

First representative of the genus *Allocyclops* Kiefer, 1932 (Crustacea, Copepoda, Cyclopoida) from the Australian subterranean waters

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A new species of the genus *Allocyclops* Kiefer, 1932 (Cyclopidae, Cyclopinae) is described from the subterranean waters of Barrow Island, Western Australia. It belongs to the subgenus *Psammocyclops* Kiefer, 1955, but has not any close relatives among the recent known species. With the addition of the new representative the genus *Allocyclops* now includes thirteen species on all continents, except Asia and Antarctica. A key to aid in their identification is provided.

Keywords : copepods, cyclopoids, taxonomy, stygofauna, Australia.

Introduction

In global context, the groundwater fauna of Australia (along with that of Africa) was very poorly known (Marmonier et al. 1993), and that mostly from the investigation of cave faunas of eastern states (Thurgate et al. 2001a, 2001b). Western Australia has been considered to have poor prospects for supporting specialized subterranean faunas, owing to the lack of water and low food input from xeric plant communities (Moore 1964, Hamilton-Smith 1967, Barr 1973, Howarth 1980). Knowledge of this region, however, has developed substantially in the last decade such that it is now recognized to include one of the world's most diverse and notable subterranean faunas (Humphreys 2000a, 2001, Karanovic & Marmonier 2002, in press). Recently, a number of stygal copepods have been described from the both ancient freshwater (Pesce et al. 1996a, Pesce & De Laurentiis 1996, De Laurentiis et al. 1999, 2001, Karanovic in press) as well as anchialine waters (Pesce et al. 1996b, Jaume & Humphreys 2001, Jaume et al. 2001, Karanovic et al. 2001, Lee & Huys 2002, Karanovic & Pesce 2002).

De Laurentiis et al. (2001) speculated that the cyclopoid copepod fauna inhabiting the groundwaters of Western Australia seems to lack true stygobitic genera.

However, the recent finding of two new species of the genus *Goniocyclops* Kiefer, 1955 completely changed this picture, and even expanded our knowledge about the possible stygomorphies in the cyclopoid copepods (Karanovic, in press). Discovery of the first *Allocyclops* Kiefer, 1932 representative in a water supply bore on Barrow Island, presented in this paper, further expands our knowledge about the Australian stygobitic cyclopoids.

Barrow Island lies on the North West Shelf of Western Australia, and is separated from the mainland by a channel about 12 m deep and 55 km wide. Owing to eustatic changes, it would have been part of the mainland for most of the previous several million years before about 8,000 BP (Humphreys 1991). It is about 12 x 27 km in extent and comprises the Miocene marine limestones (McNamara & Kendrick 1994), reaching a maximum altitude of 68 m. It has been a production oilfield for more than 30 years and produced water was, in part, disposed of into the superficial karst, a practice now stopped. Rich subterranean fauna have recently been found to inhabit Barrow Island, containing Thermosbaenacea, Syncarida, Amphipoda, Isopoda, Decapoda, etc. (Humphreys 2000b). Only one copepod species has been reported from this island so far (Lee & Huys 2002), and it is described as a new

genus in the harpacticoid family Ameiridae. *Allocyclops* (*Psammocyclops*) *consensus* n.sp. is the first cyclopoid to be described from Barrow Island, but many other copepods will be reported in the forthcoming papers.

The genus *Allocyclops* Kiefer, 1932 has been recently revised (Karanovic 2001) and subdivided into three subgenera: *Allocyclops* s.str., *Psammocyclops* Kiefer, 1955 and *Stolonicyclops* Reid & Spooner, 1998. The subgenus *Stolonicyclops* is monospecific and known so far only from North America (Reid & Spooner, 1998). *Psammocyclops* is represented by one species in Africa, Madagascar and South America each, and the Australian one also belongs to this subgenus. The subgenus *Allocyclops* is the largest one, containing four species in southern Europe, three in Africa and one in Cuba. A key for the identification of all thirteen species of the genus *Allocyclops* is also included in this paper.

