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Copepods from ground waters of Western Australia, I. The genera *Metacyclops, Mesocyclops, Microcyclops* and *Apocyclops* (Crustacea: Copepoda: Cyclopidae)

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Abstract – *Metacyclops mortoni* sp. nov. and *Mesocyclops brooksi* sp. nov. are described from ground waters of the Cape Range karst area, northwestern Australia. New localities for the species *Microcyclops varicans* G. O. Sars, 1863 and *Apocyclops dengizicus* (Lepechkine, 1900) are reported from the same area. The distribution of the above species is greatly extended to northwestern Australia.

INTRODUCTION

Until recently, notwithstanding the great extent and diverse geological, climatic and hydrological conditions of the Australian continent, very few studies were devoted to the taxonomy of copepods, especially of groundwater-inhabiting species. Even less is known of the copepod fauna of Australia outside Victoria, New South Wales and the Northern Territory.

The apparent scarcity of copepods in Australia probably results from a lack of collections over much of the continent, particularly from subterranean biotopes.

The number of recent publications on Australian freshwater copepods, especially groundwater species (Dumont and Maas 1985; Morton 1985, 1990; Hamond 1987; Dussart and Fernando 1988; Timms and Morton 1988; Pesce *et al.* 1996), reflect the growing recognition world wide of the extent and importance of groundwater communities (Marmonier *et al.* 1993). Nevertheless, the freshwater cyclopid copepods, particularly those from northwestern Australia, remain almost completely unknown. Therefore, it is not surprising that collections from different subterranean habitats in this region included two hitherto undescribed species of the genera *Metacyclops* Kiefer and *Mesocyclops* G. O. Sars, and the widespread species *Microcyclops varicans* (G. O. Sars, 1863) and *Apocyclops dengizicus* (Lepechkine, 1900).

The discovery of *Metacyclops mortoni* sp. nov. increases to two the number of congeners from Australia, the others being *M. arnaudi* (G.O. Sars, 1908) and the subspecies *M. arnaudi platypus* Kiefer, 1967.

The genus *Mesocyclops* is better represented in Australia and, besides the new species, includes at least five species viz. *M. notius* Kiefer, 1981, from Queensland and the Northern Territory, *M. darwini* Dussart and Fernando, 1988, from the Northern Territory, *M. australiensis* (= *M. thermocyclopoides australiensis*) (G. O. Sars, 1908), from New South Wales, Victoria and Tasmania, *M. cuttacuttae* Dumont and Maas, 1985, from the Northern Territory and *M. thermocyclopoides* Harada, 1931, from New South Wales and Victoria (Defaye and Kawabata 1993). *M. pehpeiensis* Hu, 1943, was recorded by Lim and Fernando (1985), but without locality data.

Finally, this paper considerably extends to the west the known distribution of both *M. varicans* and *A. dengizicus*, which were previously known within Australia only from New South Wales, Victoria and Northern Territory.

HABITAT AND ASSOCIATED FAUNA

Northwestern Australia is arid and on the Cape Range peninsula the available water is mostly groundwater accessible in a few caves within the Cape Range karst and in the general water table of the surrounding coastal plain where a freshwater lens overlies salt water (Humphreys 1993a, 1993c; 1993d). The area has a rich stygofauna with tethyan affinities (Humphreys 1993b, 1994; Humphreys and Adams 1991; Knott 1993).

Metacyclops mortoni was found only in hand-dug wells on the coastal plain of the Cape Range peninsula (C-25, C-149, C-273 and Waroora Well) and on the Ashburton River (Geebera Well) in water ranging in temperatures between 19.6 and 28.2°C and salinity between 2,550 and 17,044 mg L^{-1}. It was associated with an aquatic fauna that included Turbellaria, harpacticoid and calanoid

copepods, melitid amphipods (undescribed genus; W. D. Williams, pers. comm.), *Halosbaena tulki* Poore and Humphreys (Thermosbenacea), *Stygiocaris lancifera* Holthuis (Decapoda: Natantia), Hydracarina (Acarina), *Milyeringa veritas* Whitely (Perciformes: Eleotridae) and *Ophisternon candidum* (Mees) (Synbranchiformes: Synbranchidae).

Mesocyclops brooksi is known only from the type locality, Bobs Well, a hand-dug well in the Ashburton River valley, a river now remote from Cape Range but which formerly flowed past the tip of the peninsula (Wyrwoll *et al.* 1993). The water temperature was 25.0°C and the salinity was 1121 mg L^{-1}.

Apocyclops dengizicus was found only in a small piezometric tube located in a recently dug test pit in a back dune area adjacent to the ocean. The water temperature was 26.9°C and the salinity was 22,000 mg L^{-1}.

