

Copepods from ground waters of Western Australia, II. The genus *Halicyclops* (Crustacea: Copepoda: Cyclopidae)

G.L. Pesce¹, P. De Laurentiis¹ and W.F. Humphreys²

¹ Dipartimento di Scienze Ambientali, University of L'Aquila, Via Vetoio, I-67100 L'Aquila, Italy

² Western Australian Museum, Francis Street, Perth, Western Australia 6000, Australia

Abstract – *Halicyclops longifurcatus* n.sp. is described from groundwaters of the Cape Range karst area, north-western Australia. *Halicyclops spinifer* Kiefer 1935, from the same region, is for the first time recorded from Australia. These findings increase to three the number of congeners from Australia, the other being *H. ambiguus* Kiefer, 1967, reported from the southeastern part of the continent.

INTRODUCTION

Cyclopoid copepods have recently been collected from a variety of different groundwater habitats (sinkholes, anchialine caves, wells) on the Cape Range peninsula, northwestern Australia. The material included several interesting stygobitic and stygophilic species, amongst them an undescribed species of the genus *Halicyclops* Norman and the species *Halicyclops spinifer* Kiefer, 1935.

Halicyclops is a cosmopolitan genus, with 72 named species and subspecies, widely distributed in coastal brackish waters, ponds, marshes and sandy beaches; nineteen species, the new species included, are stygophilic inhabitants of ground water habitats, such as anchialine caves, sinkholes and different interstitial media.

The present finding increases to three the number of *Halicyclops* species from Australia, the other being *H. ambiguus* Kiefer, 1967, described from southeastern Australia.

Habitat and associated fauna

North-western 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 as well as in the general water table of the surrounding foothills and coastal plain where a freshwater lens overlies salt water (Humphreys 1993a, 1993c, 1993d).

Halicyclops longifurcatus is known only from an anchialine flooded sinkhole (cenote), 1.6 km from the ocean (Figure 24). The specimens were collected by hauling a plankton net (125 µm mesh) through the water above the marked thermo-halocline which occurs at a depth of ca. 6 m. A number of taxa have been recorded from the sinkhole above the thermo-halocline: foraminiferida, *Iravadia* sp. (Mollusca: Irvadiidae), ostracods, *Stygiocaris*

stylifera Holthuis (Malacostraca: Decapoda: Natantia: Atyidae), gerrids (Hemiptera), chironomids (Diptera), *Milyeringa veritas* Whitely (Perciformes: Eleotridae) and the algae *Rhizoclonium ?tortuosum* (Dillw.) Kuetz. (Chlorophyta: Cladophoraceae) and *Lamprothamnium papulosum* (Wallr.) J. Gr. (Charophyta: Characeae). Below the halocline occurs a strictly anchialine fauna (Yager and Humphreys 1996) with tethyan affinities (Humphreys 1993b; Humphreys and Feinberg 1994; Knott 1993). This fauna includes *Lasionectes exleyi* (Remepedia: Speleonectidae- Yager and Humphreys 1996), *Liagoceradocus* sp. nov. (Amphipoda: Hadziidae- Bradbury and Williams 1995) and *Danielopolina* sp. nov. (Ostracoda: Thaumatoocyprididae – Baltanas and Danielopol 1995).

At the surface the salinity was 20,000 mg L⁻¹ and below the thermo-halocline the salinity gradually increased with depth to 32,000 mg L⁻¹. The surface temperature was 28.5°C and dropped to 25.0°C at the thermocline, increasing with depth to 26.3°C.

Halicyclops spinifer occurred in a hand-dug pastoral well (C-361) near the coast with a salinity of 1,400 mg L⁻¹, and at 200 m above sea level in a deep cave (C-18) in central Cape Range where the salinity was 500 mg L⁻¹. The fauna associated with C-361, but not at the time of sampling for *H. spinifer* includes *Milyeringa veritas* and *Ophisternon candidum* (Mees) (Synbranchiformes: Synbranchidae), *Stygiocaris stylifera*, dipteran larvae and harpacticoid copepods. The water in C-18 contains *Microcyclops varicans* (Copepoda: Cyclopidae) (Pesce *et al.* 1996), a melitid amphipod (undescribed genus: W. D. Williams, per. comm.), and the aquatic insect *Copelatus irregularis* Macl. (Coleoptera: Dytiscidae) (further details in Pesce *et al.*, 1996).

MATERIAL AND METHODS

Various plankton nets (mesh size 125 μm) were used to collect copepods from wells, bores, caves and anchialine pools on the Cape Range peninsula and its hinterland in northwestern Australia, as described fully in Pesce *et al.* (1996).