Methods

Sample was collected with a haul-net (mesh size 250 micrometers) from a water supply bore. Haul-nets are actually simple plankton nets of a different size suitable for the bore, which can range from 30 to 180 mm in diameter. Weighed net was lowered down into the bore with one bottle screwed on its distal part, then hauled through the water column a number of times. The sample was sorted while alive under dissecting microscope and the copepods were then fixed in 70 % ethanol and assigned a field number (prefix BES). Specimen was dissected in Faure's medium, which was prepared following the procedure discussed by Stock & Vaupel Klein (1996). Dissected appendages were covered with a coverslip. For the urosome or the whole animal two human hairs were mounted between the slide and coverslip, so the parts could not be compressed. By moving the coverslip carefully by hand, the whole animal or a particular appendage could be positioned in different aspects, making possible the observation of morphological details. During the examination water slowly evaporated, and appendages eventually remained in completely dry Faure's medium. All drawings were prepared using a drawing attachment (tube) on a Leica-DMLS brightfield compound microscope, with C-PLAN achromatic objectives. Morphological terminology follows Huys & Boxshall (1991), except for the swimming legs armature formula, where a much more simplified version is used.

Results

Order Cyclopoida Sars, 1886

Family Cyclopidae Burmeister, 1834

Subfamily Cyclopinae Dana, 1853

Genus *Allocyclops* Kiefer, 1932

Subgenus *Psammocyclops* Kiefer, 1955

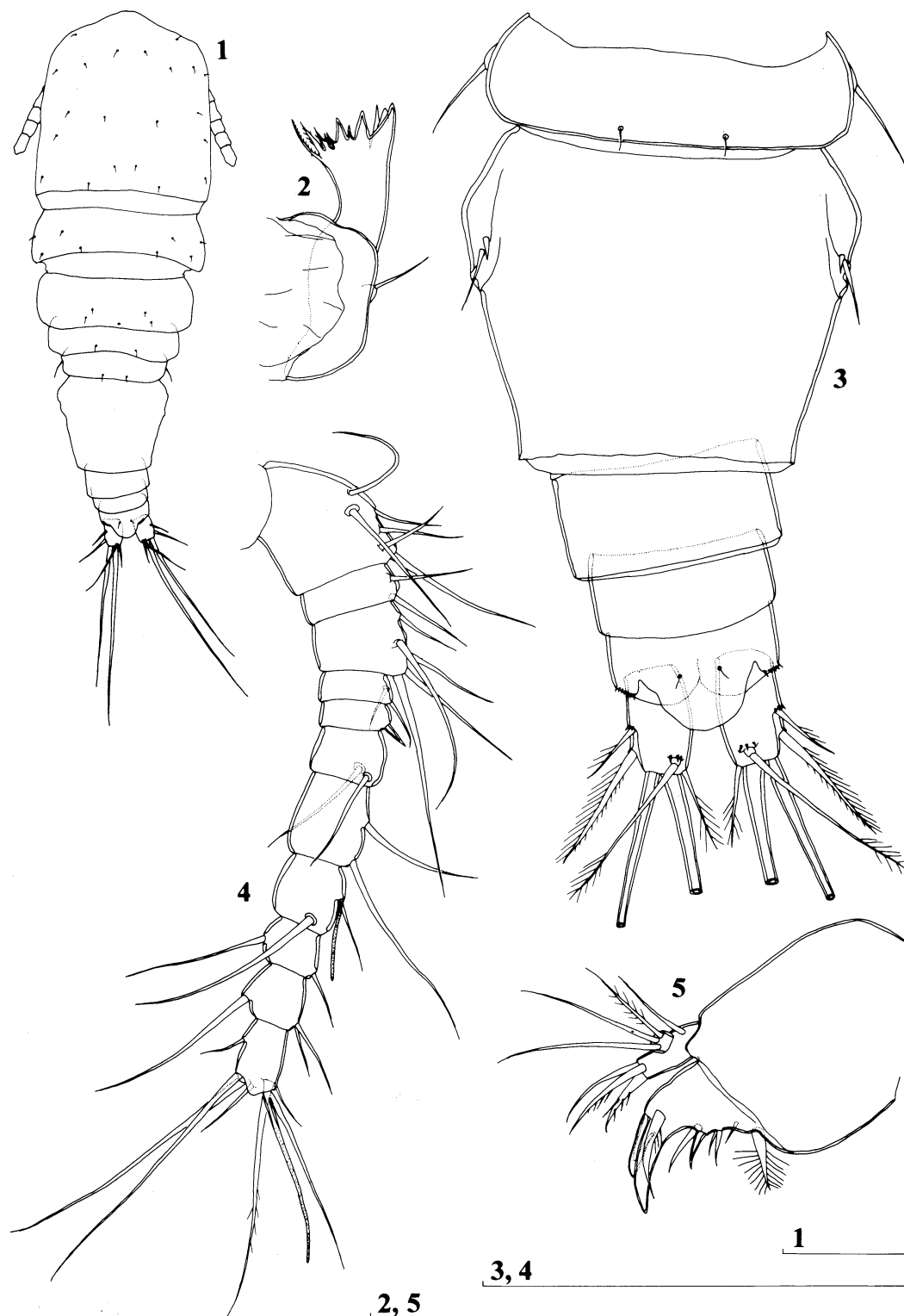
Allocyclops (*Psammocyclops*) *consensus* n.sp.

