# A NEW *ALLOCYCLOPINA* SPECIES (COPEPODA, CYCLOPOIDA, CYCLOPINIDAE) FROM A HYPORHEIC ZONE OF THE RIVER GODAVARI, INDIA, AND COMMENTS ON THE MORPHOLOGICAL CHARACTERS OF THE GENUS

BY

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## ABSTRACT

A new species of the genus *Allocyclopina* Kiefer, 1954 (Copepoda, Cyclopoida) is described from the brackish hyporheic zone of the River Godavari at Kotipalli, a small coastal village near Ramachandrapuram town in the East Godavari District of Andhra Pradesh State, India. This little-known genus, belonging to the large family Cyclopinidae, was hitherto represented by only three interstitial species: *A. madagassica* Kiefer, 1954, from Madagascar, *A. ambigua* Kiefer, 1960, from Reunion Island, and *A. australiensis* Karanovic, 2008, from South Australia. *Allocyclopina inopinata* new species, is the fourth representative of the genus and the first Asian representative of the genus. The specimens of *A. inopinata* n. sp., show a unique combination of both plesiomorphic and apomorphic character states in the female: first pedigerous somite free; antennule ten-segmented; antenna with an exopodal seta and a single inner seta on coxobasis; mandibular basis with one inner seta; maxillulary endopodite with seven setae, without coxal endite; legs 1–4 three-segmented, with last exopodite spine formula 3.4.4.3; second endopodal segment of leg 1 with a single seta, in both sexes; intercoxal plate of leg 5 reduced; leg 6 with two elements; genital double-somite showing two lateral copulatory pores, corresponding to two seminal receptacles, near its anterior margin; furcal rami with six setae each. The generic diagnosis of *Allocyclopina* is emended, and some morphological affinities with other genera in the family "Cyclopinidae" sensu lato are discussed. The status of *A. australiensis* is briefly discussed.

## RÉSUMÉ

Une nouvelle espèce du genre *Allocyclopina* Kiefer, 1954 (Copepoda, Cyclopoida) est décrite du milieu hyporhéique saumâtre du fleuve Godavari à Kotipalli, un petit village côtier près de Ramachandrapuram dans le district de Godavari Est, Etat de l'Andhra Pradesh, Inde. Ce genre

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peu connu, appartenant à la grande famille des Cyclopinidae était représenté jusqu'à présent par seulement trois espèces interstitielles: *A. madagassica* Kiefer, 1954, de Madagascar, *A. ambigua* Kiefer, 1960, de l'île de la Réunion, et *A. australiensis*, d'Australie du sud. *Allocyclopina inopinata* n. sp. est la troisième espèce du genre et la première découverte en Asie. Les spécimens de *A. inopinata* n. sp. présentent une combinaison unique d'états de caractères plésiomorphes et apomorphes chez la femelle: premier somite thoracique libre; antennule à 10 segments; coxobasis de l'antenne avec une soie exopodale et une seule soie interne; basis de la mandibule avec une soie interne; endopodite de la maxillule portant sept soies, sans endite coxale; rames de P1-P4 à trois segments et à formule des épines du troisième segment de l'endopodite 3.4.4.3; second segment de l'endopodite de P1 avec une seule soie (dans les deux sexes); plaque intercoxale de P5 très réduite; P6 comprenant deux éléments; double somite génital avec, dans sa partie antérieure ventrale, deux pores copulateurs correspondant à deux réceptacles séminaux; branches furcales portant six soies. La diagnose du genre *Allocyclopina* est émendée et certaines affinités morphologiques avec d'autres genres de la famille des «Cyclopinidae» sensu lato sont discutées. Le statut de *A. australiensis* est brièvement discuté.

## INTRODUCTION

The Cyclopinidae are a large "family", likely paraphyletic, the status of which has been under discussion over the past few decades. Several attempts have been made at defining new families for accommodating very different genera that were initially diagnosed as belonging to this family (in particular Martínez Arbizu, 2000a, b, 2001a, b, 2006). However, considering the current absence of a detailed study of this large cyclopoid group, Boxshall & Halsey (2004) and more recently Karanovic (2008) preferred to maintain the family Cyclopinidae as valid, comprising about 43 genera, widely distributed in marine waters, some representatives being also present in brackish and in inland fresh waters (Dussart & Defaye, 2006). The genus *Allocyclopina* Kiefer, 1954 was, until recently, only known by two species: *Allocyclopina madagassica* Kiefer, 1954 (type species), which was described from the Maroantsetra Lagoon (Madagascar), based on specimens found in fine sand, and *A. ambigua*, also interstitial, described by the same author in 1960 from a single female collected from interstitial water near St. Pierre, Reunion Island, east of Madagascar and about 200 km south-west of Mauritius. *A. australiensis* Karanovic, 2008 has been described from one female and one male from two different peninsulas in South Australia (the female from Yorke Peninsula, the male from Eyre Peninsula). The fortuitous discovery of a population of an undescribed species in India and its study, using light and scanning electron microscopy, have permitted to precise the morphological characteristics of the genus and to give an emended diagnosis.

Until now, three genera and four species of the Cyclopinidae sensu lato are known from coastal waters of India: *Cyclopetta orientalis* Lindberg, 1941 (Pondicherry, saltmarshes at Mahim, Bombay), *Paracyclopina intermedia* (Sewell,

1924) and *Paracyclopina longifurca* (Sewell, 1924), both from Chilka Lake (Sewell, 1924) as well as from Lake Kolleru (Ranga Reddy & Radhakrishna, 1984), and *Arenocyclopina biarticulata* Krishnaswamy, 1957 (Chennai, formerly Madras, coast). The finding of a new species, *Allocyclopina inopinata* n. sp., in India constitutes the first Asian report of the genus *Allocyclopina*. With this new species, the total number of Indian cyclopinids comes to five.

## METHODS

The specimens studied were sorted from core samples collected from the hyporheic zone of the River Godavari. A rigid piece of PVC pipe (length 33 cm, diameter 11 cm) was used for coring in small pits dug out for sampling. The cores taken from the pits were pooled into a bucket and stirred well with the habitat water. The supernatant was filtered through bolting silk plankton net (mesh size 70 $\mu$m), and the filtrate fixed in about 5% formaldehyde.

In the laboratory, specimens were transferred to 70% alcohol and subsequently into glycerol. Dissection was done in glycerol under a stereoscopic binocular microscope at a magnification of 90×. Drawings were made with the aid of a drawing tube mounted on a Leica DMLB compound microscope having bright-field and differential interference optics.

Specimens for scanning electron microscopy (SEM) were dehydrated through graded ethanol concentrations, critical-point dried, mounted on aluminum stubs, coated with gold, and examined under a JEOL 840 scanning electron microscope. Permanent preparations were mounted in glycerol and sealed with Eukitt (O. Kindler GmbH & Co, Freiburg, Germany). The type material of the new taxon has been deposited in the National Museum of Natural History, Paris (Muséum national d'Histoire naturelle, prefix MNHN).

## SYSTEMATIC ACCOUNT

Order CYCLOPOIDA Rafinesque, 1815
Family CYCLOPINIDAE Dana, 1846
Genus *Allocyclopina* Kiefer, 1954

### **Allocyclopina inopinata** n. sp.
(figs. 2-5)

Material examined. — Holotype, adult female, dissected on two slides (MNHN-Cp2377); allotype, adult male, dissected on one slide (MNHN-Cp2378); paratypes, dissected on one slide each: 6 females (MNHN-Cp2379, MNHN-Cp2381-2385) and 4 males (MNHN-Cp2386 to 2389); other paratypes, males and females, ethanol-preserved (MNHN-Cp2390); two males and three females on

SEM stubs. Other material: several females on slides (MNHN-Cp2477 to 2481), all deposited in the National Museum of Natural History, Paris. Five males and 30 females, ethanol-preserved, are in the research collections of Y. Ranga Reddy, Acharya Nagarjuna University, India. Leg. Y. Ranga Reddy, 15 January 2006.