Specimens, completely dissected, were mounted on cover slips in commercial polyvinyl-lactophenol. The figures were prepared using a camera lucida on a Leitz Laborlux D phase-contrast microscope.

Holotype and paratypes of the new species, and material of *H. spinifer*, are deposited in the Western Australian Museum, Perth, Australia (WAM); one paratype was deposited in the Museo Civico di Storia Naturale, Verona (Italy).

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

Family Cyclopidae Burmeister, 1834

Subfamily Halicyclopinae Kiefer, 1927

Genus *Halicyclops* Norman, 1903

Halicyclops longifurcatus sp. nov. Figures 1–11, 24

Material Examined

Holotype

♀ (WAM 248–94), Bundera Sinkhole (karst index number C-28), (BES 2470), Cape Range Peninsula, Western Australia, Australia, 22°25'S, 113°46'E, 6 August 1993, W.F. Humphreys and R.D. Brooks.

Paratypes

Australia: Western Australia: 9 ♀, 1 juvenile (WAM 249–94 to 257–94 and 263–94), same data as holotype; 1 ♀ (BES 2476: WAM 258–94), same locality as BES 2470.

Description

Female (holotype)

Body length 755 μm , body length range of 11 paratypes 750–760 μm . Hyaline fringes of prosomites smooth. Genital double somite about as long as broad, expanded into two rounded lateral protuberances. Hyaline fringes of genital double somite and subsequent somites serrate, fourth urosomite with small denticles on the dorsal side of hyaline fringe.

Caudal ramus long, 4.6 (holotype), 4.5–4.7 (paratypes) times longer than broad; inner apical seta reduced to slender and naked seta, outermost apical seta about as long as lateral seta; dorsal seta as long as ramus; inner middle apical seta bearing 4–5 spinules on distal part of basal half, terminal half irregularly plumose, outer middle apical seta

with 5–6 spinules on distal half, irregularly plumose distally.

Antennule 6-segmented, armed as in Figure 3. Antenna 3-segmented; basis with two inner distal plumose setae and one outer exopodal seta; middle segment with one inner seta; distal segment with 5 inner and 7 apical setae (some plumose).

Mandible reduced to coxa and gnathobase; palp consisting of two setae inserted on small protuberance.

Maxillula: praecoxa bearing four setae and two spines on inner side and four stout spines distally; palp consisting of basis bearing three setae on inner margin, one proximal exopodal seta and endopodite with three distal setae.

Maxilla as in Figure 2. Maxilliped 2-segmented; proximal segment bearing two setae, terminal segment with two inner modified setae and three long apical setae.

Swimming legs 1–4 armament as follows (roman numerals denote spines, arabic numerals denote setae).

	coxa	basis	endopodite	exopodite
leg 1	0–1	1–I	0–1;0–1;II–4	I–1;I–1;III–5
leg 2	0–1	1–0	0–1;0–2;III–3	I–1;I–1;IV–5
leg 3	0–1	1–0	0–1;0–2;III–3	I–1;I–1;IV–5
leg 4	0–1	1–0	0–1;0–2;III–2	I–1;I–1;III–5

Leg 1, basis with spine at inner corner overreaching the posterior border of the endopodite segment 2. Legs 2–3 similar to each other; distal endopodite segment with proximal seta plumose basally and spinulose distally. Leg 4 endopodite segment 3 longer than broad (1.48–1.57:1); inner apical spine slightly longer than segment and about 2 times longer than outer apical spine; inner setae spiniform, about equal in length, but only the proximal one basally plumose.

Leg 5 exopodite about twice as long as broad, and armed with one apical seta and three serrated spines.