Material Examined

Holotype female (WAM C25059), Western Australia, Barrow Island, water supply bore, 25 October 1998, leg. W.F. Humphreys & S. Eberhard (BES : 3454), 20°49'27"S 115°26'19"E : dissected on two slides.

Description

Female (holotype). Body length, excluding caudal setae, 0.421 mm. Habitus (Fig. 1) harpacticoidal, dorsoventrally compressed, with prosome/urosome ratio 1.8 and greatest width at posterior end of cephalothorax. Body length/width ratio about 3.1 ; cephalothorax about 1.5 times as wide as genital double-somite. Rostral expansion well developed. Free pedigerous somites without particular expansions laterally. Preserved specimen colourless. Nauplius eye absent. Rostrum well developed, membranous, broadly rounded and furnished with two large sensillae. Cephalothorax less than 1.2 times as long as wide ; represents 37 % of total body length. Surface of cephalothorax shield with many large sensillae ; no other ornamentation visible. Hyaline fringes of all prosomites narrow and smooth. Second pedigerous somite (first free) ornamented with several large sensillae, third pedigerous somite with 2 pairs of sensillae, while fourth and fifth with only 1 dorsal pair of large sensillae (Fig. 1). First urosomal somite (fifth pedigerous) with hyaline fringe smooth both dorsally and ventrally (Figs 3 & 6), while other urosomal somites with slightly undulated fringes. Genital double-somite 0.86 times as long as wide (dorsal view), ornamented with single pair of lateral sensillae, near genital aperture. Copulatory pore small, triangular, situated near distal end of first third of somite length ; copulatory duct short, not sclerotized. Seminal receptacle large, represents 77 % of double-somite's length, without clear distinction between anterior and posterior expansions ; posterior expansion quadriform and about twice as wide as anterior one, which spindle-shaped (Fig. 8). Ovipores situated laterally, covered with reduced sixth legs. Hyaline fringe slightly wavy. Third and fourth urosomal



Figs 1-5. *Allocyclops (Psammocyclops) consensus* n.sp., holotype (female) : 1 - habitus, dorsal view ; 2 - mandibula ; 3 - urosome, dorsal view ; 4 - antennula ; 5 - maxillula. Scales = 0.1 mm.



Figs 6-11. *Allocyclops (Psammocyclops) consensus* n.sp., holotype (female) : 6 - urosome, lateral view ; 7 - maxilla ; 8 - abdomen, ventral view ; 9 - antenna ; 10 - maxilliped ; 11 - labrum. Scales = 0.1 mm.

somites without any ornamentation and with wavy fringes both ventrally and dorsally ; third somite about 1.2 times as long as fourth somite. Anal somite with convex, smooth, broad and very long anal operculum, which produced posteriorly beyond somite limit, exceeding half length of caudal rami ; ornamented with 2 large sensillae dorsally and transverse row of minute spinules on posterior margin (Fig. 3). Anal sinus smooth.

Caudal rami (Figs 3, 6 & 8) almost parallel, with space between them less than half of 1 ramus width, and 1.7 times as long as wide ; ornamented with few spinules at base of outermost apical seta and lateral seta, and also 3 spinules at base of dorsal seta. Dorsal seta long, about 1.6 times as long as ramus, inserted at 6/7 of ramus length, uniarticulate at base and bipinnate at distal part. Lateral seta arising slightly dorsolaterally at middle of ramus length, somewhat longer than ramus width. Outermost apical seta inserted considerably subapically, very stout, spiniform, about 1.2 times as long as ramus, bipinnate. Innermost apical seta 0.4 times as long as dorsal one and about 0.6 times as long as outermost apical seta, bipinnate at distal end. Principal apical setae without braking planes ; inner seta about 1.5 times as long as outer one, and 0.34 times as long as body length.

