Gnangara Sustainability Strategy

An across-government initiative

Groundwater – Biodiversity – Land use

CYCLOPOID COPEPODS FROM THE YANCHEP NATIONAL PARK CAVES AND ELLEN BROOK VALLEY SPRINGS, WESTERN AUSTRALIA

A report prepared on behalf of the
Department of Environment and Conservation
for the Gnangara Sustainability Strategy

Danny Tang and Brenton Knott

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Cyclopoid Copepods from the YanchepNational Park Caves and Ellen Brook Valley Springs, Western Australia.

Report for the Gnangara Sustainability Strategy and the Department of Environment and Conservation prepared by
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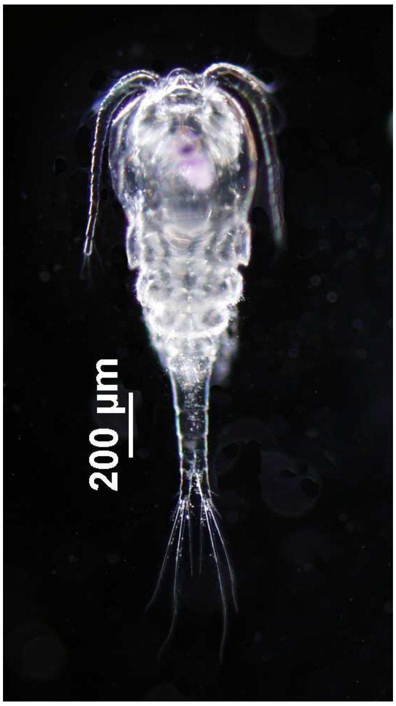

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Cyclopoid fauna

A total of eight cyclopoid species, all belonging to the family Cyclopidae, were identified in this study from recent and historical samples obtained from 12 Yanchep Caves and five Ellen Brook Valley Springs: *Australoeucyclops* n. sp., *Eucyclops* n. sp., *Macrocyclops albidus* (Jurine, 1820), *Mesocyclops brooksi* Pesce, De Laurentiis & Humphreys, 1996, *Mixocyclops* n. sp., *Paracyclops chiltoni* (Thomson, 1882), *Paracyclops* n. sp. and *Tropocyclops* confinis (Kiefer, 1930).

Australoeucyclops n. sp. was the most common species amongst the 12 cave sites, whilst *Eucyclops* n. sp. and *P*. *chiltoni* were the most common species within the five spring locations. *Tropocyclops confinis* was rarely encountered. The abundance of copepod species in nearly all samples was relatively low (<15 individuals).

Among individual sites, Lot 51 Cave, Spillway Cave, Egerton Spring and Mrs. King's Spring contained the most cyclopoid species (each site contained four taxa). In contrast, only one cyclopoid species was found in Boomerang Cave, Carpark Cave, Fridge Grotto Cave, Gilgie Cave, Yellangonga Cave, Mire Bowl Cave and Orpheus Cave.

Among the eight cyclopoid copepod species found thus far from the Yanchep Caves and Ellen Brook Valley Springs, only *Eucyclops* n. sp. is endemic to the Gnangara Mound Region. The remaining copepod taxa are relatively widespread, stygophilic forms.

Six of the eight copepod species (*Australoeucyclops* n. sp., *M*. *albidus*, *P*. *chiltoni*, *T*. *confinis*, *M*. *brooski* and *Mixocyclops* n. sp.) were found in caves containing tuart root mats as well as in habitats lacking root mats, which indicate that the occurrence of most cyclopoid copepod taxa in the Yanchep Caves is not dependent on the tuart root mat system.

Annotated digital images of the diagnostic features, as well as a taxonomic key, for the eight cyclopoid species collected from the Yanchep Caves and Ellen Brook Valley Springs are provided herein to facilitate identification of future samples.

Recommendations

a) As *Eucyclops* n. sp. is endemic to the Gnangara Mound Region and several of the habitats in which it was found (i.e. Cabaret Cave and Egerton Spring) are currently under threat of destruction, this taxon should be listed as a Vulnerable Species under the Environment Protection and Biodiversity Conservation Act 1992.

b) Sue's Spring should be conserved to protect the local flora and fauna, particularly the endemic *Eucyclops* n. sp. Further, a more intensive sampling of this spring should be carried out in August/Septermber, 2008, to fully document its fauna.

c) Sampling of bores and other springs in the Gnangara Mound Region should be conducted to determine the geographical range of *Eucyclops* n. sp.

d) Bevan Peter's Spring and Mrs. King's Spring must be re-investigated to assess their habitat condition and aquatic fauna diversity.

2. INTRODUCTION

2.1 Background

The Gnangara Mound in the Swan Coastal Plain of Western Australia is the primary groundwater resource for public, agricultural and commercial needs of the Perth Region and supports a number of groundwater-dependent ecosystems (Western Australian Planning Commission 1999a, b). The groundwater-dependent cave and spring communities on the western and eastern side, respectively, of the Gnangara Mound Region are of particular scientific interest.

Yanchep National Park, located about 5 km from the coastline, has nearly 500 karstic caves, nine of which contain an extensive root mat system produced by the native tuart tree, *Eucalyptus gomphocephala*, growing above these caves. These root mats, which develop in association with mycorrhizal fungi along the periphery of the groundwater-fed epiphreatic streams flowing through the caves, provide an abundant and constant primary food source for a diverse assemblage of aquatic invertebrates (Jasinska *et al*., 1996; Jasinska & Knott, 2000).

The helocrene, rheocrene, limnocrene and tumulus springs of the Gnangara Mound Region occur at elevations between 40–60 m above sea level along the Ellen Brook Valley (Ahmat, 1993; Jasinska & Knott, 1994). These springs are, as with other springs scattered throughout the Great Artesian Basin of central Australia, ecologically important formations. They collectively provide a stable habitat and refuge for a diverse flora and invertebrate fauna living in an essentially xeric environment (Jasinska & Knott, 1994; Knott *et al*., 2008).

Since July, 2000, the aquatic root mat community of the Yanchep Caves and flora and fauna associated with the tumulus springs have been recognised, under the Environment Protection and Biodiversity Conservation Act 1999, as Threatened Ecological Communities (TEC). Regrettably over the past several years, suburban development has occurred adjacent to some springs and the majority of the Yanchep National Park Cave streams and pools have dried-up due to a decline in groundwater levels, further threatening the survival of these TECs (Knott *et al*., 2008).

2.2 Objectives

Although the aquatic invertebrate fauna of selected Yanchep National Park Caves and Ellen Brook Valley Springs have been monitored since 1996, the specific identity of many of these invertebrates remains unknown. This is rather unfortunate as many of these invertebrate taxa may represent species of high conservation value. Clearly, knowledge of species identities is valuable not only from a zoological standpoint, but more importantly with regards to the threatened Yanchep Caves and Ellen Brook Valley Springs, for environmental management purposes as well. The current work, which identifies formally the number of species from the copepod crustacean group, is the first step in resolving this issue. Only the cyclopoid copepods are presented herein; the harpacticoid copepods will be dealt with in a separate report.

2.3 Scope

1. Document the cyclopoid copepods collected from selected Yanchep National Park Caves and Ellen Brook Valley Springs;

2. Provide a summary of the distinguishing features, including annotated digital images, of the cyclopoid species for laboratory identification purposes;

3. Develop a taxonomic key for laboratory identification purposes;
4. Clarify the conservation status of each cyclopoid species.