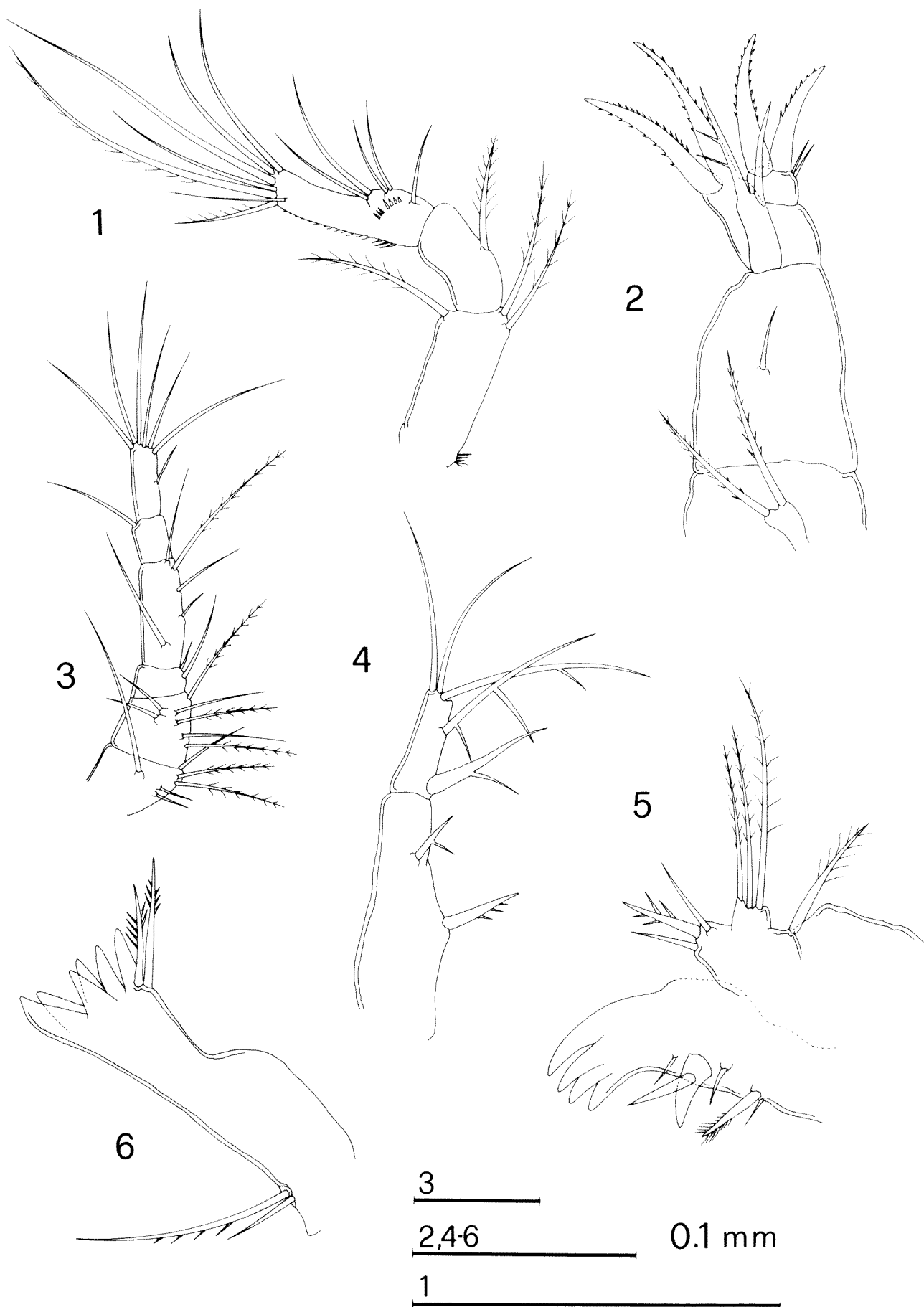
Male

Unknown.