Antennula (Fig. 4) 11-segmented, reaching 3/4 of cephalothorax length, with slender aesthetascs on eighth and eleventh segments and setal formula as follows : 6.2.5.2.1.2.2.2.2.3.7. No setae articulating on basal part, and just 1 apical seta on eleventh segment pinnate at distal end; all other setae smooth. Single seta on fifth segment spiniform and very short. Length ratio of antennular segments, from proximal end, and along caudal margins, 1 : 0.5 : 0.7 : 0.4 : 0.3 : 0.7 : 1.2 : 0.9 : 0.7 : 0.8 : 1.1.

Antenna (Fig. 9) 4-segmented, comprising long coxobasis and 3-segmented endopod. Coxobasis unornamented, armed with 1 smooth seta at distal inner corner; seta representing exopod absent. First endopodal segment also unornamented, armed with 1 smooth seta. Second endopodal segment about 1.8 times as long as wide, ornamented with short longitudinal row of minute spinules, armed with 5 smooth setae (3 lateral, 1 subapical, and 1 apical). Third endopodal segment 2.5 times as long as wide, ornamented with 2 short longitudinal rows of minute spinules, armed with 7 smooth apical setae.

Labrum (Fig. 11) trapezoidal, without any ornamentation. Cutting edge slightly concave, with 15 small but very sharp teeth between weakly produced, rounded, lateral corners.

Mandibula (Fig. 2D) with palp reduced to small protuberance, which bearing 1 smooth and short seta (not reaching middle of coxal gnathobase). Coxal gnathobase cutting edge clearly divided into 2 regions : inner group of 3 complex teeth, innermost tooth strongest, outermost sharpest ; and outer group of 6 simple teeth (2 of which very strong) and outermost unipinnate seta, which about 0.8 times as long as seta on palp.