3. METHODS

3.1 Study Sites

The specimens examined in this study were collected from a total of 17 sites (12 cave and 5 spring sites) within the Gnangara Mound Region (Figure 1; Table 1) by Edyta Jasinska and Brenton Knott from 1990–1996 as part of Edyta's Honours and PhD research studies as well as by Andrew Storey and the authors from 2002–2008 as part of the Yanchep Caves and East Gnangara Springs invertebrate monitoring program. All cave sites were, with the exception of the Lot 51 Cave, located within Yanchep National Park.

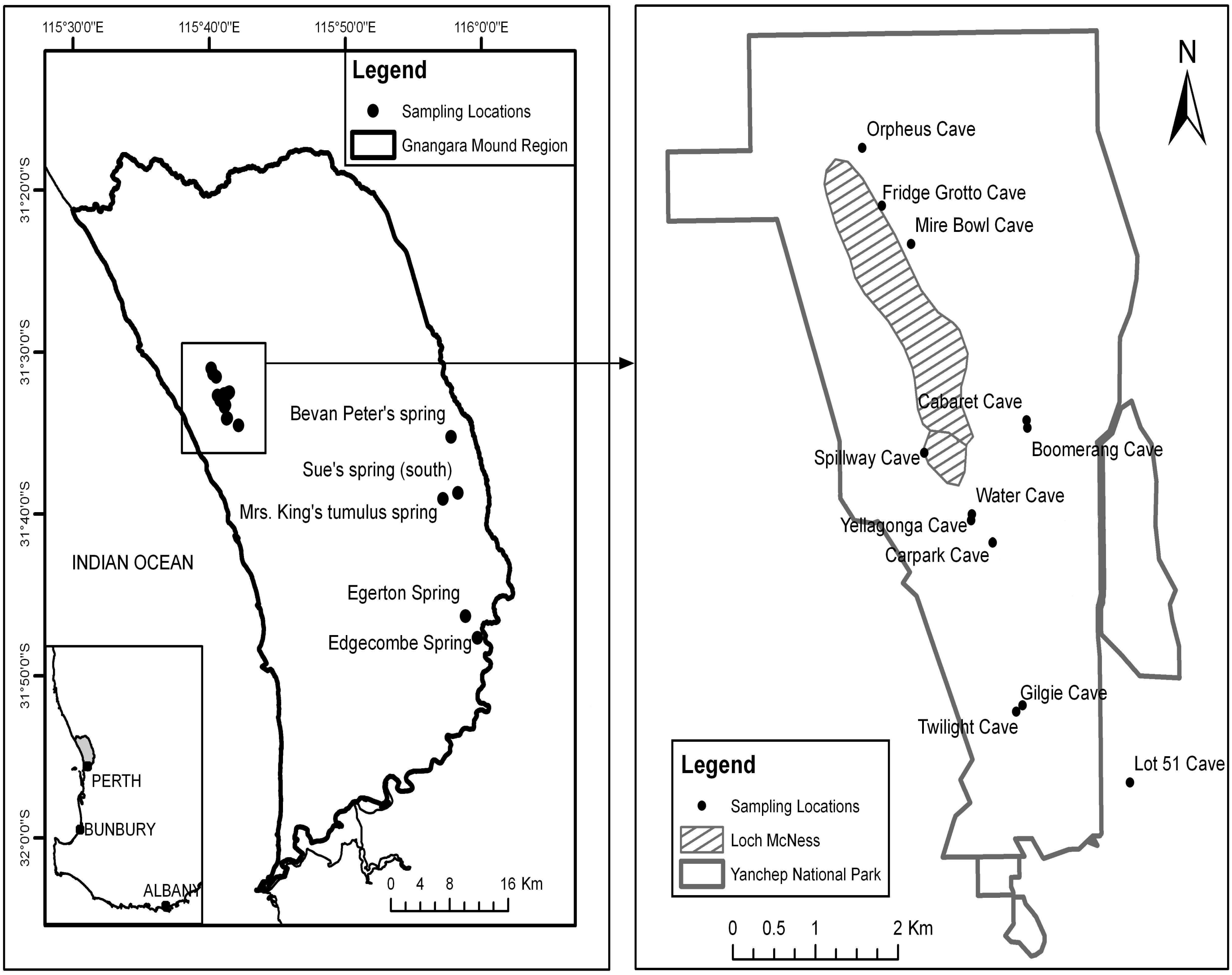

Figure 1. Map of the Gnangara Mound Region of Western Australia showing the 17 sampling locations.

Table 1. Cave and spring sites containing cyclopoid copepods (Note: caves containing tuart root mats are shaded).

[redacted]

3.2 Field and laboratory protocols

Samples were obtained during the Spring season when water levels were expected to be at their highest as follows: a) in each cave containing tuart root mats by sweeping a 70 µm mesh net across submerged root mats; b) in each cave lacking tuart root mats by sweeping a 500 µm mesh sieve along the sediment surface of epiphreatic pools; c) at each spring by sweeping a 500 µm mesh sieve along the sediment surface close to the point of the spring discharge, but if not possible due to dense cover of vegetation, along narrow water channels radiating away from the discharge point. All samples were each placed in a plastic bag, covered with water from the site, labelled and sealed tightly, and transported alive to the laboratory under cool, dark conditions.

In the laboratory, copepods were sorted from debris under a dissecting microscope and preserved in 70–100% ethanol. Preserved specimens were later soaked in lactic acid prior to examination using an Olympus BX50 microscope and/or BX51 compound microscope equipped with differential interference contrast. Selected specimens were measured using an ocular micrometer, dissected with fine insect pins, and examined using the wooden slide procedure of Humes & Gooding (1964).

3.3 Diagnostic features of cyclopoid copepods

The cyclopoid copepod species inhabiting the Yanchep Caves and Ellen Brook Valley springs can be identified, with the aid of a compound microscope, by body size, body ornamentation and structural features of the appendages, in particular those involving the antennule and legs. Definitions for specialised morphological terms (indicated in italics) used in the following text are given in Appendix 1 to facilitate the identification process. The key morphological features given for each species are based on the adult female stage only, as the adult male has not been described for all species identified, was absent for some species in the collection and is often collected far less frequently than the adult female. Total body length given in the text refers to the distance between the tip of the *cephalothorax* to the posterior margin of the *caudal rami*. Digital images of the whole animal and appendages were taken using an Olympus DP70 digital camera attached to an Olympus BX-50 compound microscope.

4. RESULTS

4.1 Cyclopoid copepod species identified

A total of eight cyclopoid species, all belonging to the family Cyclopidae and classified into seven genera, were identified in this study:

Family Cyclopidae
Subfamily Eucyclopinae
Australoeucyclops n. sp.
Eucyclops n. sp.
Macrocyclops albidus (Jurine, 1820)
Paracyclops chiltoni (Thomson, 1882)
Paracyclops n. sp.
Tropocyclops confinis (Kiefer, 1930)

Subfamily Cyclopinae
Mesocyclops brooksi Pesce, De Laurentiis & Humphreys, 1996
Mixocyclops n. sp.

Macrocyclops albidus, *P*. *chiltoni* and *M*. *brooksi* examined in this study agree favourably with the detailed descriptions of Ueda *et al*. (1996), Karaytug (1999) and Holyńska *et al*., (2003), respectively.