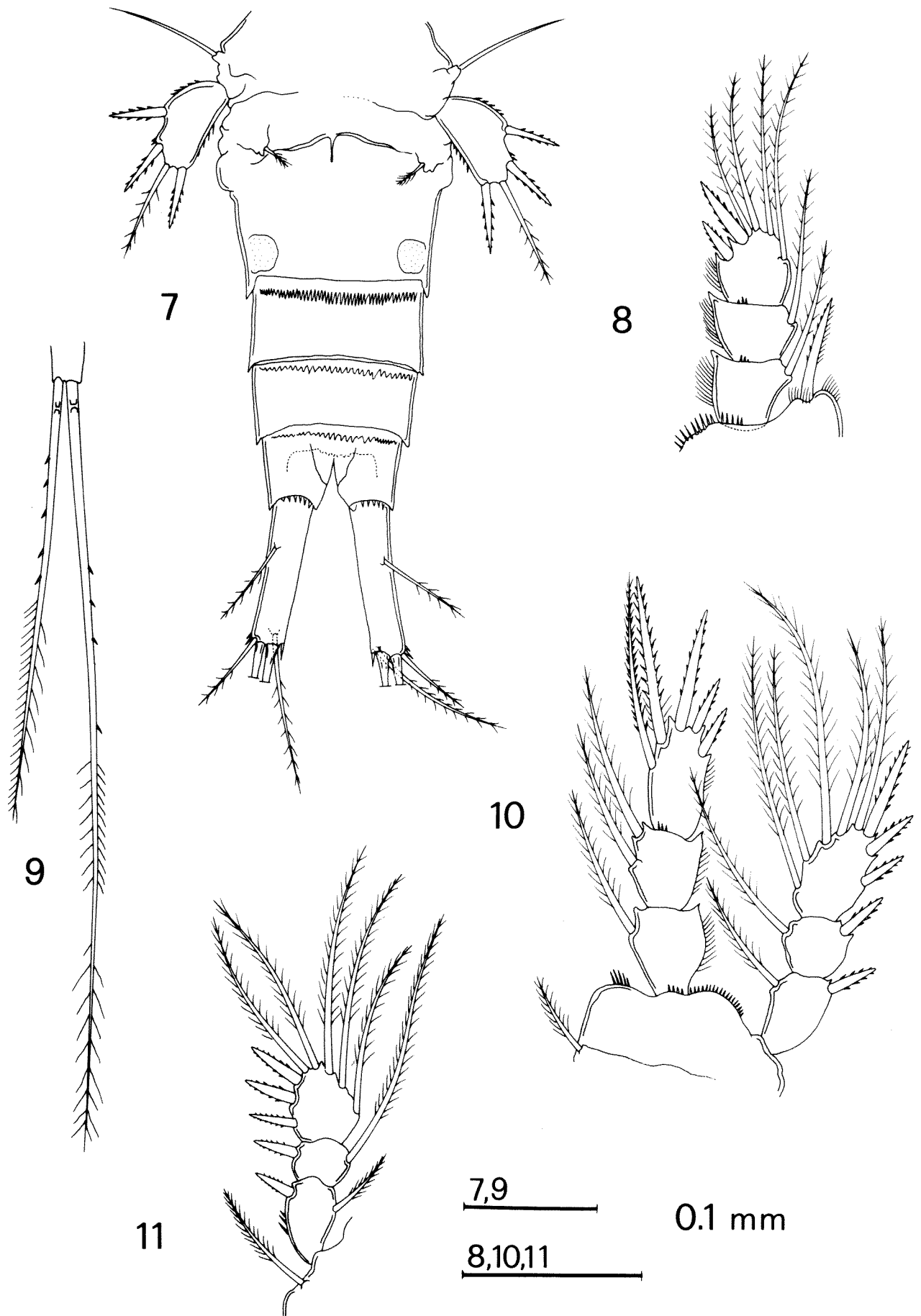
Differential Diagnosis

Several species of *Halicyclops* share with *H. longifurcatus* the lateral rounded protrusions on the genital double somite, the exopodite spine formula 3.4.4.3, and the poorly developed hyaline fringe on the fourth urosomite (Lindberg 1957).