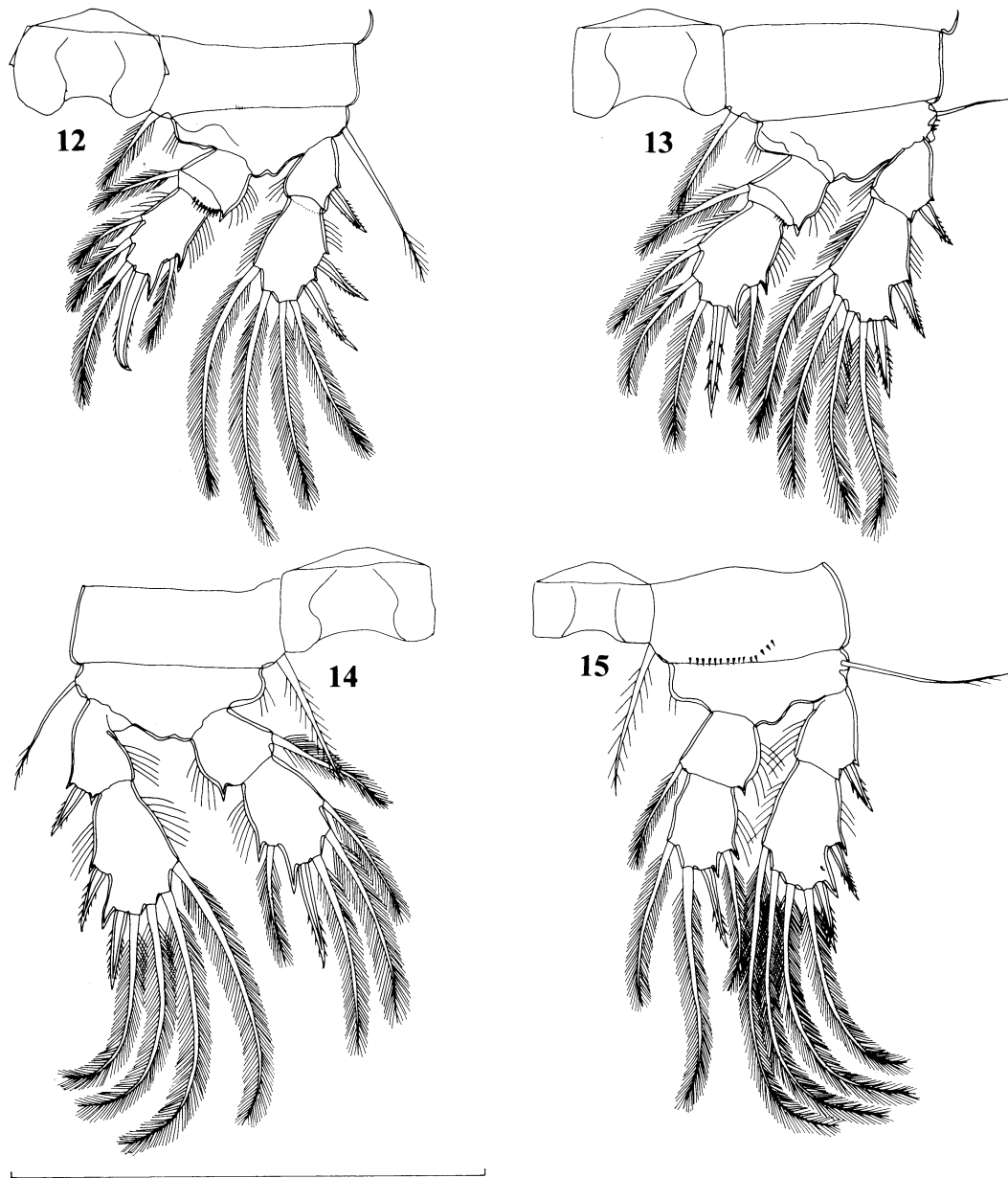
Maxillula (Fig. 5) composed of well developed praecoxa and 2-segmented palp. Arthrite of praecoxa with 4 very strong apical spines, of which only 1 ornamented with few spinules and not fused at base. Praecoxa armed with 6 armature elements along inner margin, proximalmost longest one and bipinnate ; others smooth. Palp with clearly distinct endopod, which bearing 2 smooth apical and 1 bipinnate subapical seta, and armed laterally with 1 exopodal smooth seta and apically with 3 strong seta (2 of which ornamented with several spinules).

Maxilla (Fig. 7) 5-segmented, but praecoxa fused to coxa on posterior surface, and also partly on anterior surface. Proximal endite of praecoxa robust, armed with 2 pinnate setae, distal endite small, unarmed. Proximal endite of coxa with 1 bipinnate seta ; distal endite highly mobile, elongate, and armed apically with 2 subequal bipinnate setae. Basis expanded into robust smooth claw, and armed with 2 setae ; strong seta as long as claw, unipinnate. Endopod 2-segmented ; proximal segment armed with 3 setae (2 robust and 1 slender) ; distal segment with 1 robust apical seta and 1 slender subapical seta. Longest seta on distal endopodal segment almost as long as strong seta on basis.

Maxilliped (Fig. 10) 4-segmented, composed of syncoxa, basis and 2-segmented endopod ; ornamented with longitudinal row of strong spinules along distal part of inner margin of basis and 2 spinules on first endopodal segment. Each segment armed just with 1 unipinnate and strong seta, except second endopodal which bears 1 unipinnate and 1 smooth and much shorter seta.

All swimming legs with 2-segmented exopods and endopods (Figs 12, 13, 14 & 15). Swimming legs armature formula as follows (legend : inner/outer spine or seta; inner/terminal/outer):

	Exopod		Endopod	
Segments	1	2	1	2
First leg	0/1	2/2/2	1/0	2/2/1
Second leg	0/1	2/2/2	1/0	2/2/1
Third leg	0/1	2/2/2	1/0	2/2/1
Fourth leg	0/1	2/2/2	1/0	1/2/1



Figs 12-15. *Allocyclops (Psammocyclops) consensus* n.sp., holotype (female) : 12 - first swimming leg ; 13 - second swimming leg ; 14 - third swimming leg ; 15 - fourth swimming leg. Scale = 0.1 mm.