Comparisons between the Gnangara Mound *Australoeucyclops* specimens and a set of detailed illustrations kindly provided by Dr Tomislav Karanovic (University of Tasmania) of an undescribed *Australoeucyclops* species from a dam and springs in the Margaret River area (see Eberhard 2004) revealed that these disjunct copepod populations contain individuals of the same species. Further, we discovered that the *Australoeucyclops* specimens from Cabaret Cave were misidentified previously as *Eucyclops linderi* (Lindberg, 1948) by Jasinska & Knott (2000). As Dr Karanovic (*in litt*.) is currently describing this new *Australoeucyclops* taxon, we have in this report, for reasons related to rules of the International Code of Zoological Nomenclature, deliberately refrained from using his proposed binomen.

Most *Eucyclops* species possess spinules along either a small portion or almost the entire length of the lateral margin of each caudal ramus. The absence of this feature, as exhibited by the Gnangara Mound specimens, is shared with 13 other congeners. Comparisons with these 13 related taxa revealed that the Gnangara Mound *Eucyclops* is indeed a new taxon.

The other Gnangara Mound *Paracyclops* species shares several features, such as urosomal surface ridges, 11-segmented antennule and one inner seta on the middle endopodal segment of leg 4, in common with the *Paracyclops affinis*-group [*sensu* Karaytug (1999)]. Careful comparisons with the three nominal members of this group revealed that the Gnangara Mound *Paracyclops* is a taxon new to science.

The *Tropocyclops* material agrees favourably with the illustrations of *Tropocyclops confinis* (Kiefer, 1930) provided in Dumont (1981), Yeatman (1983) and Boxshall & Braide (1991). Moreover, careful comparisons between the Gnangara Mound material and two female *T*. *confinis* specimens from Madagascar, which were kindly provided by Professor Henri Dumont (Ghent University), revealed that we are almost certainly dealing with the same species.

Comparisons between the Gnangara Mound *Mixocyclops* and Kiefer's (1944) cursory illustrations and description of *M*. *crozetensis* Kiefer, 1944 from Crozet Island suggested initially that these two geographically isolated samples contain individuals of the same species. Dr. Frank Fiers' (Royal Belgian Institute of Natural Sciences; *in litt*.) recent observations of *M*. *crozetensis* type material indicated, however, that this taxon is not conspecific with the Gnangara Mound material.

4.2 Distribution of cyclopoid copepods among sites

The cyclopoid taxa were not distributed evenly within the Gnangara Mound sites (Table 2). *Paracyclops* n. sp. was found only in the springs, whilst *Tropocyclops confinis* and *Mesocyclops brooksi* were present solely in the caves. In contrast, *Australoeucyclops* n. sp., *Eucyclops* n. sp., *Macrocyclops albidus*, *Paracyclops chiltoni* and *Mixocyclops* n. sp. were found in the Yanchep Caves and Ellen Brook Valley springs. Further, *Australoeucyclops* n. sp. was the most common species in the Yanchep Caves, yet rarely encountered in the springs. Conversely, *Eucyclops* n. sp. occurred predominantly in the springs and rarely in the Yanchep Caves.

Table 2. Distribution of freshwater cyclopoid copepods in the caves and springs of the Gnangara Mound Region of Western Australia.

		Caves												**Springs**				
Taxon	Ecology	Boomerang	Cabaret	Carpark	Lot 51	Fridge Grotto	Gilgie	Yellagonga	Mire Bowl	Orpheus	Spillway	Twilight	Water	Bevan Peters'	Edgecombe	Egerton	Mrs. King's	Sue's (South)
Australoeucyclops n. sp.	Sp		*	*	*	*	*	*	*	*	*	*	*				*	
Eucyclops n. sp.	Sb		*											*		*	*	*
Macrocyclops albidus	Sp										*						*	*
Paracyclops chiltoni	Sp	*	*								*	*	*	*	*	*		*
Paracyclops n. sp.	S*													*		*	*	
Tropocyclops confinis	E				*													
Mesocyclops brooksi	Sp				*						*							
Mixocyclops n. sp.	Sp				*		*								*	*		

Ecological codes: E = epigean; Sp = stygophile; Sb = stygobite; S* = possible stygophile.

Among individual sites, Lot 51 Cave, Spillway Cave, Egerton Spring and Mrs. King's Spring contained the most cyclopoid species (four taxa each). Only one cyclopoid species, *Australoeucyclops* n. sp., was found in Carpark, Fridge Grotto, Gilgie, Yellangonga, Mire Bowl and Orpheus Cave. Similarly, *P. chiltoni* was the only cyclopoid species recovered from Boomerang Cave.

The abundance of copepod individuals was generally low (< 15 individuals) for most species. *Tropocyclops confinis* was rarely encountered as only two individuals were collected on a single occasion during the entire sampling campaign. Nonetheless, some copepod species did occur in relatively high densities as evidenced by the collection of 411 individuals of *Australoeucyclops* n. sp. in a single sample from Yellagonga Cave.

4.3 Diagnostic features of cyclopoid copepods

4.3.1 *Australoeucyclops* n. sp.

1. Total body length is approximately 0.75 mm (Fig. 2A).
2. Each *antennule* is 12-segmented and extends to the posterior margin of the *cephalothorax* (Fig. 2B).
3. The first *exopod* segment of leg 4 lacks an inner *seta* (Fig. 2C).
4. Leg 5 is 1-segmented and bears two outer *setae* and an inner *spine* (Fig. 2D) (Note: all three *elements* are inserted at the same level).