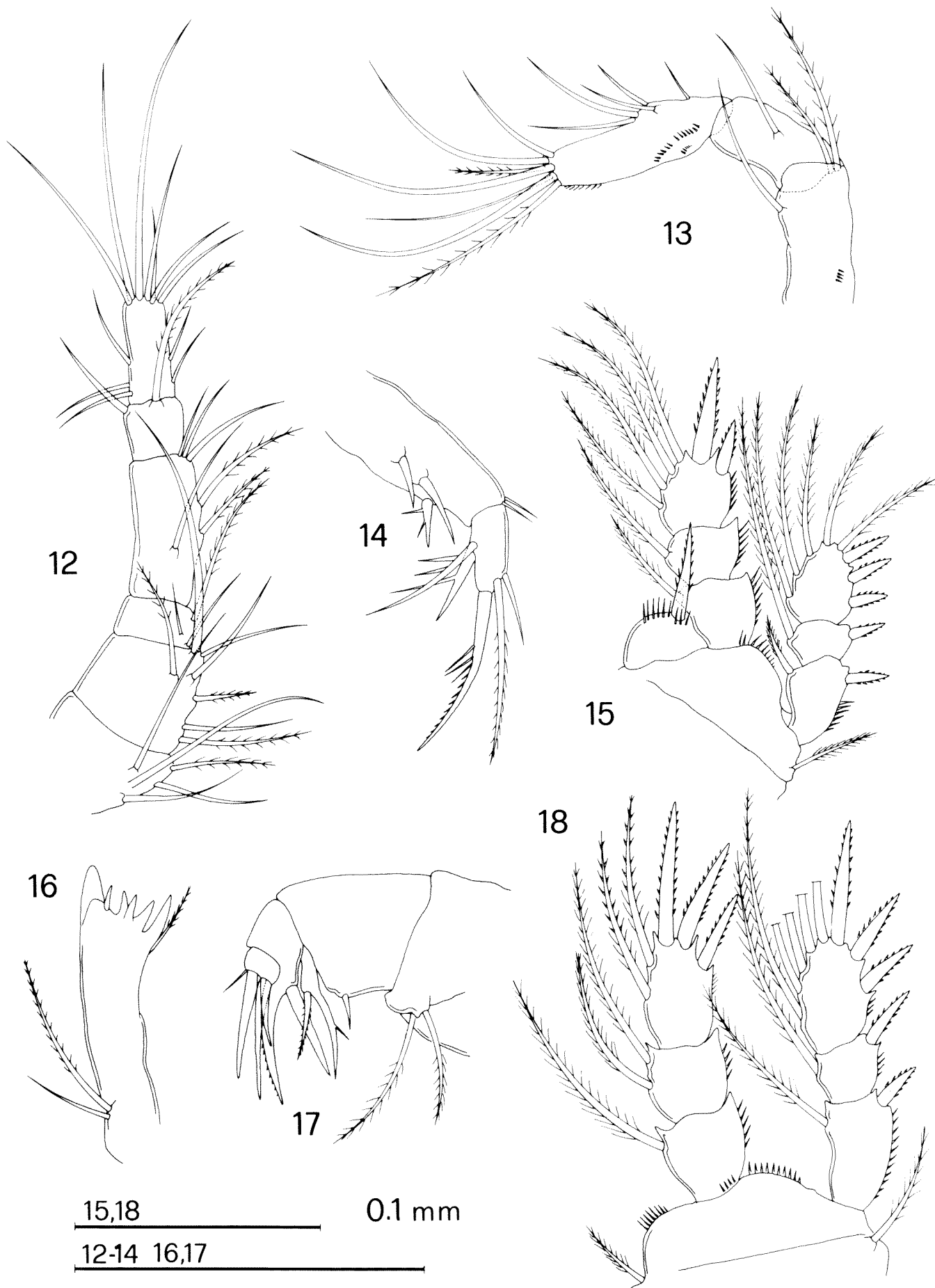
From these species, as well as from other congeners, the new species may be distinguished easily by the remarkable length of caudal rami, unusual for species of the genus *Halicyclops*, and by the mandibular palp bearing two setae.