Other material examined. — For comparison, we examined the material from Kiefer's collection, deposited in the Staatliches Museum für Naturkunde, Karlsruhe: "*Allocyclopina madagassica* n. g., n. sp., Madagaskars, Lagune von Maroantsetra, Sand, R. Paulian leg., III.52"; slides nos. 5350 (Typ., female), 5354 (Typus, male), 5371-5372 (female); "*Allocyclopina ambigua*, La Réunion, Plage St Pierre, female", slides nos. 6888, 6889, 6890.

Etymology of species name. — The specific epithet is derived from the Latin adjective "inopinatus", meaning "unexpected" and alluding to the unexpected discovery of this interesting taxon in India. The name thus is an adjective agreeing in gender with the (feminine) generic name.

Type locality. — The River Godavari is the second largest river in India. Originating in the western Ghats (only about 80 km from the Arabian Sea) near Trimbak, in the Nashik district of Maharashtra State, the river flows over a distance of 1465 km, firstly eastwards across the Deccan Plateau between the states of Maharashtra and Andhra Pradesh, and then in a southeasterly direction until it empties into the Bay of Bengal through two mouths. Its major tributaries include the Indravati, Manjira, Bindusara, and Sabari. The river has a drainage area of 313 000 $km^2$ in six states: Maharashtra, Andhra Pradesh, Karnataka, Madhya Pradesh, Chhatisgarh, and Orissa. Before discharging into the Bay of Bengal, the river divides into two streams near Rajahmundry town, giving rise to a large deltaic area, which has an extensive navigable irrigation-canal system.

The sampling site lies close to a small, coastal village called Kotipalli (fig. 1), c. 15 km from Ramachandrapuram town (18°85′N 82°02′E; average elevation 10 m). Kotipalli is picturesquely located on the bank of Godavari, about 25 km from the coastline. The sampling point experiences pure freshwater conditions only during peak monsoon activity (August–October), but is subject to tidal influence from the nearby Bay of Bengal at other times. Here, the river bank has a deposit of fine sand and detritus particles, but with little or no clay, and is completely devoid of macrophytic vegetation. Sampling was done during ebb tide.

Description of adult female (holotype). — Total body length, excluding furcal setae, 370 $\mu$m. Preserved specimens colourless. Nauplius eye absent.

Habitus (fig. 2a) relatively robust, with prosome/urosome ratio 1.1 and greatest width (127 $\mu$m) at posterior end of cephalosome. Body length/width ratio 2.9.

Prosome (fig. 2a) as long as its greatest width and 52.8% of total body length, with distinctly marked off, slipper-shaped integumentary window on cephalosome; window 0.6 times as long as cephalosome and with one central integumentary pore. Cephalosome 1.9 times as wide as genital double-somite, not produced posterolaterally. Rostrum well developed, membranous, almost

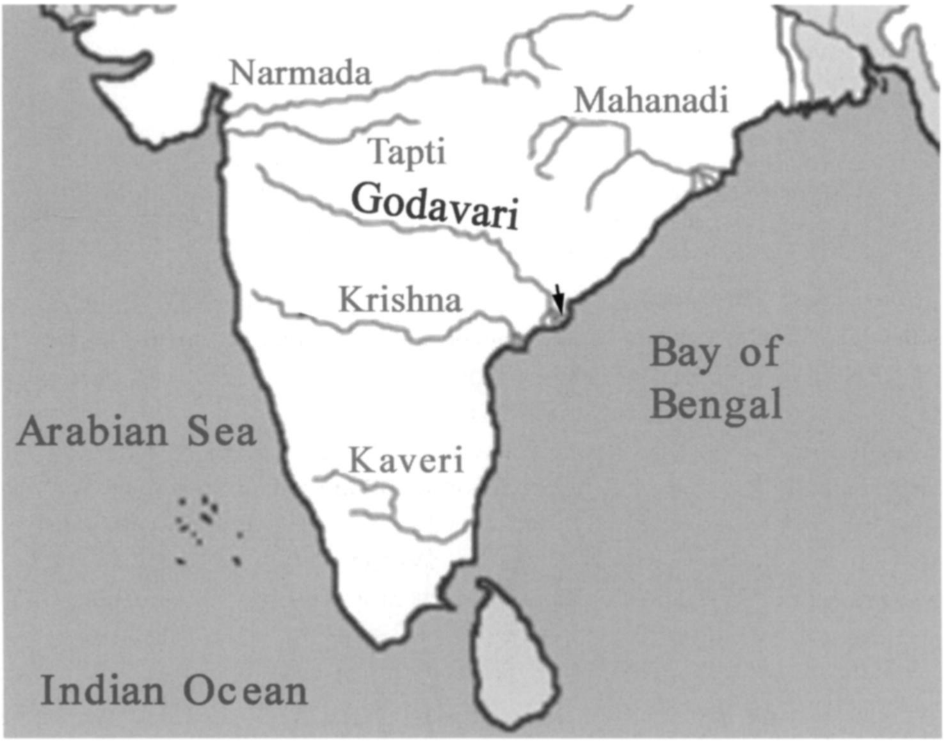


Fig. 1. Map showing the type locality (arrow) of the new species.

rectangular, and furnished with two sensilla. First pedigerous somite free, with rounded posterolateral angles. Second and third pedigerous somites with somewhat produced, narrow posterolateral corners. Third pediger also produced but wide. Second to fourth pedigers with a pair of sensilla each. Fifth pedigerous somite 0.7 times as wide as genital double-somite. Surface of cephalosome with six sensilla, two anterolateral and four posterolateral. Hyaline fringes of prosomites narrow and smooth. Fifth pedigerous somite with smooth fringe dorsally and ventrally, and no sensilla discernible. Sclerotized pseudosomite present between prosome and urosome.

Genital double-somite (figs. 2a, b, 6a, b) 1.2 times as long as wide, ornamented with several sensilla both dorsally and ventrally. Hyaline fringe of genital double-somite as well as next two somites smooth on both surfaces. At the anterior part of the somite, two symmetrical pores (figs. 2c, 6f), likely the openings of glands related to reproduction. Copulatory pores paired, crescent-shaped (fig. 6a, b, d (ca); not visible on fig. 2c), symmetrical, located anteriorly on ventral surface, covered by the fifth legs, detail in fig. 6d, showing presence of a thin valve. Gonopores, opening latero-dorsally at the level of P6, situated at the extremity of a chitinized thickening starting at anterior level of each seminal receptacle (figs. 2a, b, d, 6e).

