton ecology. Originally, Hutchinson (1961) relates the paradox, an apparent massive violation of the principle of competitive exclusion (Hardin, 1960), to the intriguing possibility of the co-existence of a number of phytoplankton species in “a relatively isotropic or unstructured environment, all competing for the same sorts of materials.” Quantitative answer to this question, however, is still elusive, thus signifying an important gap in our understanding of community dynamics (Fox et al., 2010).

It must also be noted that while the diaptomid species richness is high, their endemism low in the northeastern India. The converse is true of the Peninsula, which, according to Mani (1974), “*per se* is biogeographically *India vera*, the largest and oldest region of differentiation of the original floras of India” where I have found nearly half of about 50 known Indian diaptomid species existing as endemics.

This indeed is remarkable and “suggestive of an event of adaptive radiation in the extreme south of India” (Dumont and Ranga Reddy, 1993: 93). In other words, the diaptomid species richness, as opposed to their endemism, shows a definite declining biogeographic gradient from the northeastern point of Deepor Beel to the southernmost point (Kanayakumari) of the Peninsula – a distance of about 3400 km.

ACKNOWLEDGEMENTS

I thank the Department of Science & Technology, Ministry of Science & Technology, Government of India, New Delhi, for providing funding support under a Major Research Project (SR/SO/AS-21/2011), Lieut.-Col. M. S. Reddy for offering me and my wife local hospitality and logistic support in collecting plankton samples from Assam and Meghalaya states, and Mr. Shabuddin Shaik for taking and processing the digital images and composing the figure plates.

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RECEIVED: 1 June 2013.

ACCEPTED: 17 August 2013.

AVAILABLE ONLINE: 11 September 2013.