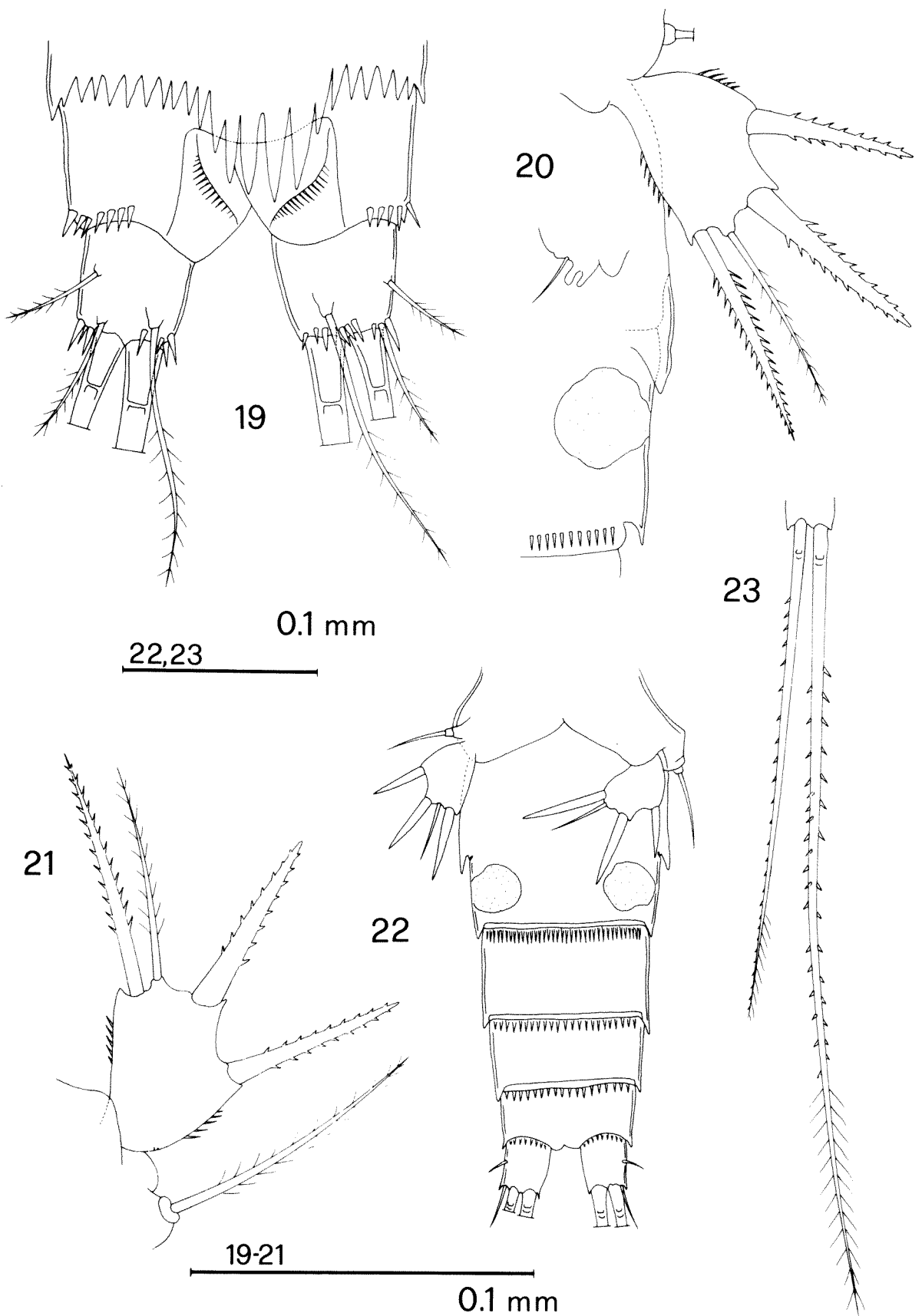
Figures 1-6 *Halicyclops longifurcatus* sp. nov. (holotype): 1, antenna; 2, maxilla, inner; 3, antennula; 4, maxilliped; 5, maxillula; 6, mandible.