Second exopodal segment spine formula : 2.2.2.2. Intercoxal sclerite of all swimming legs with deeply concave distal margins, and without any ornamentation. Coxae of first, second and third leg also without any ornamentation, while coxa of fourth leg with transverse row of spinules near distal margin ; all coxae armed with long and plumose seta on distal inner corner. Basis of first leg without spine at inner distal corner. Outer seta on basis of first swimming leg very long, bipinnate at distal end as well as seta on fourth leg ; those on second and third legs shorter, seta on second leg smooth, on third leg bipinnate. All setae on endopods and exopods slender and plumose ; no modified setae observed. Second endopodal segment of fourth swimming leg about 1.4 times as long as wide ; only apical spine 0.9 times as long as segment, and about 0.35 times as long as apical seta (Fig. 15). All swimming legs ornamented with long setules along inner margins of exopods and outer margins of endopods, as well as along outer margin of second exopodal segments ; first and second leg additionally ornamented with long setules along inner margin of second endopodal segment and with transverse row of spinules along posterior margin of first endopodal segment.

Fifth leg (Fig. 6) simple cuticular plate, short and broad, inserted laterally and basally fused to somite. Remnant of proximal segment small protuberance, armed with single short (in comparison with somite) and smooth seta. Distal segment like small protrusion, extending little beyond somite fringe ; armed with 2 subequal smooth setae, which about 0.8 times as long as seta on proximal segment protuberance.

Sixth leg (Fig. 6) also undistinct, small cuticular plate, inserted dorsolaterally on genital double-somite and armed with outer minute spine and inner short and smooth seta.

Male : Unknown.

Etymology

The species name is from the Latin noun *consensus*, which means unity, harmony, agreeing in gender with the masculine generic name and referring to its morphological features, which more closely unites three subgenera of the genus *Allocyclops*.

Discussion

Unfortunately, only one female of *Allocyclops* (*Psammocyclops*) *consensus* n.sp. was collected and examined, so some important characters of the small cyclopoids (such is the sexual dimorphism in the

swimming legs) could not be checked. However, there is no room for doubt that this species belongs to the genus *Allocyclops* Kiefer, 1932. The appearance of the genital double-somite, antennula, a very characteristic fifth leg, as well as all other characters, perfectly fit into the emended generic diagnosis given by Karanovic (2001). On the subgeneric level the situation is somewhat different. Only one apical spine on the fourth leg endopod and all coxal setae present, clearly put the new species in the subgenus *Psammocyclops*, but some other characters (such is the presence of antennal exopod seta, segmentation of the maxillular palp and relative length of the fifth leg setae) could not be used anymore in the subgeneric diagnosis. *Allocyclops* (*P.*) *consensus* is actually melting the boundaries between the *Allocyclops* subgenera (*Allocyclops* s.str., *Psammocyclops* Kiefer, 1955, and *Stolonicyclops* Reid & Spooner, 1998) in a way that it would not be possible to reconsider and revalidate their original generic statuses anymore (at least not using the traditional morphological methods alone). However, there is no reason for rejecting the recent subdivision of the genus, since it is very useful in the taxonomic practice and it may have some phylogenetic importance as well. Unfortunately, any phylogenetic analysis in the genus *Allocyclops* must wait for the detailed redescriptions of the majority of species, because their original descriptions are not in accordance with the standards of modern taxonomy, as they give no information about many morphological features.

Although clearly belonging to the subgenus *Psammocyclops*, *A. (P.) consensus* has no close relative among recent known species and it can be easily distinguished from the other three species in the subgenus by the swimming legs armature formula. From *A. (P.) excellens* (Kiefer, 1955) [syn. *Allocyclops ritae* Dumont & Lamoot, 1978] it additionally differs by the caudal rami shape, much shorter proximal seta on the fifth leg, much longer anal operculum and the presence of only two reduced armature elements on the female sixth leg (see Kiefer 1955 ; 1956 ; Dumont & Lamoot, 1978), although both species have a very similar seminal receptacle. From *A. (P.) silvaticus* Da Rocha & Bjornberg, 1988 the new species differs, beside the swimming legs armature formula, also by the shape of the caudal rami and anal operculum, as well as by the armature of the antenna, mandibula, maxilliped and by the much more harpacticoid-like body shape (see Da Rocha & Bjornberg 1988). *Allocyclops (P.) transsaharicus* (Lamoot, Dumont & Pensaert, 1981) shares with *A. (P.) consensus* very short caudal rami, posteriorly produced anal operculum and only two armature ele-