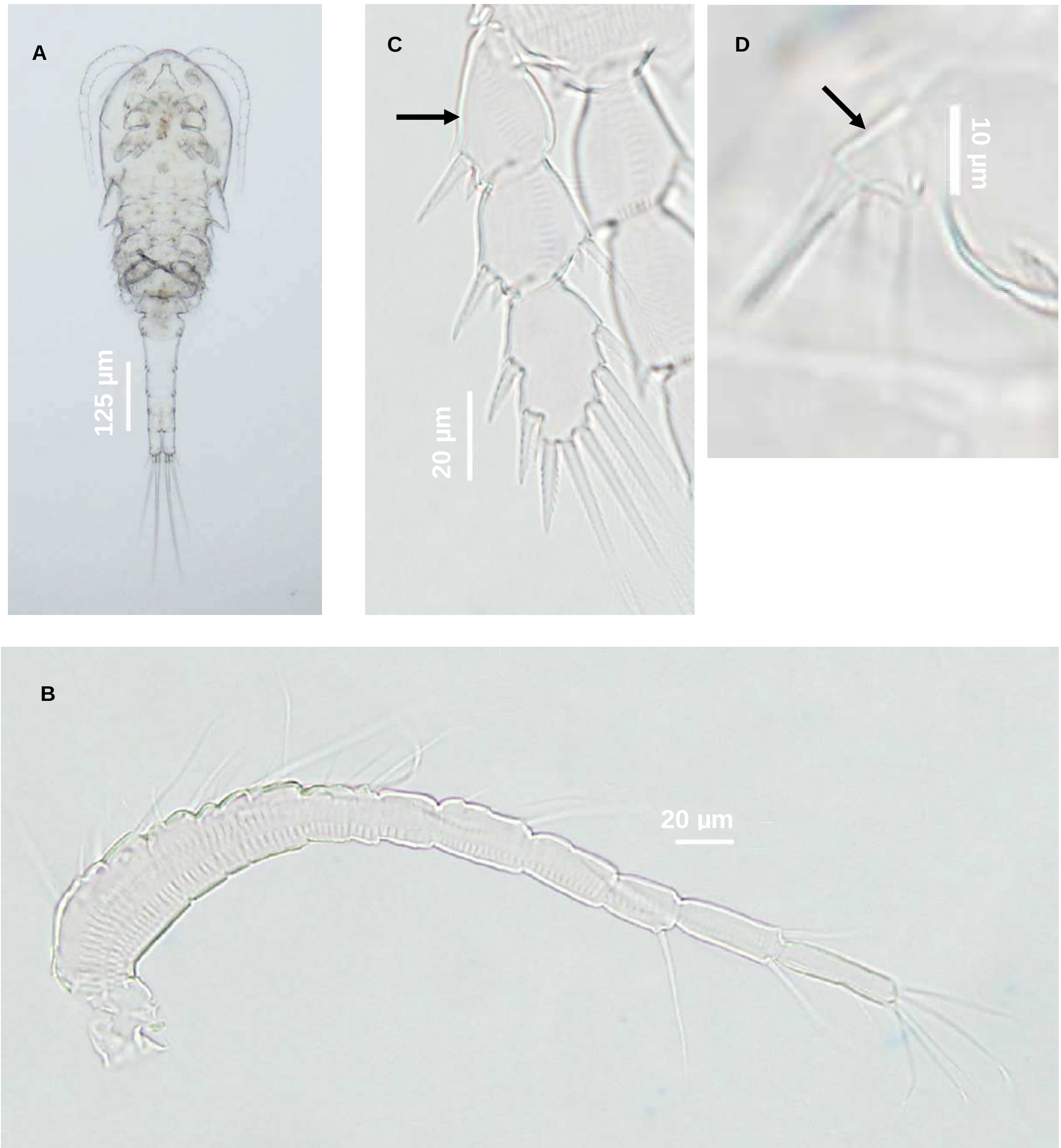

Figure 2. *Australoeucyclops* n. sp., adult female. a) habitus; b) antennule; c) exopod of fourth leg showing absence of inner seta on first segment (arrowed); d) leg 5 (arrowed) showing one inner spine and two adjacent setae.

4.3.2 *Eucyclops* n. sp.

1. Total body length is about 0.70 mm (Fig. 3A).
2. Each *antennule* is 12-segmented and extends to the posterior margin of the *cephalothorax* (Fig. 3B).
3. Leg 5 is 1-segmented and bears a long outer *seta*, long middle *seta* and long inner *spine* (Fig. 3C) (Note: the middle seta is inserted on a different level than the other two adjacent *elements*).
4. Ventral surface of each *caudal ramus* is furnished with a row of small spinules (Fig. 3D).

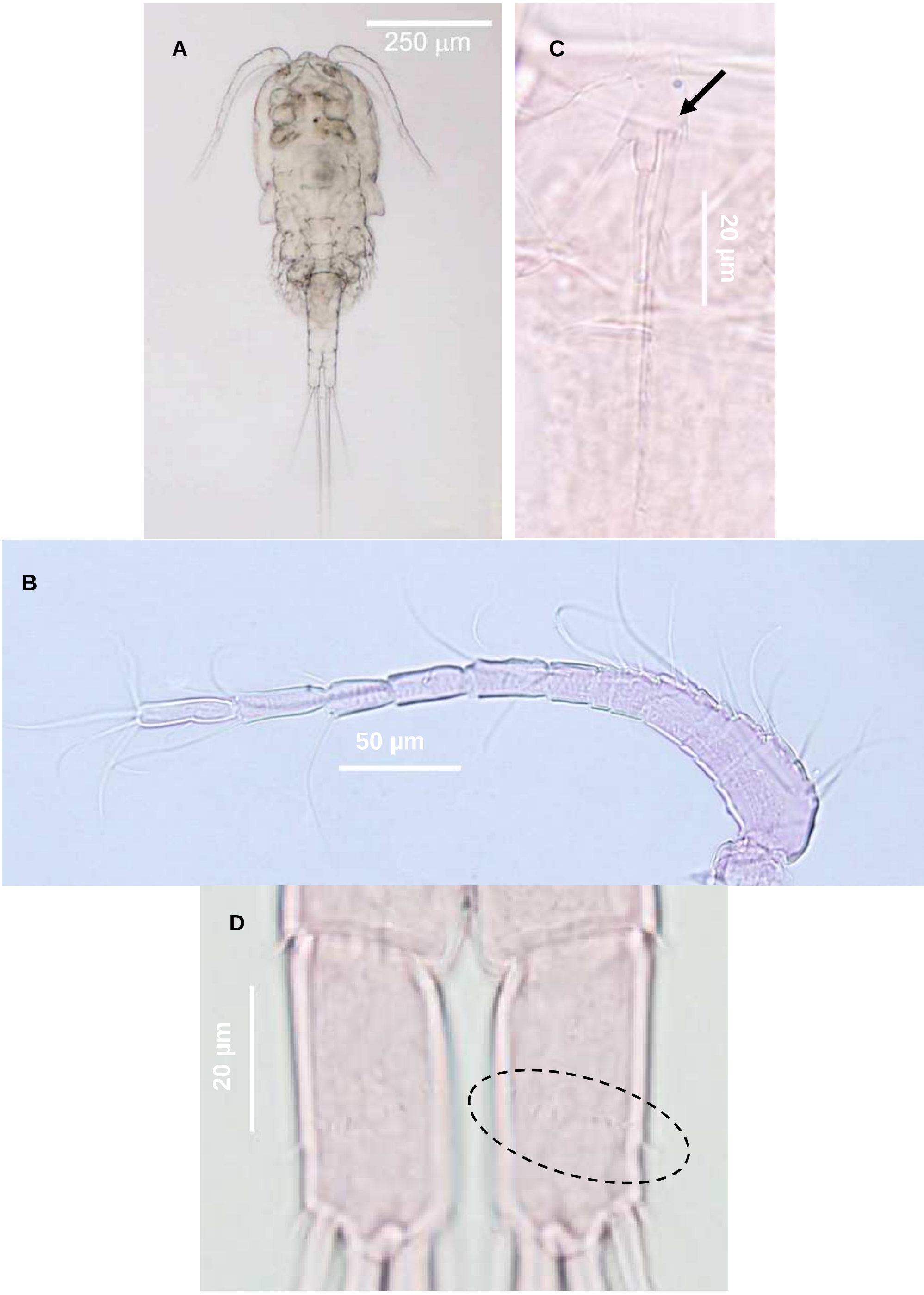

Figure 3. *Eucyclops* n. sp., adult female. a) habitus; b) antennule; c) leg 5 (arrowed) showing three long elements; d) ventral surface of caudal rami showing small spinules (circled).

4.3.3 *Macrocyclops albidus*

1. Total body length is about 1.40 mm (Fig. 4A).
2. Each *antennule* is 17-segmented and extends to the second leg-bearing *somite* (Fig. 4B).
3. Third *endopod* segment of leg 4 bears a reduced (short) inner distal *seta* (Fig. 4C).
4. Leg 5 is 2-segmented: the first segment is furnished with *spinules*; the second segment bears three distal *elements* (Fig. 4D).