Figures 7-11 *Halicyclops longifurcatus* sp. nov. (holotype): 7. abdomen and caudal rami, ventral view; 8, endopodite of leg 1; 9, middle apical caudal setae; 10, leg 4; 11, exopodite of leg 1.



Figures 12-18 *Halicyclops spinifer*: 12, antennula; 13, antenna; 14, maxilliped; 15, leg 1; 16, mandible; 17, maxilla; 18, leg 4.



Figures 19-23 *Halicyclops spinifer*: 19, anal somite and furcal rami, dorsal view; 20, legs 5-6, and lateral spine on genital somite; 21, leg 5; 22, abdomen and caudal rami, ventral view; 23, medial caudal setae.

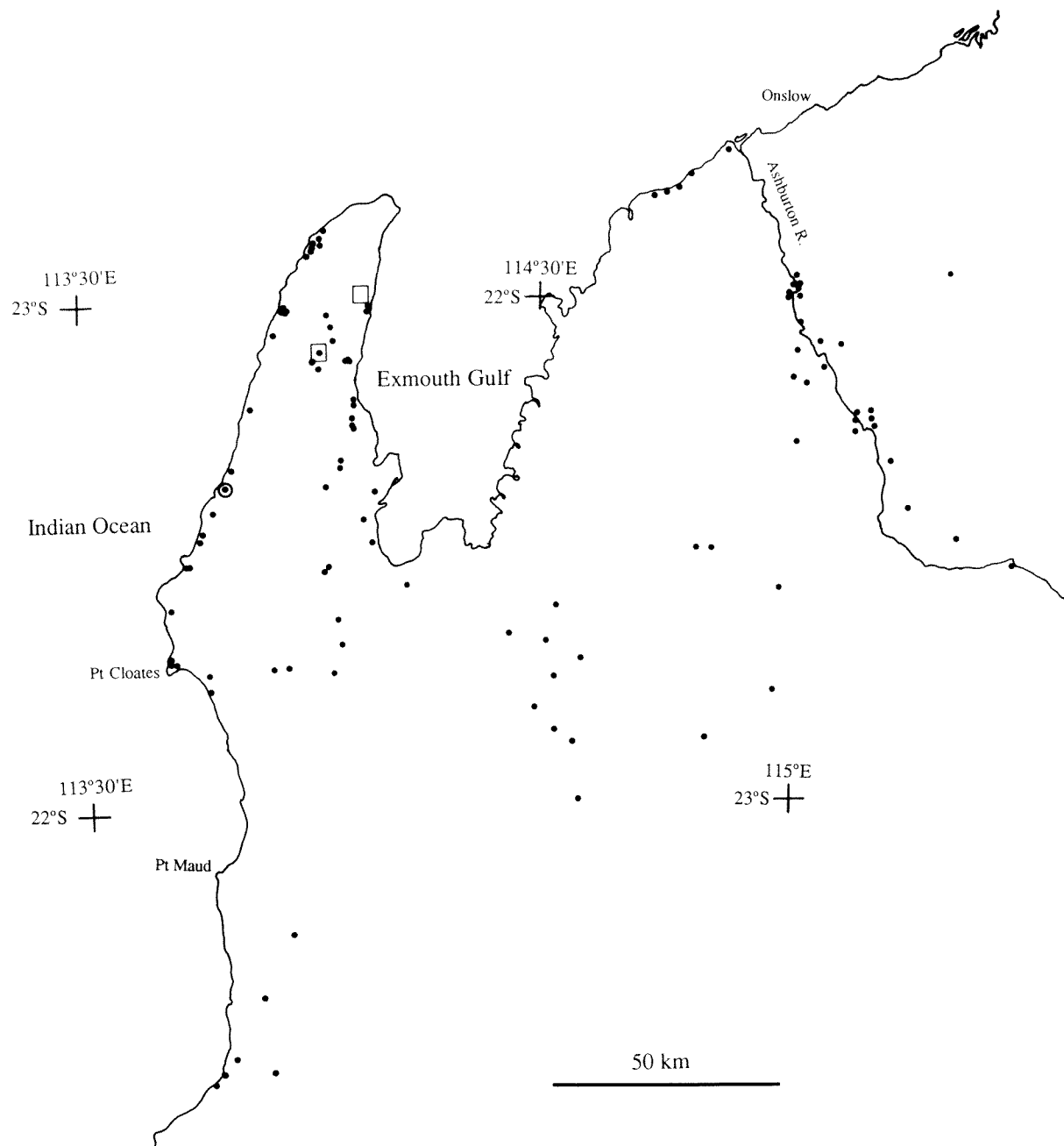


Figure 24 Location of the collection sites for *Halicyclops longifurcatus* sp. nov. (O) and *H. spinifer* (□) in northwestern Australia. The small dots denote sites where stygofauna was found.

Etymology

The specific epithet is derived from the remarkable length of the caudal rami, unusual for the species of *Halicyclops*.

Halicyclops spinifer Kiefer, 1935

Figures 12–24

Material Examined

Australia: Western Australia: 2 ♀ and 1 juv. (WAM 260–94 to 262–94), Mowbowra Well (BES 2221), Cape Range peninsula, 22°00'S, 114°07'E, 9 June 1993, R.D. Brooks; 1 ♀ (WAM 259–94), cave C-18 (BES 2372), Cape Range peninsula, 22°05'S, 114°00'E, 12 July 1993, R.D. Brooks.

Supplementary Description

Body length, 540 μ m (holotype), 550–560 μ m (2 paratypes). Hyaline fringes of all prosomites smooth. Genital double somite slightly longer than broad, with a well developed chitinous, sharp spine curved backward on each side. Hyaline fringes of genital double somite and two subsequent somites serrate; hyaline fringe of urosomite 4 well developed dorsally, with dorsomedial denticulations much longer and stouter than lateral ones.

Caudal ramus about as long as broad; innermost apical seta difficult to distinguish from row of spinules along distal margin of ramus; outermost apical seta about as long or slightly longer than

ramus; dorsal seta about three times longer than ramus; inner middle apical seta bearing numerous spinules on both sides of basal and middle part, plumose distally; outer middle apical seta barbed on the inner distal margin, spinulose along the outer margin.

Antennule 6-segmented, armature as in Figure 12. Antenna 3-segmented; basis with two inner distal plumose setae and one outer subdistal exopodal seta, second segment with one inner seta, distal segment with 5 inner and 7 apical setae (some plumose).

Mandible, maxillule and maxilla without particular characteristics as compared to the original description.

Maxilliped 2-segmented; proximal segment with three inner spiniform setae (one modified) and two outer subdistal setules; distal segment bearing two inner modified setae and three apical and subapical setae.

Swimming legs 1–4 armament as follows (numerals as in *H. longifurcatus*):

	coxa	basis	endopodite	exopodite
leg 1	0-1	1-I	0-1;0-1;II-4	I-1;I-1;III-5
leg 2	0-1	1-0	0-1;0-2;III-3	I-1;I-1;IV-5
leg 3	0-1	1-0	0-1;0-2;III-3	I-1;I-1;IV-5
leg 4	0-1	1-0	0-1,0-2;III-2	I-1;I-1;III-5

Leg 1 basis with spine at inner corner reaching about the posterior border of the endopodite segment 2. Legs 2–3 similar to each other, distal endopodite segment with proximal seta plumose basally and serrate distally. Leg 4 endopodite segment 3 about 1.3 times longer than broad, inner apical spine longer than segment and outer apical spine; inner setae plumose basally and spinulose distally.

Leg 5 exopodite slightly longer than broad, and armed with one seta and three serrated spines, longer than segment.

Leg 6 as in Figure 20.