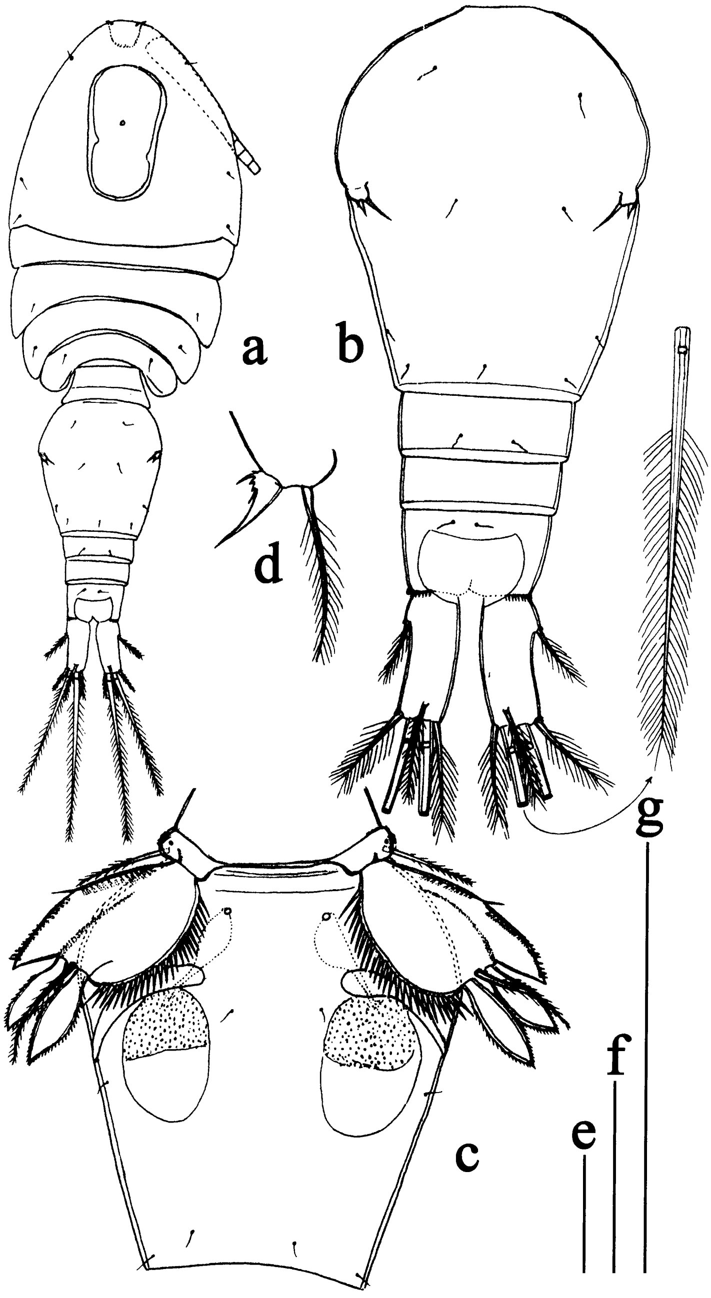


Fig. 2. *Allocyclopina inopinata* n. sp., holotype, adult female: a, habitus, dorsal; b, abdomen, dorsal; paratype, adult female: c, genital double-somite, ventral; d, leg 6. Scale e for d; scale f for a, b; scale g for c. Scale e = 10 $\mu$m; f and g = 100 $\mu$m.

Seminal receptacles paired, relatively large, ovoid, symmetrical, occurring at about midlength, close to lateral margins (figs. 2c, 6c).

Preanal urosomites (figs. 2a, b, 6a) with a pair of small cuticular pores. Anal somite ornamented with two dorsal sensilla, two ventral pores, and a transverse row of tiny spinules on each side dorsally; ventral posterior margin spinulose. Anal operculum smooth, broad, representing 83% of the somite's width and slightly overreaching posterior margin of somite. Anal sinus widely open, without apparent ornamentation.

Furcal rami (figs. 2b, 6a) symmetrical, slightly divergent and 38% longer than anal somite, each ramus 2.3 times as long as its maximum width, proximal quarter wider than rest, inner margin outcurved, ornamented with tiny spinules at base of lateral and outermost apical setae, and a transverse row of about ten somewhat large spinules on ventral distal margin. Six furcal setae on each ramus. Dorsal seta 0.7 times as long as ramus, inserted at 6/7 of ramus' length and uniarticulate at base. Lateral seta inserted at 29% of length from base of outer margin and almost as long as maximum width of ramus. Outermost apical seta stout, about 0.7 times as long as ramus. Innermost apical seta roughly as long as outermost one. Principal apical setae with breaking planes. Inner seta about 1.6 times as long as outer one, 0.3 times as long as body. All furcal setae plumose.

Antennule (fig. 3a) 10-segmented, only slightly bent inwards, with remnants of ancestral segmentation on third and sixth segments, longer than the other segments, unornamented, reaching 0.7 of cephalosome length, with one slender aesthetasc each on segments 6, 9, and 10. Setal formula: 3.3.8.2.0.3.2.2.2.9. One seta on segments 1, 6, and 7, three setae on segment 3, and four setae on segment 10 are long, most setae smooth. Length ratio of antennular segments from proximal end along median axis, 1.0; 0.5; 1.1; 0.4; 0.6; 1.6; 0.6; 0.4; 0.4; 0.6. Segmental homologies (based on *Cyclopicina longifurcata* (T. Scott, 1901)): I-V, VI-VII, VIII-XI, XII-XIII, XIV, XV-XX, XXII-XXIII, XXIV, XXV, XXVI-XXVIII.

Antenna (fig. 3b) 4-segmented, consisting of coxobasis and three-segmented endopodite. Coxobasis 2.5 times as long as wide, with linear row of spinules close to distal 2/3 of outer margin and a transverse row of spinules near distal inner corner; armed with one long outer seta, representing exopodite, and one relatively short inner seta. First endopodal segment 1.5 times as long as wide, ornamented with transverse row of spinules near distal inner corner, armed with one smooth surface seta at midlength, close to inner margin. Second segment 1.8 times as long as maximum width, ornamented with transverse row of tiny spinules at distal outer corner, armed with five setae: one seta at midlength of inner margin, and three nearly equal setae and one long, sturdy seta at distal inner corner. Third segment 2.1 times as long as wide, ornamented with three transverse rows of spinules on