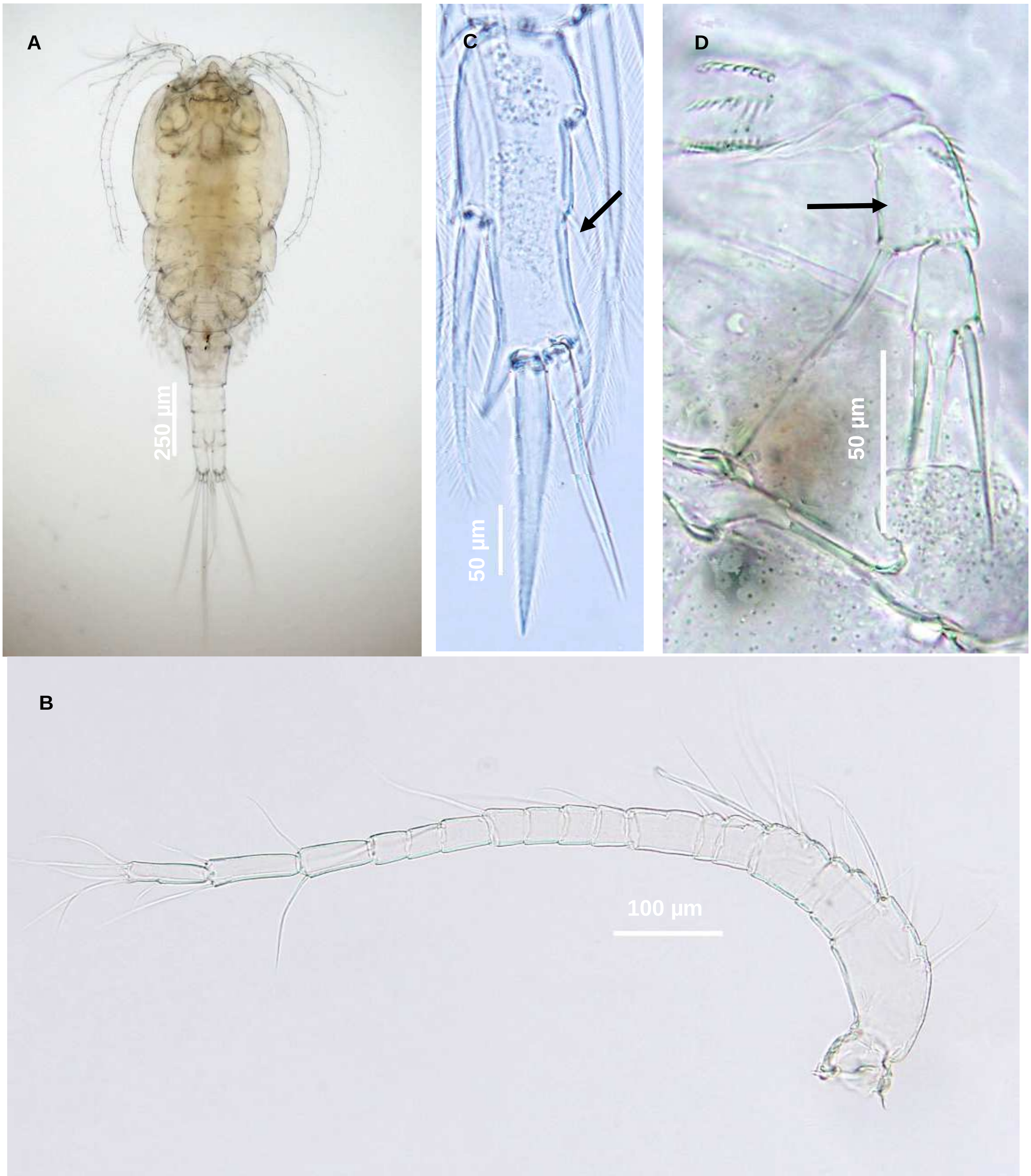

Figure 4. *Macrocyclops albidus* (Jurine, 1820), adult female. a) habitus; b) antennule; c) terminal endopodal segment of leg 4 showing highly reduced inner distal seta (arrowed); d) leg 5 (arrowed) showing spinules on first segment and three elements on second segment.

4.3.4 *Paracyclops chiltoni*

1. Total body length is roughly 0.75 mm (Fig. 5A).
2. Each *antennule* is 8-segmented and extends to nearly the middle of the *cephalothorax* (Fig. 5B).
3. Leg 5 is 1-segmented and bears two outer *setae* and an inner *spine* (Fig. 5C) (Note: all three *elements* are inserted at the same level).
4. Somites 2 to 4 on the *urosome* bear numerous surface pores (Fig. 5D).