Microcyclops varicans was collected in a variety of habitats containing waters ranging in temperatures between 23.9 and 26.9°C and salinity between 99 and 9448 mg L^{-1}. These sites included a bore and a hand-dug well at the base of the Cape Range peninsula, a hand-dug well on the Ashburton River and, interestingly, water in the dark zone of an 80 m deep cave (C-18) within central Cape Range– where it occurs with a second species of the undescribed genus of melitid amphipod mentioned above, the only other aquatic species known from the range. This cave contains a diverse troglobitic fauna derived from a rain forest (both temperate and tropical) litter fauna – the area is now arid (Humphreys 1993a, 1993c). In addition, the aquatic insect *Copelatus irregularis* Macl. (Coleoptera: Dytiscidae) has been recorded in this cave (itself a big range extension from the Kimberley, central Australian Ranges and North-east Queensland).

MATERIAL AND METHODS

Groundwater was sampled for fauna at 261 sites on the Cape Range peninsula and in the Ashburton River valley in 1993; 185 of these sites yielded stygofauna (Figure 29). The groundwater was accessed through bores, wells, soaks, piezometers and caves. Bores were sampled for fauna using a plankton net with a 125 µm mesh and of a size suitable for the bore, the nets ranged from 30 mm to 180 mm in diameter. Wells were sampled by hand nets (125 µm mesh) and by Cvetkov (1968) phreatobiological nets (300 mm diameter, 250 µm mesh). Samples were variously taken through the entire water column and from various depths within the water column – occasionally the outflow from bore pumps was sampled by straining through a net (125 µm mesh). In all situations baited traps were sometimes used.

Comprehensive water analyses are available for seven of the eleven sites mentioned in this paper (Humphreys 1994). Where direct measurements were not made the salinity (total soluble salt: TSS) was estimated from the electrical conductivity measured in the field.

Permanent mounts were made in commercial polyvinyl-lactophenol medium. Dissected specimens were drawn at magnification of 400x and 1000x, the latter using an oil immersion lens and "camera lucida" mounted on a Leitz Laborlux D phase-contrast microscope. Type material is deposited in the Western Australian Museum (WAM).

Terminology applied to body and appendages according to Huys and Boxshall (1991).

SYSTEMATICS

Family Cyclopidae Burmeister, 1834

Genus *Metacyclops* Kiefer, 1927; sensu Lindberg, 1961

Metacyclops mortoni sp. nov.

(Figures 1–15)

Material Examined

Holotype

♀ (WAM 183–94), Kudamurra Well (C–25), Cape Range peninsula, Western Australia (station BES 2199), Australia, 21°54'S, 113°49'E, 1 June 1993, R.D. Brooks.