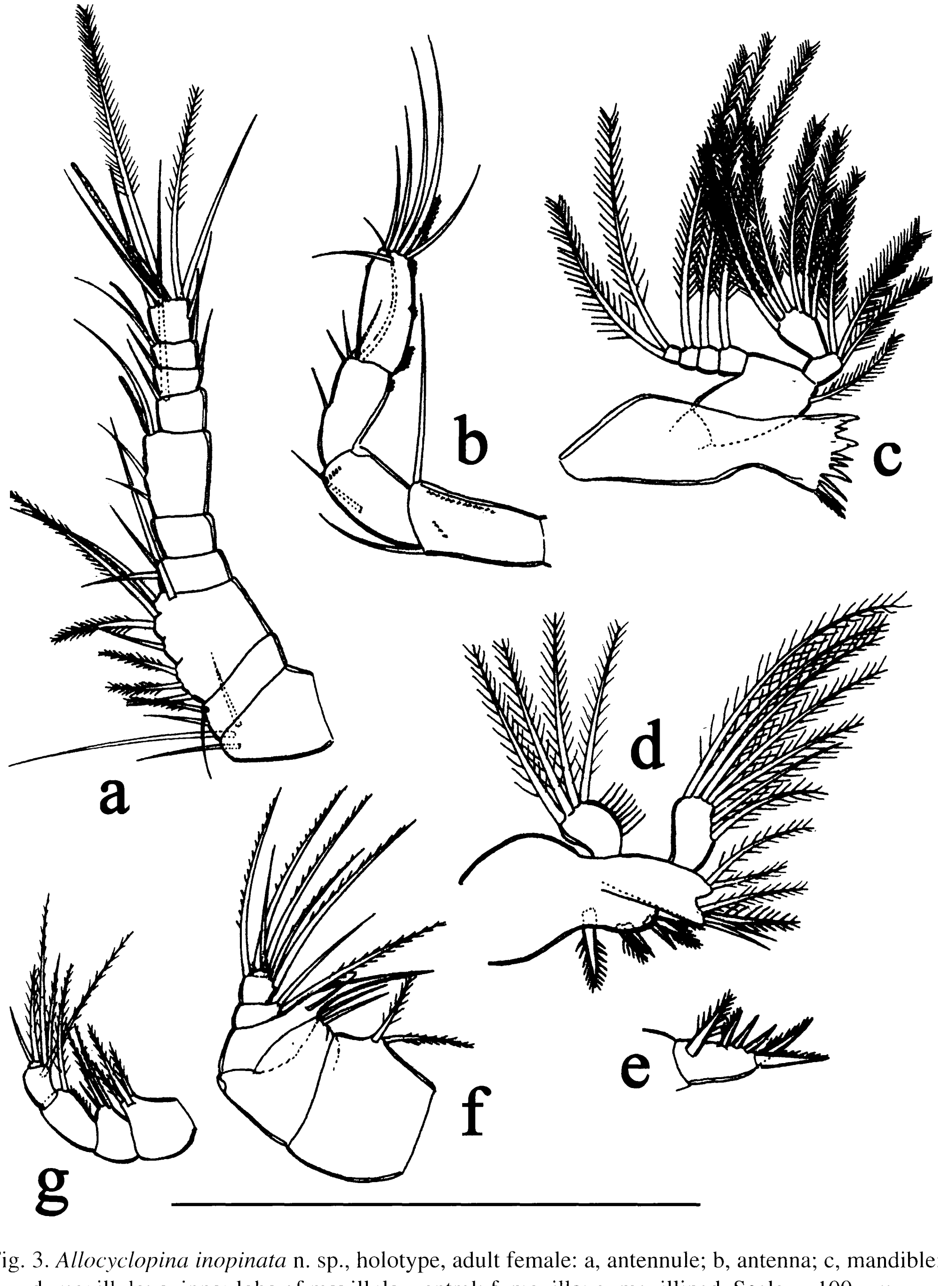


Fig. 3. *Allocyclopina inopinata* n. sp., holotype, adult female: a, antennule; b, antenna; c, mandible; d, maxillule; e, inner lobe of maxillule, ventral; f, maxilla; g, maxilliped. Scale = 100 $\mu$m.

outer margin and one transverse row of spinules on distal inner margin, armed with seven unequal setae (one of these spiniform and bipinnate and one subapical).

Labrum (not figured) with external edge crescent-shaped, ornamented with three rows of spinules; anterior row consisting of about 15 short spinules, middle row with about ten spinules of intermediate length; posterior row also having about 10 spinules, of greatest length (not figured).

Mandible (fig. 3c): coxal gnathobase with eight teeth (three of these complex; innermost the strongest) and one bipinnate seta. Palp large, biramous, unornamented. Basis with one inner seta. Endopodite two-segmented, setal formula 3, 6. Exopodite four-segmented, setal formula 1, 1, 1, 2; all setae plumose.

Maxillule (fig. 3d, e): praecoxal arthrite shorter than palp and with six stout but unequal spines. Coxal epipodite and endite absent. Basis with two endites, proximal endite with four setae (one of these stout, spiniform), distal endite with two unequal setae. Endopodite one-segmented, with seven setae. Exopodite one-segmented, armed with four setae; inner margin ornamented with long spinules.

Maxilla (fig. 3f): praecoxa with one small endite at midlength of inner margin, bearing two somewhat short, pinnate setae. Coxal endite with two setae. Basis produced into strong claw and with one smooth seta at proximal inner angle. Endopodite three-segmented; first endopodal segment armed with two unequal setae. Second longer than wide, incurved, armed with three unipinnate setae. Third segment very small, vaguely separated from second segment and armed with three setae (two of these unipinnate and one smooth).

Maxilliped (fig. 3g) five-segmented, consisting of syncoxa, basis, and three-segmented endopodite. Syncoxa with a single endite at distal inner corner, carrying three pinnate setae. Basal endite also with three setae (two of these equal, bipinnate; one short, smooth). First endopodite segment 1.5 times as long as wide, ornamented with spinules on inner margin and armed with one bipinnate seta. Second segment 1.4 times as long as wide, armed with three bipinnate setae. Third segment very small, with two setae (one of these bipinnate, other one smooth).

Legs 1-4 (fig. 4a-d) biramous, with three-segmented rami; spine and setal formula: see table I.

Last exopodal segment spine formula: 3.4.4.3; setal formula: 4.5.5.5. Intercoxal plates of legs 2 and 3 ornamented at distal lateral corners, but those of legs 1 and 4 smooth. Only intercoxal plate of leg 1 with convex lobe mid-distally. All coxae ornamented with spinules on outer margin and at distal outer angles, and armed with a plumose seta at distal inner corner. Coxa of leg 1 with a transverse row of spinules close to distal outer corner. Basis of each leg ornamented with spinules on inner margin and armed with slender lateral seta on outer margin; basal seta of leg 1 longer than exopodite and plumose distally. Spine at distal inner corner of basis of leg 1 (fig. 4a) sturdy and nearly as long as first two endopodal segments combined. All setae slender and plumose (plumosity omitted in figures). All armature elements of all exo- and endopodal segments with small spinules at

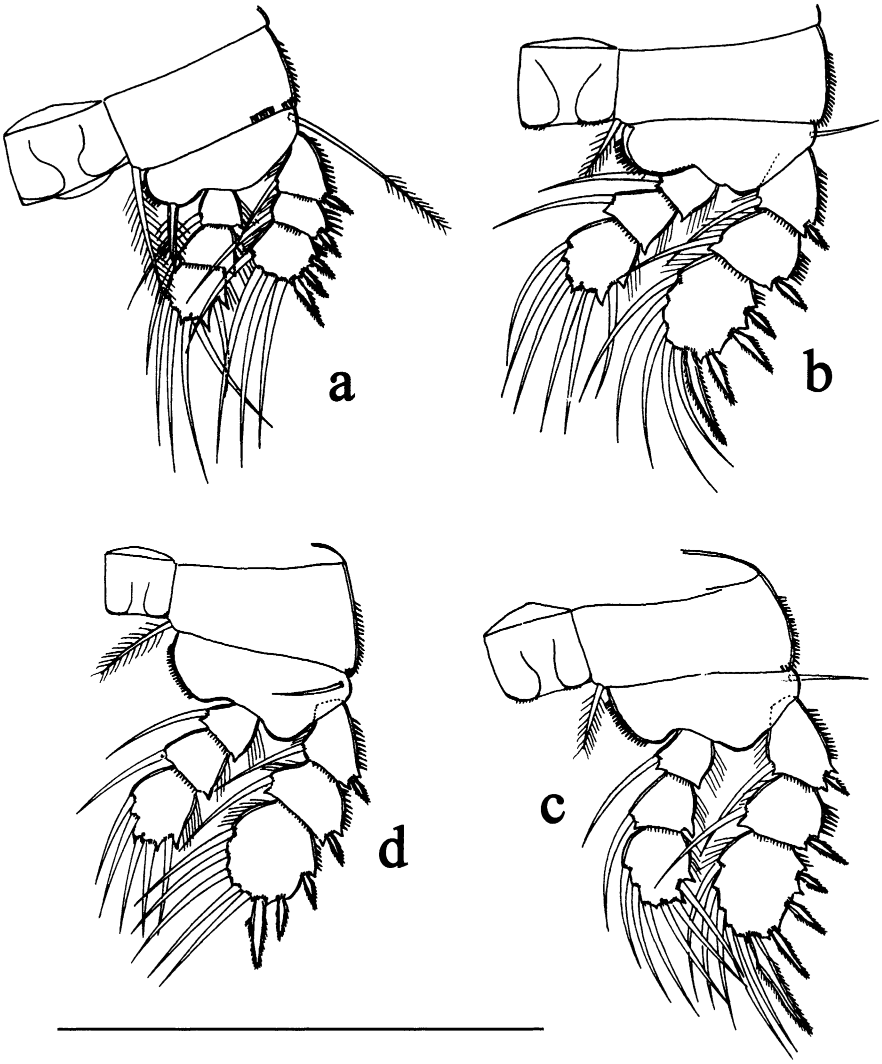


Fig. 4. *Allocyclopina inopinata* n. sp., holotype, adult female: a, leg 1; b, leg 2; c, leg 3; d, leg 4. Scale = 100 $\mu$m.

base; first and second segments of all exo- and endopodites with a transverse row of spinules on distal margin, all exopodal segments with spinules on outer margin; hairs present along inner margin of all exopodal segments. Third exopodal segment roughly spherical on legs 1 and 4 and oval on legs 2 and 3. Third endopodal segment, in frontal view, with a single cuticular pore at base of inner apical seta on all swimming legs. Apical spine on third exopodal segment of legs 2 and 3 longer than its segment, but that on fourth leg shorter.