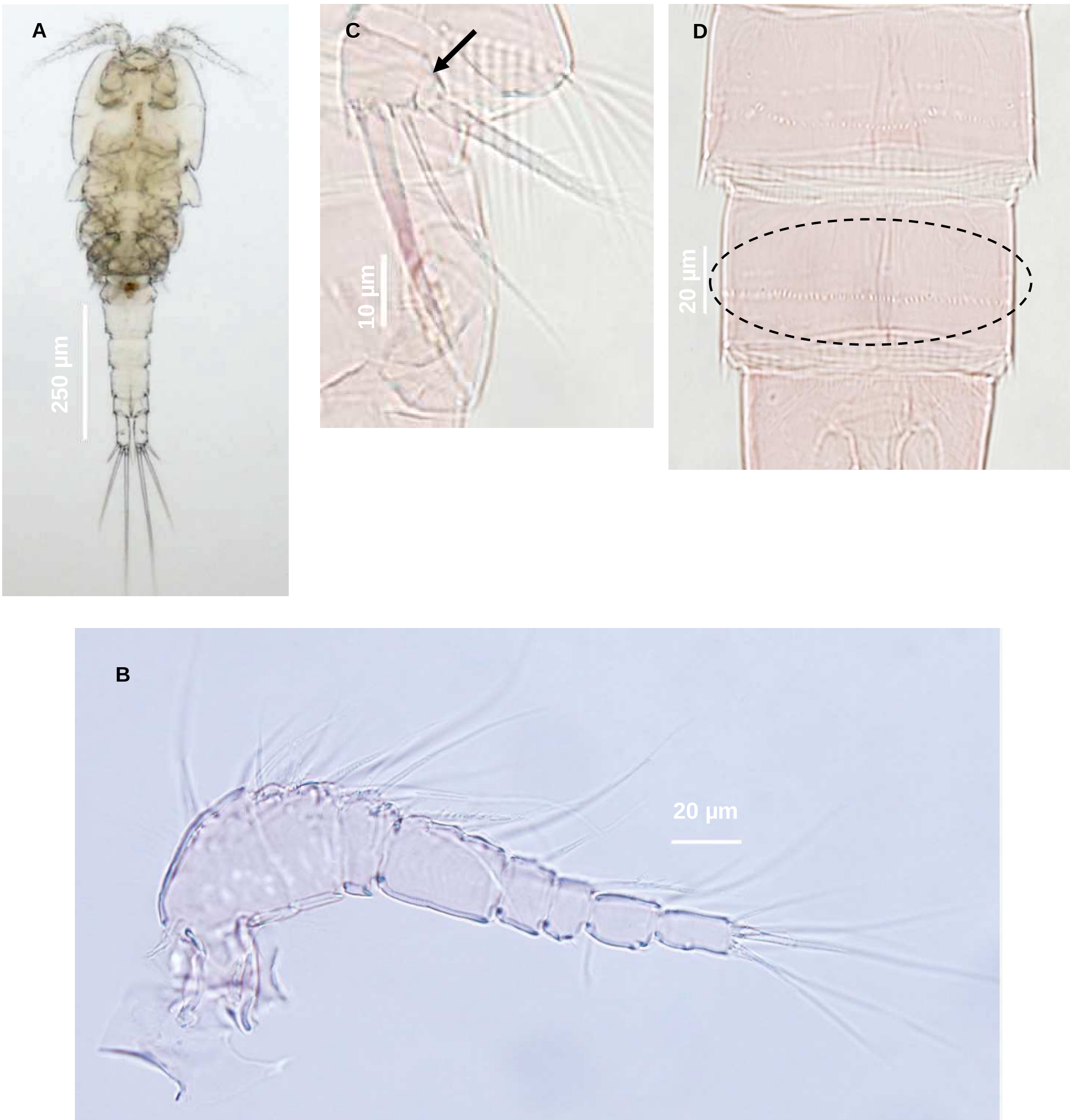

Figure 5. *Paracyclops chiltoni* (Thomson, 1882), adult female.
a) habitus; b) antennule; c) leg 5 (arrowed) showing three elements;
d) surface pores (circled) on somites 3 and 4 of urosome.

4.3.5 *Paracyclops* n. sp.

1. Total body length is roughly 0.53 mm in specimens with telescoped somites on *urosome* (Fig. 6A) and 0.73 mm in non-telescoped specimens.
2. Each *antennule* is 11-segmented and extends to nearly the middle of the *cephalothorax* (Fig. 6B).
3. The third *exopod* segment of leg 3 bears four *spines* [and five setae] (Fig. 6C).
4. Leg 5 is 1-segmented and bears two outer *setae* and an inner *spine* (Fig. 6D) (Note: the outermost *element* is inserted at a different level than the other two elements).
5. Somites 2 to 4 of urosome furnished with transverse surface ridges (Fig. 6E).

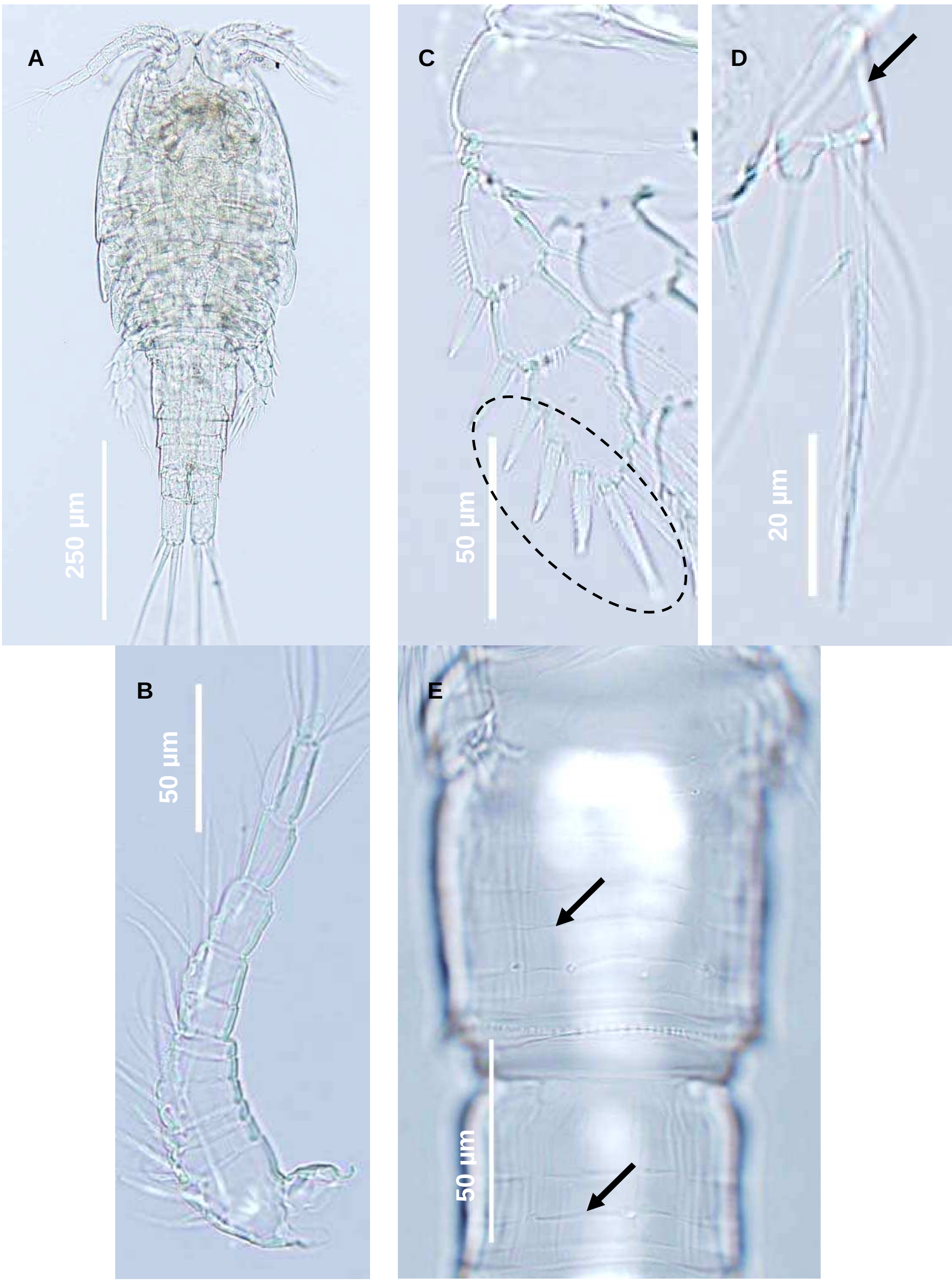

Figure 6. *Paracyclops* n. sp., adult female. a) habitus; b) antennule; c) leg 3 showing four spines (circled) on third exopod segment; d) leg 5 (arrowed) showing three elements; e) somites 2 and 3 of urosome showing transverse surface ridges (arrowed).

4.3.6 *Tropocyclops confinis*

1. Total body length is approximately 0.68 mm (Fig. 7A).
2. Each *antennule* is 12-segmented and extends beyond the second leg-bearing *somite* (Fig. 7B).
3. The third *endopod* segment of leg 4 bears relatively long and thin *elements* (Fig. 7C).
4. Leg 5 is 1-segmented and bears three *elements* (Fig. 7D) (Note: the middle seta is inserted on a different level than the other two adjacent *elements*).