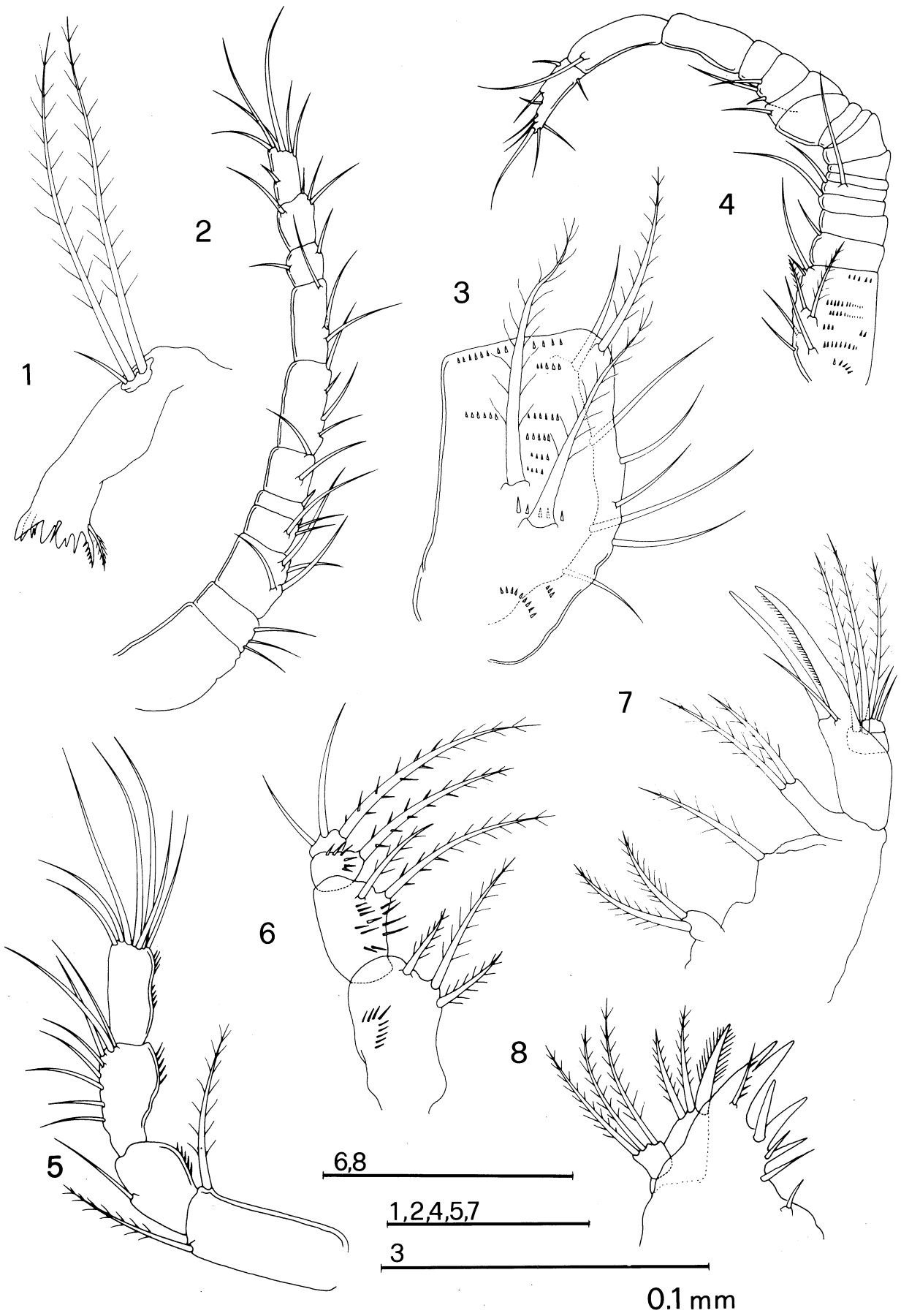
Paratypes

Australia: Western Australia: 1 ♂ (allotype) (WAM 2–184), 2 ♀ (WAM 185, 186–94), Geebera Well, Ashburton River (BES 2321), 22°06'S, 115°08'E, 26 June 1993, R.D. Brooks and W.F. Humphreys; 2 ♀, (WAM 187, 188–94), Five Mile Well (C-273) (BES 2196), 21°51'S, 113°52'E, 1 June 1993, R.D. Brooks; 2 ♀ (WAM 189, 190–94), Tulki Well (C–149) (BES 2213), 22°05'S, 113°54'E, 2 June 1993, R.D. Brooks; 2 ♀ (WAM 191, 192–94), Waroora Well, Pt. Maud (BES 2227), 23°09'S, 113°48'E, 11 June 1993, R.D. Brooks.