TABLE I
Spine and setal formula of legs 1-4 of *Allocyclopina inopinata* n. sp.

| | Coxa | Basis | Exopodite | Endopodite |
|---|---|---|---|---|
| Leg 1 | 0-1 | 1-I | I-1; I-1; II, I, 4 | 0-1, 0-1, 1, 2, 2 |
| Leg 2 | 0-1 | 1-0 | I-1; I-1; III, I, 5 | 0-1, 0-1, 1, 2, 3 |
| Leg 3 | 0-1 | 1-0 | I-1; I-1; III, I, 5 | 0-1, 0-1, 1, 2, 3 |
| Leg 4 | 0-1 | 1-0 | I-1; I-1; II, I, 5 | 0-1, 0-1, 1, 2, 2 |

Leg 5 (figs. 2c, 6b, e), left and right legs connected by vestigial intercoxal plate reduced to cuticular fold (see arrow on fig. 6f), two-segmented, basipodal segment about twice as wide as long, ornamented with a single cuticular pore ventrally and with a row of spinules on outer margin and also medially, armed with bipinnate seta arising from dorsal outer corner. Exopodite one-segmented, 1.7 times as long as wide, expanded posteriorly into a very large, foliaceous structure, with hollow on dorsal side; distal outer angle produced into pointed, triangular lobe; inner margin ornamented with about 25 large, postero-laterally directed spinules on inner margin; outer margin with one large spinule at midlength and a longitudinal row of spinules anteriorly and posteriorly to this spinule; armed with two large but unequal, leaf-like, acutely pointed distal spines, distally having spinulose lateral margins, and one medial, plumose seta.

Leg 6 (fig. 2d) located dorso-laterally on genital double-somite, large, more or less oval, composed of a cuticular plate, armed with two elements: one, outer, acutely pointed spine having three spinules and two short, pointed processes at proximal outer corner, and one inner plumose seta.

Description of adult male (allotype). — Total body length, excluding furcal setae, 325 $\mu$m. Habitus (fig. 5a) more slender than in female, prosome/urosome ratio about 1.0, and greatest width (100 $\mu$m) at posterior margin of second pedigerous somite. Body length/width ratio 3.25. Cephalosome 1.5 times as wide as genital double-somite. Rostrum well developed. Pedigerous somites almost as in female.

Cephalosome (fig. 5a) nearly as long as its greatest width, representing 37.2% of total length, with well-marked circular integumentary window, mostly in proximal half. Hyaline fringes and sensilla of prosomites as in female.

Genital somite (fig. 5b, c) about as long as wide, with nine dorsal sensilla. Second and third abdominal somites with two dorsal sensilla each. Anal somite with two proximal sensilla and two dorso-lateral integumentary pores. Ornamentation of anal somite and anal sinus as in female.

Furcal rami (fig. 5b, c) parallel, twice as long as wide, with two proximal sensilla. Armature similar to that of female.

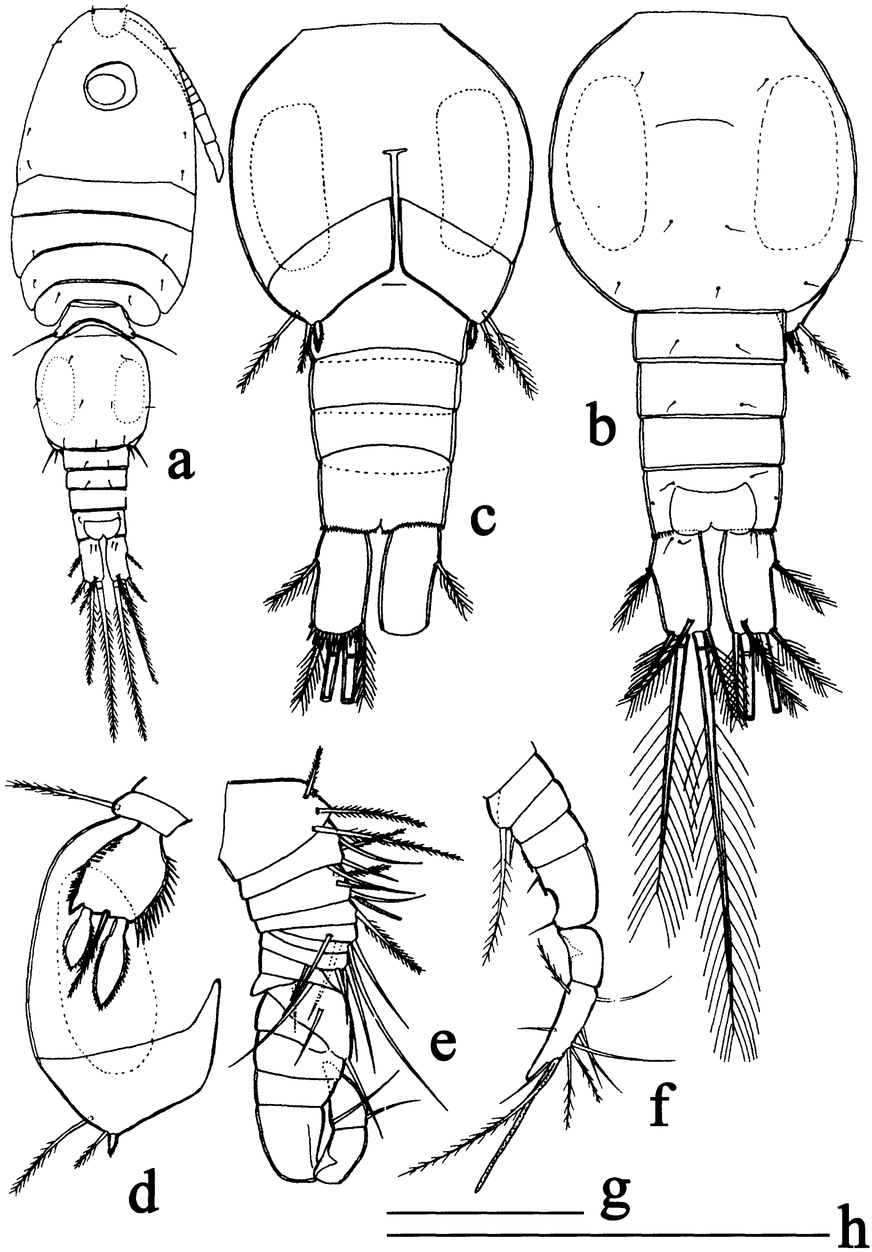


Fig. 5. *Allocyclopina inopinata* n. sp., allotype, adult male: a, habitus, dorsal; b, abdomen, dorsal; paratype, adult male: c, abdomen, ventral; d, P5 and P6; e, antennule; f, antennular segments 11-16. Scale g for a; scale h for b-f. Scales = 100 $\mu$m.