ments on the female's fifth leg (Lamoot et al. 1981), but differs by the presence of the exopodal seta on antenna, armature formula of the antennula, body shape and, of course, by the swimming legs armature formula. This species, however, seems to be the closest one to the Australian representative. *Allocyclops* (*P.*) *consensus* has all three armature elements on the fifth leg smooth and slender, as well as *A. (S.) heggiensis* (Reid & Spooner 1998) from the United States (see Reid & Spooner 1998), while in all other species of the genus the innermost element is a spine or spiniform seta. Considering how small is the difference between spine, spiniform seta and seta, on such a small appendage, and how easy is to misinterpret them, it is very hard to establish the phylogenetic importance of this character.

Together with the new species from Australia, the genus *Allocyclops* now includes thirteen species, for which the following key to aid in their identification is provided (see Karanovic 2001) :

1. Second endopodal segment of fourth swimming leg with 2 apical spines 6
 - Same segment with 1 apical spine 2
2. Coxae of all swimming legs with seta on their inner-distal corner 3
 - Coxae of second, third and fourth legs without seta on their inner-distal corner *A. (Stolonicyclops) heggiensis* (Reid & Spooner, 1998)
3. Second endopodal segment of fourth swimming leg with 3 inner setae 5
 - Same segment with 2 inner setae 4
4. Spine formula of second exopodal segments of swimming legs 2.3.3.2 *A. (Psammocyclops) excellens* (Kiefer, 1955)
 - Same formula 2.2.2.2 *A. (Psammocyclops) consensus* n.sp.
5. Spine formula of second exopodal segments of swimming legs 3.3.3.2 *A. (Psammocyclops) silvaticus* Rocha & Bjornberg, 1988
 - Same formula 3.4.4.3 *A. (Psammocyclops) transsaharicus* (Lamoot, Dumont & Pensaert, 1981)
6. Innermost apical seta on caudal rami longer than outermost one 7
 - Same seta shorter than outermost one 9
- 7 - Anal operculum short and quadrate 8
 - Anal operculum clearly convex *A. (Allocyclops) chappuisi* Kiefer, 1932

8. Caudal rami more than 3 times as long as wide
 - *A. (Allocyclops) cavicola* Chappuis, 1951
 - Caudal rami less than 3 times as long as wide
 - *A. (Allocyclops) botosaneanui* Plesa, 1981
9. Anal operculum smooth 10
 - Anal operculum finely serrated
 - *A. (Allocyclops) orcinus* (Kiefer, 1937)
10. Basis of first leg with spine on distomedial corner 11
 - Same segment without spine
 - *A. (Allocyclops) arenicolous* (Fryer, 1956)
11. Setal formula of second exopodal segment of swimming legs 5.5.5.5 12
 - Same formula 5.4.4.4
 - *A. (Allocyclops) montenegrinus* Karanovic, 2001
12. Caudal rami about 3 times as long as wide ; innermost apical seta about 2 times shorter than outermost one
 - *A. (Allocyclops) kieferi* Petkovski, 1971
 - Caudal rami about 1.5 times as long as wide ; innermost apical seta slightly shorter than outermost one
 - *A. (Allocyclops) minutissimus* (Kiefer, 1933)

As noted by Karanovic (in press), the subterranean copepods (both cyclopoids and harpacticoids) from Western Australia exhibit clear Tethyan connection if they have a marine origin, and they have mostly Gondwana or Eastern Gondwana connection if they are of the freshwater origin. *Allocyclops* (*P.*) *consensus* is not an exception, since the species of the subgenus *Psammocyclops* are distributed in South America, Africa, Madagascar and now in Australia as well. That is an obvious Gondwana connection, and that is why we probably need to continue using the subgeneric division of the genus *Allocyclops*. The subgenus *Psammocyclops* is still unknown on the Indian subcontinent, but the subterranean freshwaters there still await serious investigation (Ranga Reddy 2001, Karanovic & Pesce 2001, Karanovic & Ranga Reddy in press). Hopefully, the continuing studies of the Australian subterranean waters will result in finding more representatives of this interesting taxon and contribute to our better understanding of its zoogeography and the zoogeography of the subterranean animals in general.

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