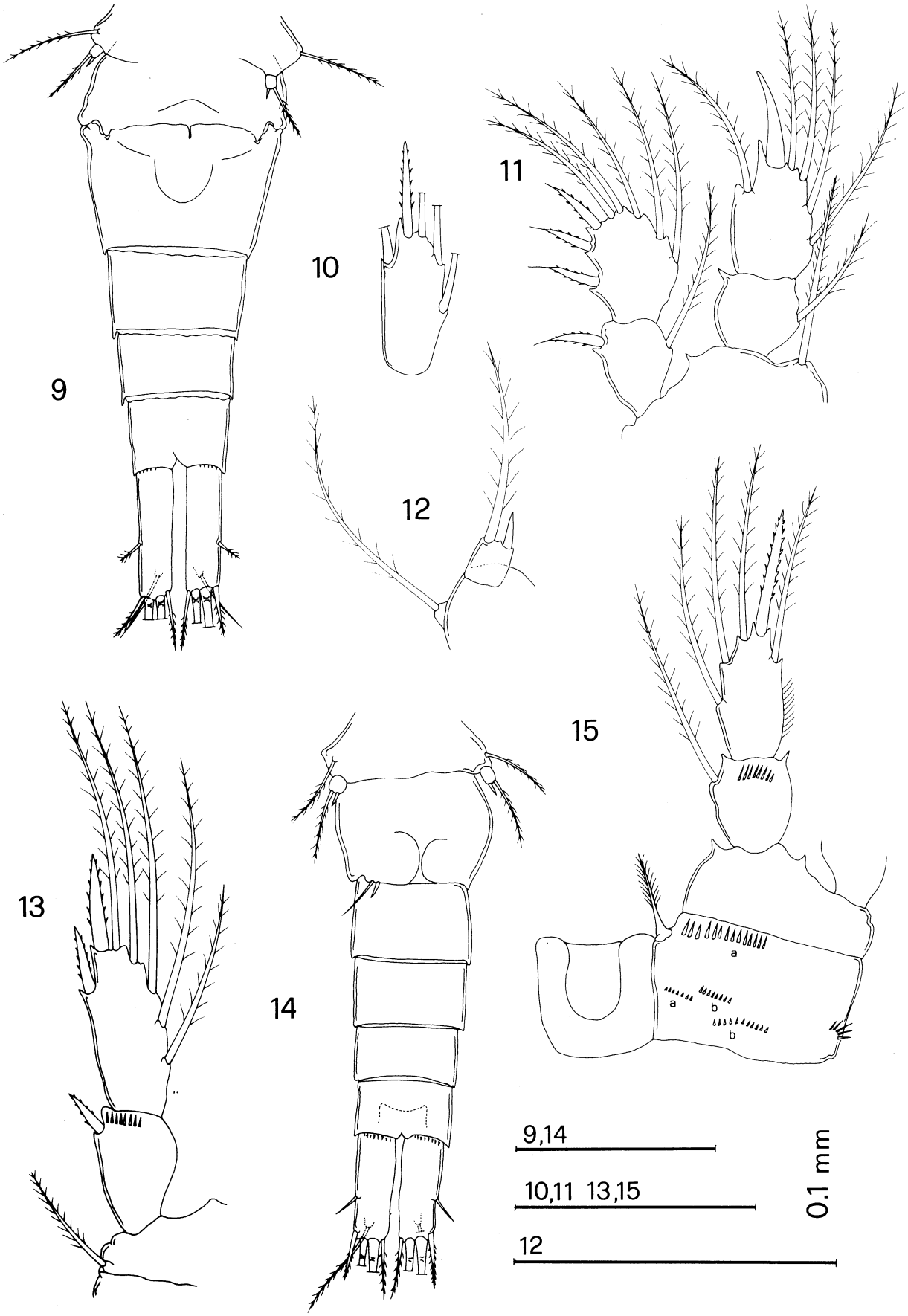
Description

Female

Length of holotype, excluding antennule and caudal setae, 555 µm; range of length of 6 paratypes 540–560 µm. Body widest at first prosomite. Genital segment about as long as broad, anterior 2/3 faintly expanded laterally; seminal receptacle with well developed subcircular anterior expansion, lateral canals almost horizontal. First urosomites naked, anal somite with small spinules along posterior margin; anal operculum not well defined.



Figures 1–8 *Metacyclops mortoni* sp. nov., 1–3, 5–8 (holotype), 4 (allotype): 1, mandible; 2, ♀ antennule; 3, basal segment of antennule, ventral; 4, ♂ antennule; 5, antenna; 6, maxilliped, posterior side; 7, maxilla; 8, maxillula.



Figures 9–15 *Metacyclops mortoni* sp. nov., 9, 11–13, 15 (holotype), 14 (allotype), 10 (female paratype): 9, urosome and caudal rami, ventral; 10, endopodite 3 of leg 4; 11, leg 1; 12, leg 5; 13. exopodite of leg 4; 14, urosome and caudal rami, ventral; 15, endopodite, basis, coxa and connecting plate of leg 4 (a: frontal side; b: caudal side).

Caudal rami, 3.6 (holotype), 3.5–3.7 (6 paratypes) times longer than broad; lateral seta inserted at distal half of ramus; dorsal seta shorter than ramus; terminal inner seta slightly longer than outermost.

Antennule 11-segmented, shorter than first prosomite; basipodite armed with 9 rows of small spinules, three dorsal, well-developed plumose setae and 7–8 lateral setae; remaining setation as in Figure 2.

Antenna 4-segmented; basipodite with well developed exopodal seta reaching about tip of the second segment, and one inner, subdistal plumose seta [type 3a, according to Reid (1991)]; first segment with one seta, second segment with eight setae, terminal segment with seven setae; no spine pattern was observed on both frontal and caudal side of the basipodite.

Maxilliped 4-segmented, comprising syncoxa, basis and 2-segmented endopodite; syncoxa armed with 3 inner plumose setae representing vestigial endites and a row of small spinules; basis with two inner plumose setae and numerous long spinules; first endopodal segment bearing a single spinulose seta and a row of 5–6 spinules, second endopodal segment with a spinulose seta and two shorter naked setae.

Mandible, maxillule and maxilla without particular characteristics as compared to those of congeners.

Swimming legs 1–4 with 2-segmented rami. Spine and setae formula of distal segments of exopodites 3.4.4.2 and 5.5.5.5, respectively. Couplers of all legs lacking ornament. Spine on the basipodite of leg 1 well developed, reaching about tip of distal segment of endopodite.

Leg 4, coxa with four rows of spinules, arranged as in Figure 15; distal segment of the endopodite about 2 times longer than broad, armed with one apical spine, slightly longer or about as long as the segment.

Leg 5 consisting of one free segment, slightly longer than broad; spine slightly shorter than segment.

Male (Allotype)

Length 530 µm. Habitus slender. Antennule geniculate, 17-segmented. Leg 5 similar to that of female. Leg 6 consisting of two spiniform setae, ventral seta shorter and stouter than dorsal one. Caudal rami sexually dimorphic, shorter (L/l = 2.9–3.1) than those of female.

Affinities

The genus *Metacyclops* (sensu Lindberg 1961) is widespread in tropical and temperate regions. At present it includes 52 named species and subspecies, only two, *M. arnaudi* and *M. arnaudi platypus*, are recorded from Australia.