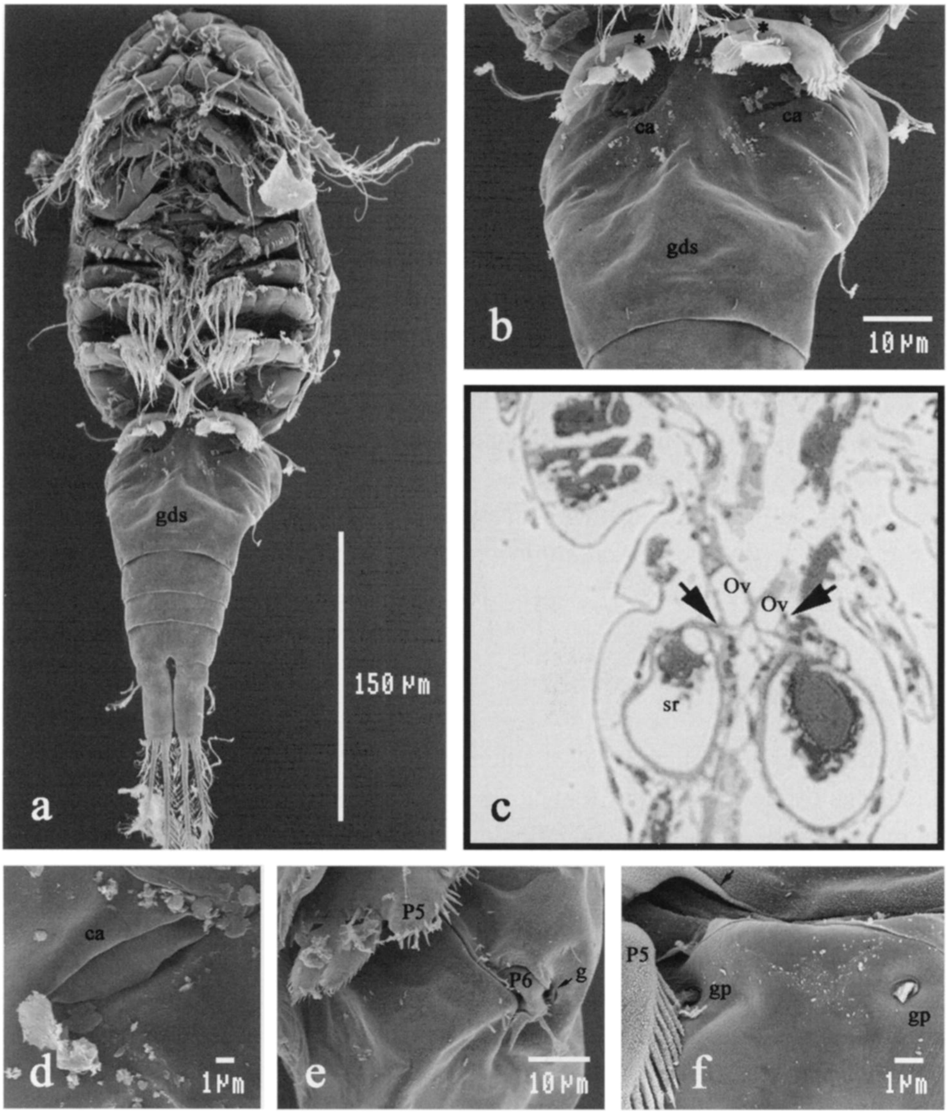


Fig. 6. *Allocyclopina inopinata* n. sp., female. a, habitus, ventral, SEM; b, genital double-somite, showing the paired ventral copulatory pores (ca), SEM; c, longitudinal histological sections from fourth pedigerous somite to genital double somite, showing the two seminal receptacles and the arrival of oviducts at the level of the anterior part of each seminal receptacle; d, detail of the copulatory aperture, note the thin flap covering the aperture; e, lateral view of P6 and aperture of the gonopore (g); f, paired gland pores at the anteriormost part of the genital double-somite, the arrow indicates the reduced intercoxal plate of P5. Abbreviations: ca, copulatory apertures; g, gonopore; gds, genital double somite; gp, gland pore.

Antennule (fig. 5e, f) 16-segmented, digeniculate, with geniculation between $9^{th}$ and $10^{th}$ and between $14^{th}$ and $15^{th}$ segments; slightly longer than cephalosome. Ninth segment smallest. First segment with a short, transverse row of spinules. Segments 3 and 16 with one aesthetasc each. Setal formula as follows: 4.4.3.1.4.1.3.2.1.2.1.1.0.2.0.10.

Other cephalic appendages and swimming legs as in female.

Leg 5 (fig. 5d) as in female except for the following differences: ornamentation of basal segment not discernible; distal segment small in size, with reduced number of long spinules on inner margin.

Leg 6 (fig. 5c, d) distinct, large cuticular plate, armed with one long, plumose seta dorsally, and one short plumose seta and one sturdy, bipinnate spine apically.

Variation. — The shape of the integumentary window and the length–width ratio of the furcal rami are somewhat variable in both sexes. The body length varies from 303 $\mu$m to 447 $\mu$m in females, with an average length of 370 $\mu$m (n = 40), and from 333 to 360 $\mu$m in males, with an average of 343 $\mu$m (n = 10).

Sex-ratio. — Females far outnumbered males, constituting 84% of the population examined.

Discussion. — The new species conforms to the characters of the genus *Allocyclopina*, defined twice by Kiefer (1954 in German, 1956 in French): P5 bisegmented in both sexes; natatory legs all with three-segmented rami and spine formula of the exopodites 3.4.4.3; antennule 10-segmented, a single seta on the outer edge of the furcal rami, female P6 composed of 2 elements. Dussart (1982) completed the diagnosis thus: mandibular exopodite 4-segmented; setal formula of natatory legs 4.5.5.5, P5 bi-segmented with the distal segment bearing four setae and spines, lateral furcal seta inserted in the first third of the outer edge of the furcal ramus.

*Allocyclopina inopinata* n. sp. distinctly differs from *A. madagassica* and *A. ambigua*, mainly by the morphology of P5. In the new species, the distal segment of female P5 is not only characteristic in its shape, particularly by the presence of a prominent, acutely pointed lobe at the distal outer angle, but also possesses two terminal, leaf-like modified setae and an internal row of long spinules. This "lobe" is not present in *A. madagassica* or in *A. ambigua*.

However, sexual dimorphism concerning the shape and armature details of P5 is less pronounced in the new species than in *A. madagassica*. A similar comparison with *A. ambigua* is not possible at this juncture, because its male is yet to be known. In the *A. madagassica* male, the shape of P5 is quite different from that of the female. The distal segment of the female P5 is rounded with small terminal spines, shorter than the median seta, in the male it is oval and the spines are longer. In *A.*

*inopinata* n. sp., the difference is less marked, but the male P5 is smaller and the external "lobe" is less prominent than in the female.

*A. inopinata* n. sp. differs also from *A. madagassica* by the setation of the mandibular palp: the exopodite bears on its apical segment two long setae in the new species, while these are very unequal in length in *A. madagassica*; furthermore, in *A. madagassica*, the first and second endopodal segments have 2 and 5 setae, respectively, while in *A. inopinata*, the setation is, respectively, 3 and 6. Also, the two setae on the fourth endopodal segment are not as distinctly unequal in the new species as in *A. madagassica*.

Concerning the antennular pattern, the new species has the same segmentation as *A. madagassica* (checked on Kiefer's specimens) with large segments 3 and 6 (by fusion of several segments). In *A. ambigua*, the number of segments is identical, but segment 3 is smaller, possibly corresponding to another type of segmentation by fusion, which has not been possible to establish from Kiefer's slides, due to the bad state of preservation. Other differences concern the relative lengths of the furcal setae in females. *A. inopinata* n. sp. has a short dorsal seta, shorter than the externalmost and the internalmost setae (length ratio of dorsal seta/internalmost seta: 0.6), *A. ambigua* has a long dorsal seta, 2.8 times as long as the internalmost seta. *A. madagassica* has a dorsal seta slightly shorter than the internalmost seta and an internalmost seta longer than the externalmost seta (length ratio = 1.29). The lateral furcal seta is inserted at 42% the length from the base of the outer margin of the furca in *A. ambigua*, while it is located at 26% and 29% in *A. madagassica* and *A. inopinata*, respectively. P1-P4 are identical in their segmentation and chaetotaxy in all three species. Furthermore, *A. inopinata* n. sp. can be distinguished from *A. madagassica* by the structure of the male P6, which has two spines in *A. madagassica* but one short spine and two unequal setae in *A. inopinata*.