Remarks

H. spinifer fits a group of species [*thermophilus* group, according to Herbst (1983)] which are characterized by a well developed chitinous spiniform process on each side of the genital double somite.

The nominate group includes the following other species: *H. thermophilus* Kiefer, 1929; *H. venezuelaensis* Lindberg, 1954; *H. japonicus* Ito, 1956; *H. latus* Shen and Tai, 1964; *H. antiguaensis* Herbst, 1983; *H. dedeckeri* Brownell, 1983.

Comparison between the specimens from Australia and the original description of *H. spinifer*, revealed minor differences only in the shape of the genital double somite and pseudopericulum, and in the size of the lateral spines on the genital double

somite. For the latter, however, Falavigna da Rocha (in litt.) showed wide variation in the number and size of spinules forming the pseudopericulum, in the length/width ratio of the genital double somite, as well as in the shape and size of the lateral spines of the same somite in specimens of *H. spinifer* from Brazil.

From a biogeographical point of view, beside the Australian continent, *H. spinifer* is at present known for India, Iran and Brazil (Falavigna da Rocha, in litt.).

ACKNOWLEDGEMENTS

For determining the associated fauna we thank Mrs S. Slack-Smith, Dr T. Entwistle and Dr. L. B. Holthuis. We are also grateful to Dr J.W. Reid and Dr C. Plesa for valuable suggestions, and to Dr Falavigna da Rocha for reading and commenting on the manuscript. Field collecting was funded by the National Estate Grants Scheme and the water analysis by the Water Authority of Western Australia.

REFERENCES

- Baltanas, A. and Danielopol, D. (1995). Cladistic analysis of *Danielopolina* species (Ostracoda: Thaumatozoididae) and the origin of anchialine fauna. *Mitteilungen Hamburgisches Zoologisches Museum und Institut* 92: 315–324.
- Bradbury, J.H. and Williams, W.D. (1995). Two new species of anchialine amphipod (Crustacea: Hadziidae: *Liagoceradocus*) from Western Australia. *Records of the Western Australian Museum* 17: 395–409.
- Herbst H.-V. (1983). Ein neuer Copepode (Cyclopoida: Gnathostoma) von dem Westindischen Inseln: *Halicyclops antiguaensis* n. sp. *Bijdragen tot Dierkunde* 52: 262–266.
- Humphreys, W.F. (1993a). Cave fauna in semi-arid tropical Western Australia: a diverse relict wet-forest litter fauna. *Mémoires de Biospéologie* 20: 105–110.
- Humphreys, W.F. (1993b). Stygofauna in semi-arid tropical Western Australia: a Tethyan connection?. *Mémoires de Biospéologie* 20: 11–116.
- Humphreys, W.F. (ed.). (1993c). The biogeography of Cape Range, Western Australia. *Records of the Western Australian Museum, Supplement* 45: 1–248.
- Humphreys, W.F. (1993d). The significance of the subterranean fauna in biogeographical reconstruction: examples from Cape Range peninsula, Western Australia. *Records of the Western Australian Museum, Supplement* 45: 165–192.
- Humphreys, W.F. (1994). *The subterranean fauna of the Cape Range coastal plain, northwestern Australia*. Report to the Australian Heritage Commission and the Western Australian Heritage Committee. 202 pp. Unpublished.
- Humphreys, W.F. and Feinberg, M.N. (1994). Food of the blind cave fishes of northwestern Australia. *Records of the Western Australian Museum* 17: 29–33.

- Huys, R. and Boxshall, G.A. (1991). *Copepod evolution*. London, Ray Society, 468 pp.
- Kiefer, F. (1967). Cyclopiden aus Salzhaltigen Binnengewässern Australiens (Copepoda). *Crustaceana* **12**: 299-302.
- Knott, B. (1993). Stygofauna from Cape Range peninsula, Western Australia: tethyan relicts. *Records of the Western Australian Museum, Supplement* **45**: 109-127.
- Lindberg, K. (1957). Cyclopides (Crustacés copépodes) de la côte d'Ivoire. *Bulletin I.F.A.N.* **19**, sr.A (1): 134-179.
- Pesce, G.L., De Laurentiis, P. and Humphreys, W.F. (1996). Copepods from ground waters of Western Australia. I. The genera *Metacyclops*, *Mesocyclops*, *Microcyclops* and *Apocyclops*. *Records of the Western Australian Museum* **18**: 67-76.
- Yager, J. and Humphreys, W.F. (1996). *Lasionectes exleyi*, sp. nov., the first remipede crustacean recorded from Australia and the Indian Ocean, with a key to the world species. *Invertebrate Taxonomy* **10**: 171-187.

Manuscript received 15 December 1994; accepted 12 March 1996.