Lindberg (1961) established two species-groups within the genus, viz. the minutus-group and the gracilis-group, embracing species characterized by one or two distal spines on the endopodite 3 of leg 4, respectively. *M. mortoni* is a member of the *minutus*-group, but it does not match any species in either Lindberg's (1961) or Herbst's (1988, 1990) keys of *Metacyclops*, because of the combination of the following characters: antennula 11-segmented, with first segment spinulose; basipodite of the antenna with 2 setae; legs 1–4 spine formula 3.4.4.2, endopodite 3 of leg 4 with one apical spine; couplers of legs 1–4 lacking ornament; inner caudal seta longer than outermost, male leg 6 consisting of 2 setae.

The spine formula 3.4.4.2 of legs 1–4 is a striking feature of the new species; within the genus *Metacyclops* deviation from the characteristic formula 3.4.4.3 has been reported only in *M. trispinosus* Dumont, 1981, from West Africa, which has a spine formula 3.3.3.3.

Etymology

The species is dedicated to Mr D.W. Morton in recognition of his recent valuable contributions to the knowledge of Australian copepods.

Genus *Mesocyclops* G. O. Sars, 1914

Mesocyclops brooksi sp. nov.

Figures 16–28

Material Examined

Holotype

♀ (WAM 193–94), Bobs Well, Ashburton River, Western Australia, Australia (BES 2333), 22°29'S, 115°23'E, 28 June 1993, W.F. Humphreys and R.D. Brooks.

Paratypes

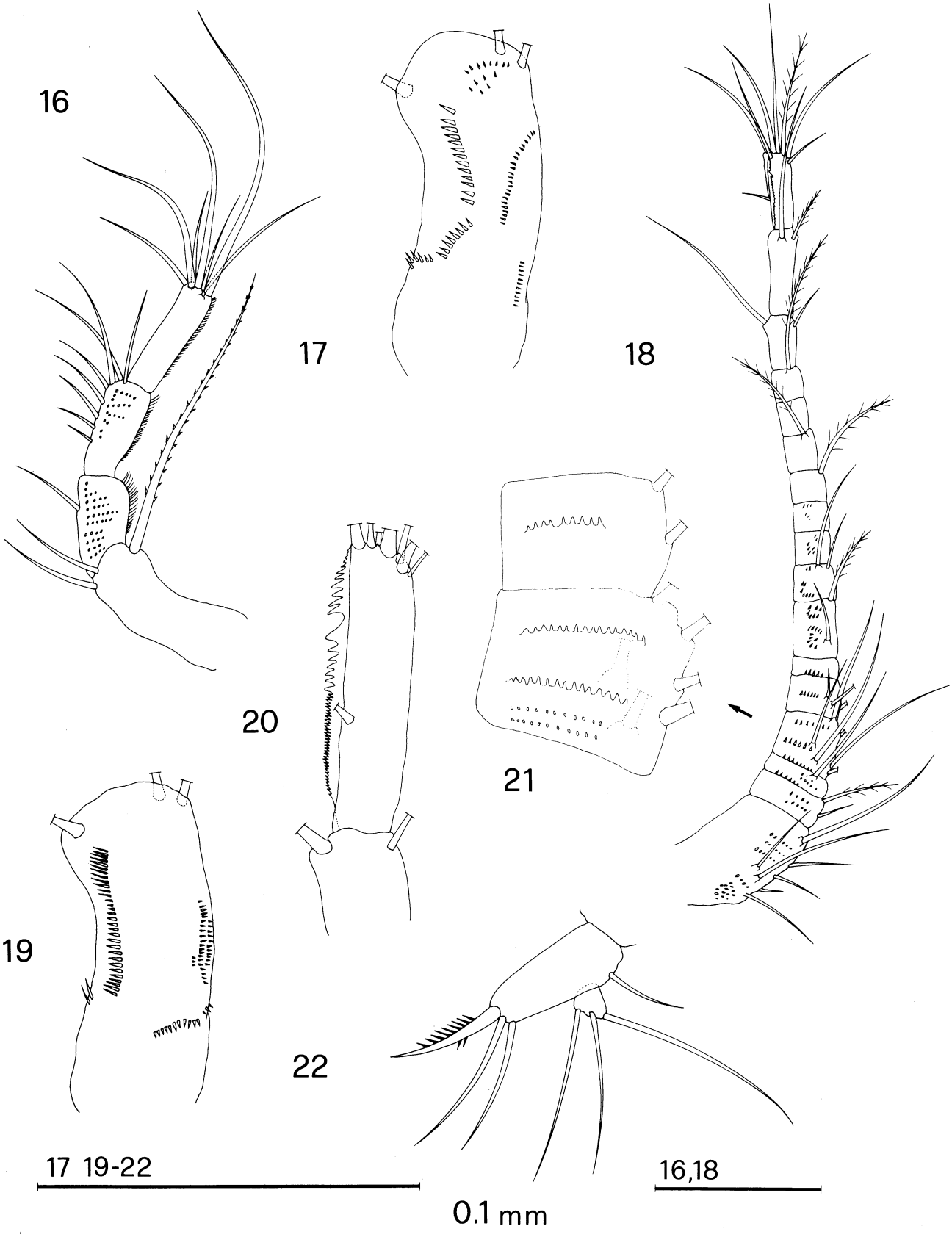
Australia: Western Australia: 1 ♀, 1 ♂, same data as holotype (WAM 194, 195–94).