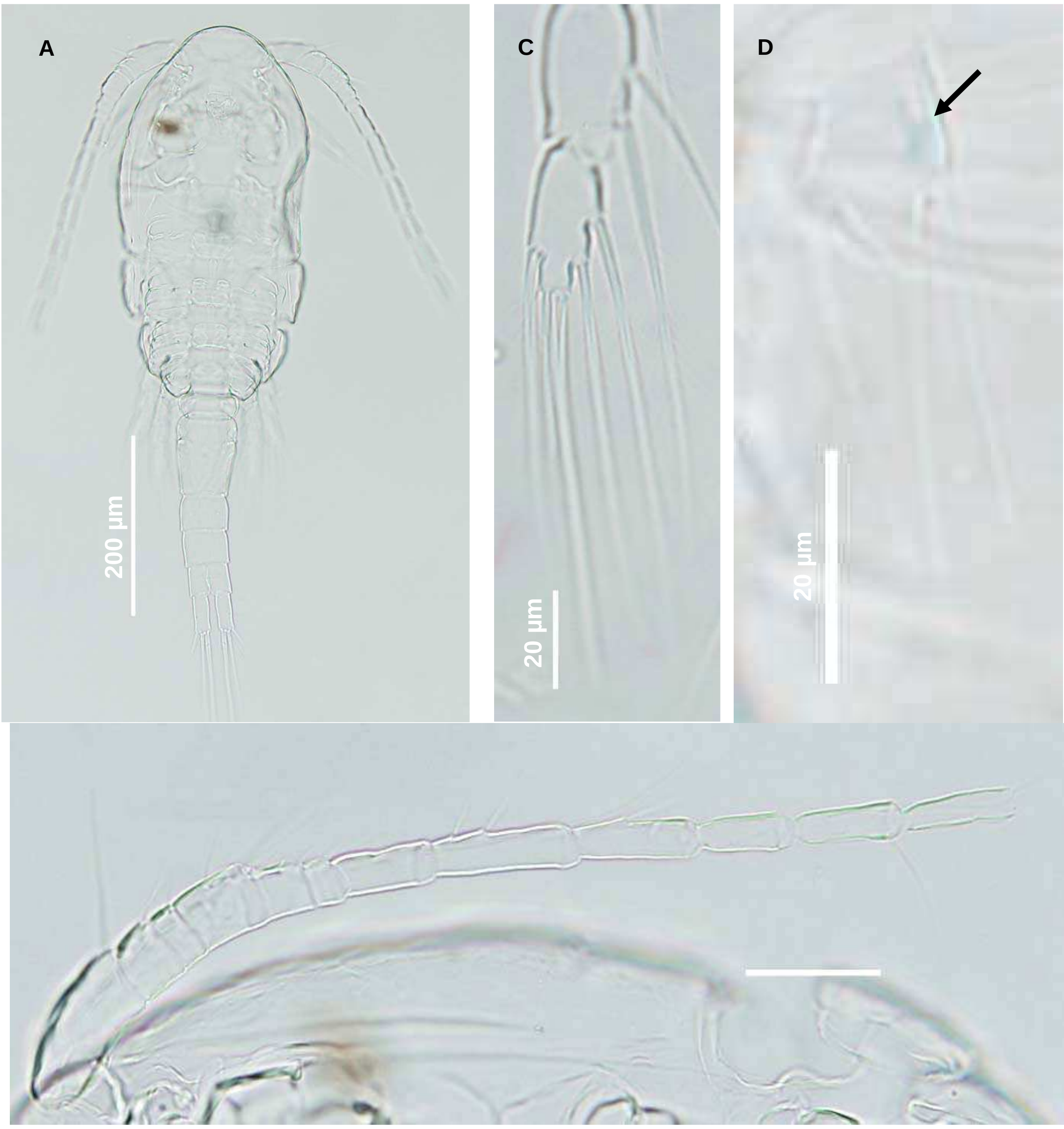

Figure 7. *Tropocyclops confinis* (Kiefer, 1930), adult female. a) habitus; b) antennule; c) second and third segments of leg 4 endopod showing long and thin elements; d) leg 5 (arrowed) showing three elements.

B

4.3.7 *Mesocyclops brooksi*

1. Total body length is roughly 1.20 mm (Fig. 8A).
2. Each *antennule* is 17-segmented and extends to the second leg-bearing *somite* (Fig. 8B).
3. The body and *cephalic* appendages, particularly the *antennule* (Fig. 8C), *antenna* and *maxilla*, are covered with surface pits.
4. Leg 5 is 2-segmented; the second segment bears an apical *seta* and inner *spine* (Fig. 8D).

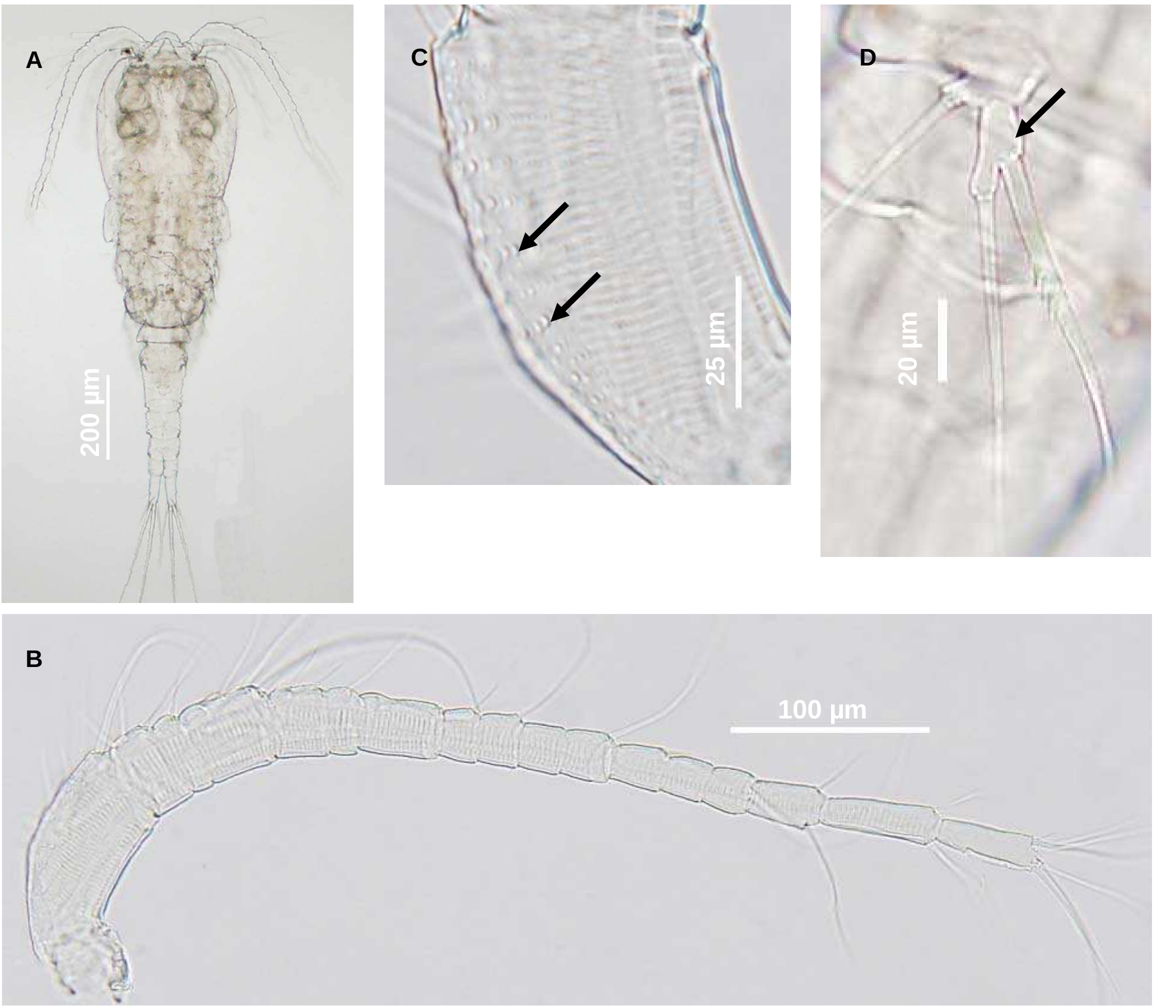

Figure 8. *Mesocyclops brooksi* De Laurentiis, Pesce & Humphreys, 1996, adult female. a) habitus; b) antennule; c) first segment of antennule showing surface pits (arrowed); d) leg 5 (arrowed) showing two elements on second segment.