*A. inopinata* n. sp. (as *A. madagassica* and *A. ambigua*) differs from *A. australiensis* by many characters. These differences are as follows: *A. australiensis* has the first pedigerous somite incompletely fused to the cephalosome, a different segmentation and chaetotaxy of the antennule (14 segments in female, 16 in male, female setal formula 3.5.11.6.7.2.2.2.7), the maxillule with the syncoxal arthrite bearing 9 elements, the maxilliped 6-segmented with a different chaetotaxy, the swimmings legs with the last exopodal segment spine formula 4.4.4.3. However, the antennae are identical, as well as the structure of P5, P6, the structure of the furcal rami in both sexes, and the general morphology of the female genital double somite. These differences are important enough to suggest that *A. australiensis* might belong to a subgenus of *Allocyclopina* or to another genus of the Cyclopinidae.

We here propose an emended diagnosis for the genus *Allocyclopina*, excluding at the moment *A. australiensis* from the genus.

## **Allocyclopina** Kiefer, 1954

*Allocyclopina* Kiefer, 1954: 45-49, figs. 1-14.

Amended diagnosis. — Copepods with cyclopiniform body, of small size, mostly less than 400 $\mu$m and with greatest width at posterior margin of cephalosome. First pedigerous somite free; second to fifth pedigerous somites with rounded postero-lateral corners; sclerotized pseudosomite present between prosome and urosome. Last thoracic somite and first abdominal somite of female completely fused, forming a genital double somite; copulatory pores paired, each located under the P5, corresponding to two seminal receptacles. Anal operculum smooth, broad, convex. Furcal rami bearing 6 setae each. Antennule 10-segmented in female, 16-segmented in male. Antenna four-segmented, with an exopodal seta. Mandibular palp large, biramous, with endopodite two-segmented, with 3 and 6 setae, and exopodite four-segmented, with 1, 1, 1, and 2 setae. Both exo- and endopodite of maxillule 1-segmented, with 4 and 7 setae respectively. Maxilliped 5-segmented, with, respectively, 3, 3, 1, 3, and 2 setae. Legs 1-4 biramous, with three-segmented rami; last exopodal segment spine formula: 3.4.4.3; setal formula: 4.5.5.5; 1 inner seta present on first exopodal segment of P1-P4; 1 inner seta on second endopodal segment of P1-P4. Fifth leg two-segmented, without true intercoxal plate although reduced plate discernible; basipodite short, bearing an external seta, exopodite enlarged, flattened, bearing four elements, which are present in both sexes: two distal leaf-like spines with a thin seta between them, and a small seta or spine on the external edge.

Type species: *Allocyclopina madagassica* Kiefer, 1954, by original designation.

This genus shows many affinities with *Parapseudocyclopinodes* Lindberg, 1961. Both share the free first pedigerous somite, the single inner seta on the coxobasis of the antenna (in *P. dacunhai* Lindberg, 1961), the mandible with 4-segmented exopodite and 2-segmented endopodite, P1 to P4 3-segmented, with the last exopodite spine formula 3.4.4.3., with a single seta on the second endopodal segment and 5 setae on the third endopodal segment of P1; the second segment of P5 with 4 setae or spines. But they notably differ by the antennule (19-segmented in *P. dacunhai*), the P5 3-segmented in the male, and the furca possessing 7 setae in *P. dacunhai*. *Allocyclopina* is also similar to *Cyclopina* Claus, 1863, sharing the long $6^{th}$ segment of the antennule (fusion of two, homologous to ancestral segments XV-XX), the furcal rami with six setae, the mandible with 4-segmented exopodite, the second endopodal segment of P1 with 1 seta, but differing in particular by the number of segments of the antennule, by the structure of the maxilliped, by the spine formula of the exopodites of legs P1-P4 (4.4.4.3. in *Cyclopina*), and by the endopodite of P1 with six setae on the third segment in *Cyclopina*.

In this diagnosis of the genus, new characters have been introduced, particularly the unfused first pedigerous somite; the presence of paired seminal receptacles, and some features of the P5. We will not examine these characters throughout the whole family Cyclopinidae sensu lato, but will give some examples to illustrate their diversity within this family.

According to Boxshall & Halsey (2004), the family Cyclopinidae is composed of 43 genera, mainly marine, with only a few occurring in brackish and freshwater conditions. Only the genera *Cyclopetta* G. O. Sars, 1913, *Paracyclopina* Smirnov, 1935, *Pseudocyclopina* Lang, 1946, *Cyclopinoides* Lindberg, 1953, *Allocyclopina* Kiefer, 1954, *Microcyclopina* Pleşa, 1961, and *Cryptocyclopina* Monchenko, 1979 are recorded as having representatives in coastal, more or less brackish, waters. The family Cyclopinidae, generally considered as paraphyletic, is in the course of revision. Its status has been amply debated to the present day, and new families have been created in attempts to accommodate (groups of) genera surmised to represent monophyletic units: Cyclopettidae Martínez Arbizu, 2000a, Giselinidae Martínez Arbizu, 2000b, Psammocyclopinidae Martínez Arbizu, 2001a, Hemicyclopinidae Martínez Arbizu, 2001b, Schminkepinellidae Martínez Arbizu, 2006. In addition, two other families have been proposed but not yet published (P. Martínez Arbizu, in prep.).

In the family Cyclopinidae (sensu Boxshall & Halsey, 2004) the first pedigerous somite is defined as "sometimes free". It is free in the Cyclopettidae, so, in the genera *Cyclopetta*, *Paracyclopina*, *Arctocyclopina*, and *Paracyclopina*; in the Psammocyclopinidae comprising *Psammocyclopina* and *Metacyclopina*; and in the Schminkepinellidae, thus in the genera *Einslepinella*, *Schminkepinella*, *Muceddina*, *Barathricola*, and *Cyclopinella*. This character is also present in the genus *Allocyclopina*.

The first pediger is incorporated into the cephalothorax in *Erythropolites* Huys & Boxshall, 1990, *Herbstina* Huys & Boxshall, 1990, *Microcyclopina* Pleşa, 1961, and *Glareolina* Huys & Boxshall, 1990. This character is defined as a family character in the recently described families.

Given our existing knowledge of the Cyclopinidae "sensu lato", the presence of paired seminal receptacles and copulatory pores in *Allocyclopina* is unique, despite the fact that these characters are not systematically described in the diagnoses. Some authors studied these characters, especially in the Calanoida (Cuoc et al., 1997; Barthélémy et al., 1998; Barthélémy, 1999). The characters related to the female genitalia can vary according to the group considered, and in the calanoid family Metridinidae, for instance, the three genera of which the family is composed show a different organization of these structures (Cuoc et al., 1997), each genus being characterized by a unique internal structure. Also, in the calanoid family Acartiidae, the genus *Acartia* has paired copulatory pores and seminal receptacles, conserved in all species studied, thus demonstrating an interesting new approach for analysing phylogenetic relationships, at least at the generic level (Barthélémy, 1999). In the two large, predominantly freshwater families, Cyclopidae (Cyclopoida) and Diaptomidae (Calanoida), the organization of these stuctures is uniformly conserved. In the Cyclopidae, the seminal receptacle is unique with only a single copulatory pore.