Description

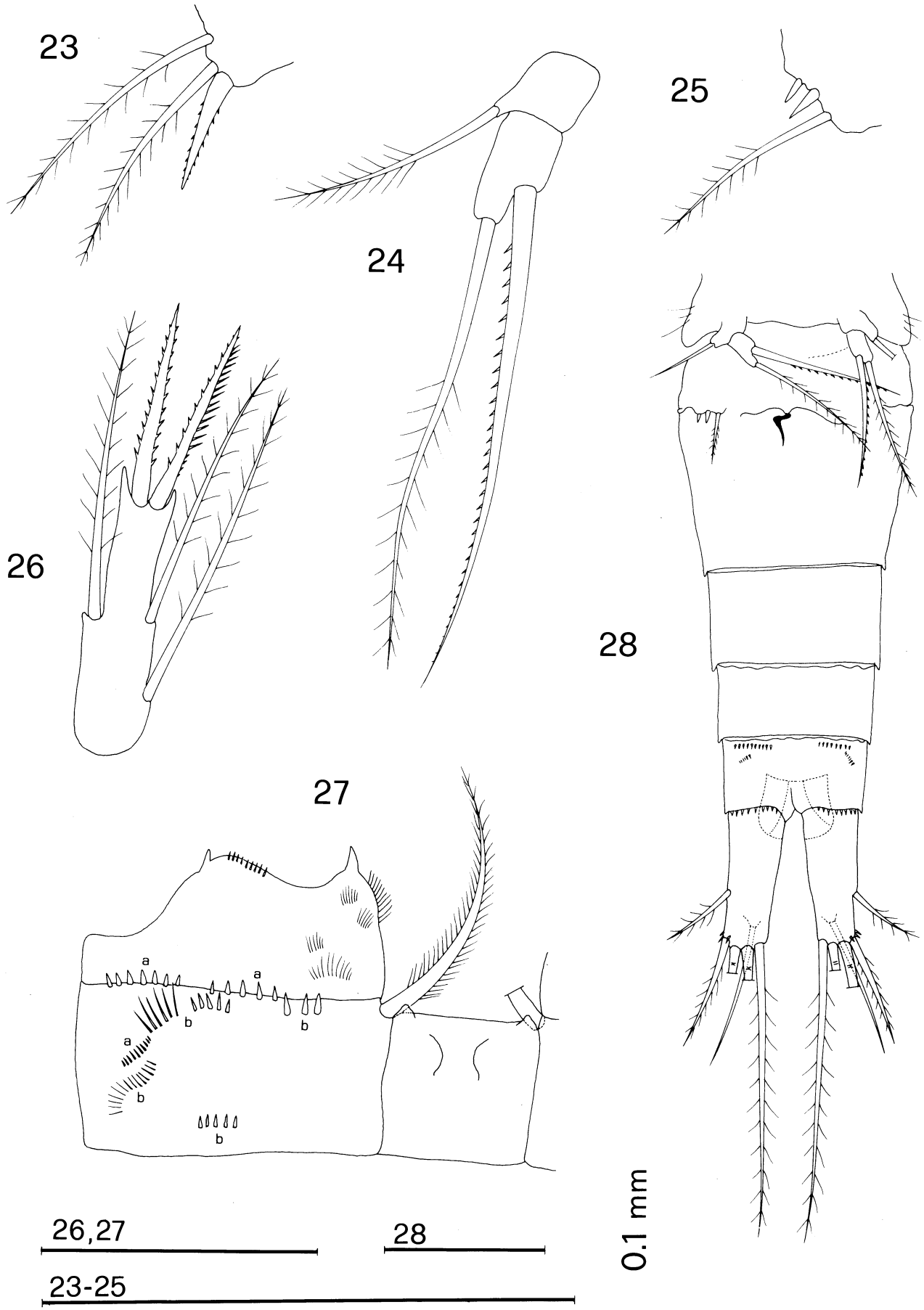
Female

Total body length 1350 µm (holotype), 1320 µm (paratype). Fifth thoracic segment with few setules laterally. Genital segment about as long as broad. Owing to the preparation the seminal receptacle is partially obscured in both specimens, pore canal recurved.

Antennule 17-segmented, reaching the distal margin of the third thoracic segment; spinule patterns are present on segments II–X; segments IV–V with two (IV) or one (V) crenelate lamellas; segments I–IV with several rows or groups of small integumental circular pits on dorsal surface; distal



Figures 16–22 *Mesocyclops brooksi* sp. nov. (holotype): 16, antenna; 17, antenna, basipodite (caudal side); 18, antennule; 19, antenna, basipodite (frontal side); 20, antennule, distal segment; 21, antennule, segment 4; 22, maxillulary palp.



Figures 23–28 *Mesocyclops brooksi* sp. nov., 23 (male paratype), 24–28 (holotype): 23, ♂ leg 6; 24, leg 5; 25, ♀ leg 6; 26, endopodite 3 of leg 4; 27, basis, coxa and connecting plate of leg 4 (a: frontal side; b: caudal side); 28, urosome and caudal rami.

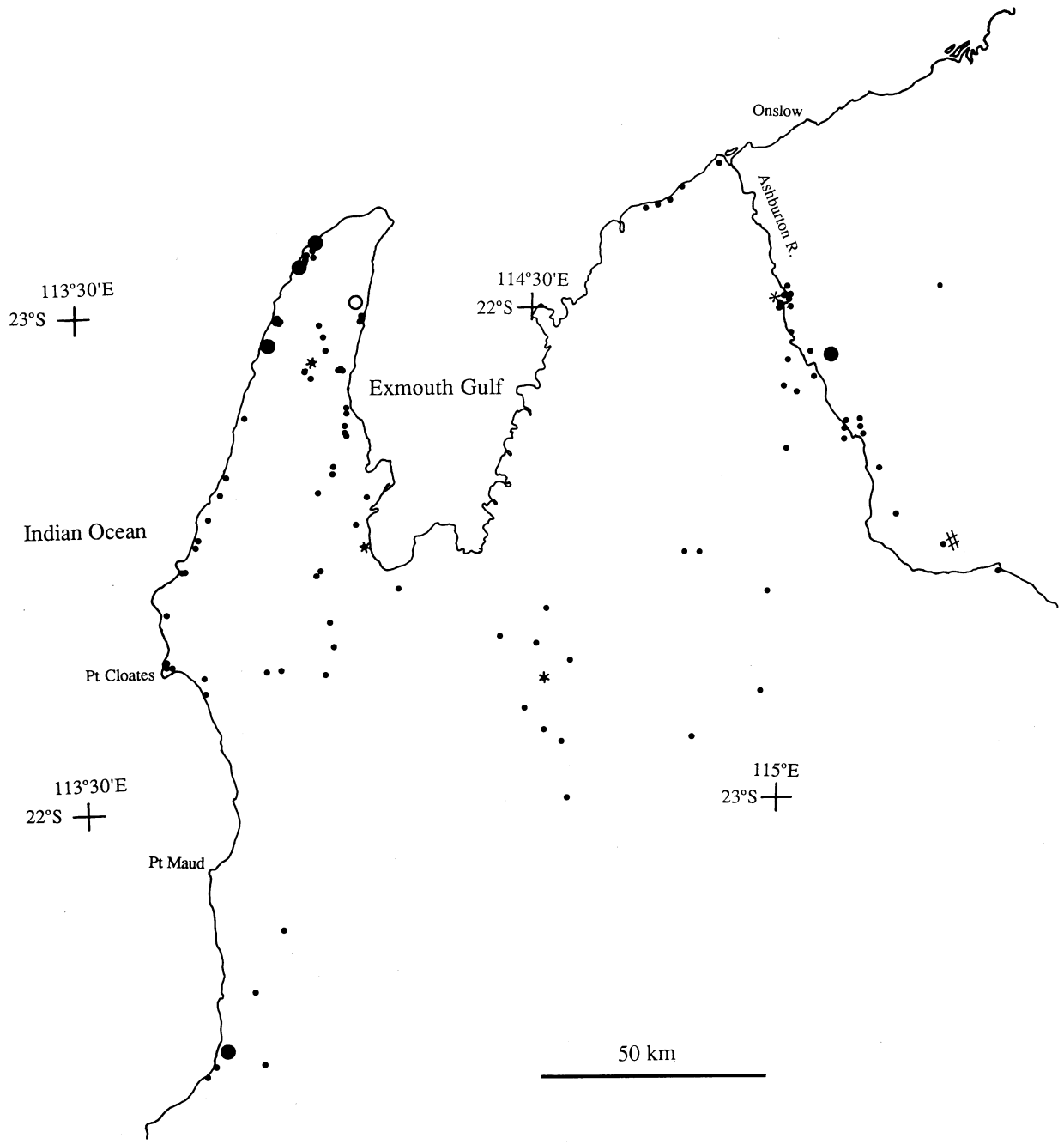


Figure 29 The location of the samples in northwestern Australia: *Metacyclops mortoni* sp. nov. (●); *Mesocylops brooksi* sp. nov. (#); *Apocyclops dengizicus* (○); *Microcylops varicans* (✻). The small dots denote sites where stygofauna was found.

segment with hyaline lamella provided with one deep notch; remaining ornamentation as in Figures 18, 20, 21.

Antenna. Endopodite 3-segmented; first segment with one inner seta, second segment with eight setae, third segment with an apical group of seven setae; segments I–II with rows of small integumental pits. All segments with a row of setules on the external side. Basipodite with vestigial exopodal seta overreaching tip of the distal segment of the endopodite, and two short subdistal setae, frontal side with the characteristic row of long spinules along the outer margin, 2–3 rows of small spinules on the inner margin, and a transverse row of spinules below.