In the Cyclopinidae sensu lato, the character state of the number of copulatory pores and seminal receptacles appears diverse. One copulatory pore and one seminal receptacle have been observed in *Cyclopina*, *Oromiina* Jaume & Boxshall, 1997, and *Ginesia* Jaume & Boxshall, 1997 (cf. Jaume & Boxshall, 1997, Canary Islands, anchihaline), in *Pterinopsyllus illgi* Wilson, 1973 and *Cyclopinoides schulzi* Herbst, 1964 (in Huys & Boxshall, 1991); it is probably the case in *Procyclopina uguaipuku* Lotufo, 1995; in the Giselinidae (cf. Martínez Arbizu, 2000b); it is unclear in the Schminkepinellidae except for *Muceddina* Jaume & Boxshall (1996) in which the character state is one copulatory pore and one seminal receptacle. One copulatory pore and possibly two seminal receptacles are present in *Cyclopicina longifurcata* (T. Scott, 1901) (see fig. 7a in Huys & Boxshall, 1990). In the Cyclopettidae (cf. Martínez Arbizu, 2000a), the number and location of the copulatory pore(s) are unclear. In the Psammocyclopinidae, *Psammocyclopina georgei* Martínez Arbizu, 2001, "a copulatory pore located midventrally on genital double somite" is recorded by Martínez Arbizu (2001a). In *Heptnerina confusa* Ivanenko & Defaye, 2004 as in *Troglocyclopina* (cf. Jaume & Boxshall, 1996), a single median copulatory pore is shown, with a copulatory canal dividing into two ducts going each towards a small seminal receptacle located at the level of the gonopore, posteriorly of the P6, perhaps the same in *Heterocyclopina vietnamensis* Pleşa, 1968. Many other conditions are not yet known (e.g., genera *Arenocyclopina* Krishnaswamy, 1957; *Cuipora* Lotufo & Rocha, 1991; *Cyclopuella* Por, 1979; *Cyclopicina* Lindberg, 1953; *Glareolina* Huys & Boxshall, 1990; *Microcyclopina* Pleşa, 1961; *Herbstina* Huys & Boxshall, 1990; etc.). Only a thorough examination of all species will permit evaluation of the real taxonomic significance of this character complex. However, it has been established already that the presence of paired seminal receptacles and copulatory pores constitutes a plesiomorphic character state.

The organization observed in *A. inopinata* n. sp. is basically similar to that presented by Huys & Boxshall (1991, fig. 2.8.31A) for *Archinotodelphys polynesiensis* Monniot, 1987 (family Archinotodelphyidae, copepods living in association with ascidians). Here, the anterior pores are interpreted as copulatory pores leading to the paired oval seminal receptacles. In the new species, we did not interpret these pores as copulatory pores. We consider that the paired apertures located under the P5 are the copulatory pores. New histological investigations on well-preserved material will be necessary to confirm this hypothesis. In the specimens of the other two species from the Kiefer collection, it was not possible to definitively identify these paired structures, but as the genital double somite is so analogous, we thought we could hypothesize that these structures are shared by the three species.

In Kiefer's (1954, 1956) diagnoses of the genus *Allocyclopina*, the P5 are considered as completely distinct. In fact, re-examination of Kiefer's specimens as well as the SEM photographs of *A. inopinata* n. sp. show, that they are not completely separated and that a remnant of the coxa or the intercoxal plate is discernible, forming a small, chitinous fold along the separation between the 5$^{th}$ pedigerous somite and the intercalary "pseudosomite". The intercoxal plate of P5 has been observed in many genera of the "Cyclopinidae", for instance in *Cuipora*, *Cyclopicina*, *Cyclopinella*, *Herbstina*, *Heptnerina*, *Pterinopsyllus*, *Psammocyclopina* (Psammocyclopinidae), *Procyclopina*, *Troglocyclopina*, *Hemicyclopina*, and *Monchenkiella* (all in the family Hemicyclopinidae), and in the whole Giselinidae and Schminkepinellidae, but its absence has been reported from several others: *Arctocyclopina* Mohammed & Neuhof, 1985, *Arenocyclopina* Krishnaswamy, 1957, *Cyclopetta* (Cyclopettidae), and *Heterocyclopina* Pleşa, 1968.

The presence of integumentary windows has not been included in the generic diagnosis, as its presence was not confirmed for all three species. Integumentary windows have been described mainly in harpacticoids, particularly in the Parastenocarididae (cf. Reid, 1994; Ranga Reddy & Defaye, 2007) and Canthocamptidae (cf. Por & Hadel, 1986; Hamond, 1987), and also in Cletodidae, Tachidiidae, Stenheliidae, Harpacticidae, and Chappuisiidae (see review in Hosfeld, 1999). They are interpreted as osmoregulatory in function and would represent an adaptation for life in more or less brackish waters. In Cyclopoida, they have been reported in *Bryocyclops* (cf. Defaye & Heymer, 1996) and *Halicyclops* (cf. Fiers, 1995), both belonging to the family Cyclopidae but not in the "Cyclopinidae". The examination of the types of *A. madagassica* Kiefer, 1954 did not reveal such a structure on the cephalosome, perhaps because of the fragility of the structure in the current preservation conditions. These structures seem to have appeared independently in various copepod taxa. Though their phylogenetic significance at high taxonomic levels thus seems problematic, their presence, form, and location are useful at least in species discrimination. The presence of integumentary windows will need to be confirmed for *A. madagassica* and *A. ambigua*, in order to be considered as a generic character.

In the genus *Allocyclopina*, a typical combination of characters has been identified. Some are considered plesiomorphic character states: the first pedigerous somite free, the presence of seven setae on the endopodite of the maxillule, the paired genitalia, all swimming legs three-segmented, the intercoxal plate (although reduced) of the P5. Others, which are rarely encountered together in other genera of the Cyclopinidae sensu lato, could be interpreted as apomorphic, such as the antennule 10-segmented, the antennary coxobasis with two elements: an inner seta and the exopodal seta, the second endopodal segment of P1-P4 with one seta (often two), the 6 furcal setae; the swimming legs exopodite spine formula of 3.4.4.3 (rare for the family Cyclopinidae sensu lato), and the female P6 bearing 2 elements (instead of 3). The emended diagnosis of the genus *Allocyclopina*, thanks to the description of the new species, *A. inopinata*, should permit, in the course of the revision of this large family, to identify pairs of sister-groups, and thus, to contribute to a better understanding of the phylogenetic relationships within the large "Cyclopinidae"-group.

Distribution and ecology. — This new taxon appears to be essentially an interstitial, brackish water representative, as evident from its co-occurring fauna: an unidentified dominant ectinosomatid, strays of *Leptastacus* sp., *Mesochra* sp., *Tachidius* sp., an unidentified ameirid, and *Parastenocaris curvispinus* Enckell, 1970, all belonging to the Copepoda Harpacticoida. Also, nematodes and oligochaetes were found in the core samples. Another cyclopinid, *Paracyclopina longifurca* (Sewell, 1924), acartiid calanoid copepods and their developmental stages, among others, were common planktonic forms in the tidal water at the type locality.

The fact that this genus has been found in Madagascar, in India, and in Australia, suggests a common Gondwanan origin. This very ancient cyclopinid lineage presumably existed before the separation of the Antarctic-Australia block (at about 130 Ma) from the block Madagascar-India. The separation of the Madagascar and India blocks, then occurred at about 90 Ma. Up to that period, Madagascar was joined to greater India; its eastern margin being fused to the western margin of India (in Raval & Veereaswamy, 2003). Maroantsetra Lagoon, in which *A. madagassica* has been collected, is located at the north-eastern part of Madagascar, while *A. inopinata* n. sp. has been collected in the eastern part of India. From this period, these cyclopinid populations would have colonized the interstitial brackish waters; this leads one to think that *Allocyclopina* should have also representatives on the west coast of India. Vicariance appears to be the more probable hypothesis to relate the patterns of distribution of the four *Allocyclopina* species now described; but the dispersal model might probably be concerned. The uncertain generic status of *A. australiensis*, as suggested by its remarkable morphologic differences with the other *Allocyclopina* species, is likely the result of a long isolation of the widely distributed members of an ancient Gondwanan lineage.

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