Maxillulary palp not provided with spines. Other mouthparts as usual in the genus.

Legs 1–4, spine and setae formula typical for the genus; couplers without setules on the caudal side. Leg 1, inner margin of the basipodite not armed with a spine. Leg 4: endopodite about 3.5 times longer than broad; apical spines subequal, outer spine equally serrated on both margins, inner spine with outer margin completely set with spinules, internal margin regularly serrated; couplers with pair of blunt tubercles, coxopodite armed with 3 (frontal side) and 4 (caudal side) rows of spines/setules; caudal side of the basipodite on its distal

internal margin with a row of small spinules, on its distal and subdistal margin with 4–5 rows of thin setules.

Leg 5. Spinous seta about as long as the plumose seta; setae not reaching to the posterior margin of the genital segment.

Leg 6 consisting of two small spines and one long plumose seta; characteristic group of small pores present at its basis.

Caudal rami about 3 times longer than broad, without cilia on the inner margins; dorsal seta longer than the apical outer seta, inner seta about 2.5 times longer than corresponding outermost.

Male

Smaller than females, total body length, excluding antennule and caudal setae, 1270 µm. Antennule geniculate, with integumental pits as in females. Spine and pit pattern on the basipodite and endopodite of antenna, structure of legs 1–5 and ornamentation of fifth thoracic segment as in females. Leg 6 consisting of a protuberance bearing one stout spine and two plumose setae.

Affinities

Mesocyclops is a cosmopolitan and widespread genus found mainly in surface fresh waters, rarely in ground waters. It includes 66 species and subspecies, which are especially common in the tropics and subtropics, a few species also occur in temperate and arctic regions.

Taxonomic understanding of the genus has greatly improved during recent years on account of recognition of formerly overlooked micro-characters, such as morphology of the hyaline lamella on the distal segment of the antennula, the presence or absence of spine patterns on the antennular segments, the presence or absence of spines on the maxillulary palp, the armature of the intercoxal plate of leg 4, the ornamentation of the spines on the distal segment of the endopodite of leg 4 and the presence or absence of setules on the fifth thoracic segments (Van de Velde 1984; Dussart and Fernando 1988; Reid 1993).

Following Kiefer's (1981) excellent review of *Mesocyclops*, the closest relatives to *M. brooksi* are *M. notius* and *M. australiensis*.

From the above species, *M. brooksi* is readily distinguishable by the shortness of the genital segment, the different length ratio between inner and outer distal spines on the endopodite 3 of leg 4 (subequal in *M. brooksi*, the inner shorter than outer in both *M. australiensis* and *M. notius*), the different serration along the margins of the inner apical spine of the endopodite of leg 4, and the shorter caudal rami.

Additionally, a salient feature of the new species is the integumental pits on the dorsal surface of the antennule and antenna, both in male and females. Circular pits on some segments of the antennule in *Mesocyclops* species were firstly pointed out by Von Daday (1906), who interpreted them as integumental tubercles. Subsequently, Reid and Saunders (1986) reported similar structures in specimens of *Mesocyclops* aspericornis (Von Daday, 1906) from Venezuela, considering them as sensory structures, advantageous in spatially restricted habitats. Nishida (1986) showed identical structures in marine cyclopoids of the genus *Oithona*, interpreting them as chemo- or mechanoreceptors in mating behaviour, which could represent "areas of increased friction during copulation". Reid and Saunders (1986) also referred to such integumental pits in species of the genus Thermocyclops, suggesting that closer investigations of these structures should be carried out in future species descriptions.

Etymology

Named after Mr R.D. Brooks, a collector of the new species.

Genus *Microcyclops* Claus, 1893

Microcyclops varicans (G. O. Sars, 1863)

Material Examined

Australia: Western Australia: 2 ♀ (WAM 196, 197–94), Cashen Well, Exmouth Gulf Station (BES 2146), 22°29'S, 114°06'E, 24 May 1993, W.F. Humphreys and R.D. Brooks; 1 ♀ (WAM 198–94), River Well, Ashburton River (BES 2318), 22°00'S, 115°02'E, 26 June 1993, W.F. Humphreys and R.D. Brooks; 1 ♀ (WAM 199–94), Dry Swallet Cave (C-18), Cape Range (BES 2372), 22°05'S, 114°00'E, 12 July 1993, R.D. Brooks; 1 ♀ (WAM 200–94), Number 8 Bore, Cape Range peninsula (BES 2379), 22°45'S, 114°31'E, 20 July 1993, R.D. Brooks.

Genus *Apocyclops* Lindberg, 1942

Apocyclops dengizicus (Lepechkine, 1900)

Material Examined

Australia: Western Australia: 1 ♀ (WAM 201–94), Marina piezometer bore C, Exmouth (BES 2234); 21°57'S, 114°08'E, 16 June 1993, R.D. Brooks.

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