4.3.8 *Mixocyclops* n. sp.

1. Total body length is approximately 0.33 mm (Fig. 9A).
2. Each *antennule* is 11-segmented and extends to middle of the *cephalothorax* (Fig. 9B).
3. Legs 1 to 4 have 2-segmented *rami* (Fig. 9C).
4. Leg 5 is 2-segmented; the second segment bears a long apical *seta* and very small, inner *spine* (Fig. 9D) (Note: the inner spine is best observed when the *prosome* is separated from the *urosome* (i.e. leg 5 is not obscured by the setae of leg 4).

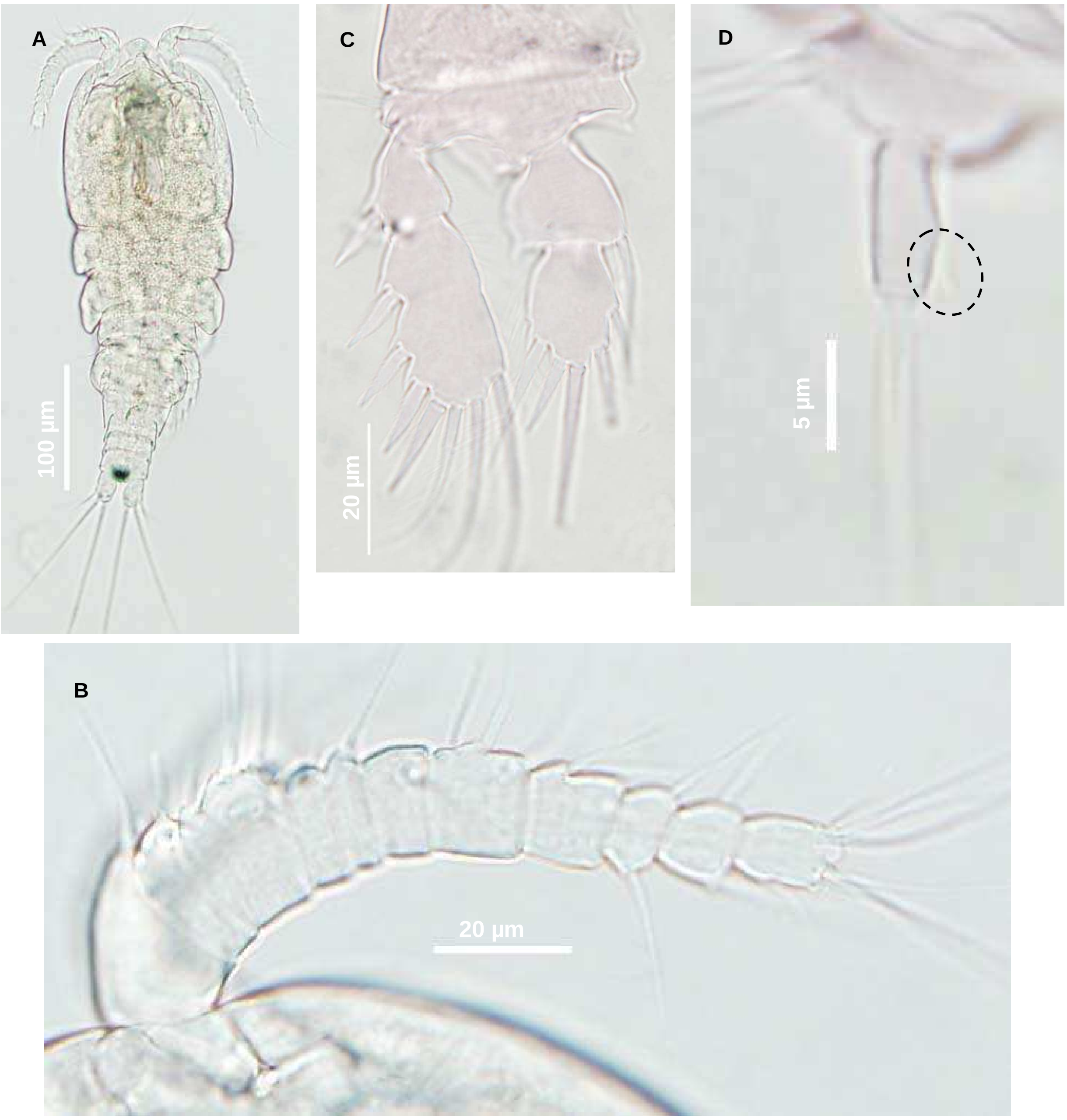

Figure 9. *Mixocyclops* n. sp., adult female. a) habitus; b) antennule; c) leg 4; d) leg 5 showing long apical seta and small inner spine (circled) on second segment.

5. TAXONOMIC KEY

It is worth mentioning here several attributes that will enable you to recognize rapidly a copepod crustacean prior to using this key. The copepods you may encounter will have the opposite members (i.e. right and left sides) of the first four leg pairs joined medially by a flat plate called an *intercoxal sclerite*. Test this by using a fine needle to move one leg pair; both the right and left legs should move in unison. Another copepod attribute is the absence of appendages on the abdominal somites, except the posteriormost (last) *somite* which bears a single pair of unsegmented appendages known as the *caudal rami*. If these two characters are not found in your specimen(s), then you have another type of arthropod/animal. The next course of action would be to either use other keys, such as those presented in Williams (1980), or consult with taxonomic specialists to identify your material.

The characters used in the following simplified key can be observed without the need for dissection(s) using a compound microscope and applies to the adult female only. Prior to examination, it is highly recommended that specimens are immersed in lactic acid for 1-2 hours to clear the animal, thus making the appendages more visible. As with the diagnostic features given previously, definitions for specific morphological terms (indicated in italics) used in the following key are given in Appendix 1. After keying out your copepod specimen(s), it is essential to confirm the identification(s) by comparing with the suite of features listed above and, more importantly, the publication listed in brackets (where applicable) following the species name.

1. *Antennule* 8-segmented .... *Paracyclops chiltoni* [Karaytug (1999)]

— *Antennule* 11-segmented.. 2

— *Antennule* 12-segmented.. 3

— *Antennule* 17-segmented.. 5

2. Leg 5 two-segmented; legs 1 to 4 with 2-segmented *rami*..................... *Mixocyclops* n. sp.

— Leg 5 one-segmented; legs 1 to 4 with 3-segmented *rami*.................... *Paracyclops* n. sp.

3. Inner *seta* on first *exopod* segment of leg 4 absent .... *Australoeucyclops* n. sp.

— Inner *seta* on first *exopod* segment of leg 4 present 4

4. *Spinules* on ventral surface of *caudal rami* present .... *Eucyclops* n. sp.

— *Spinules* on ventral surface of *caudal rami* absent..
.... *Tropocyclops confinis* [Yeatman (1983)]

5. Second segment of leg 5 bears three *elements* ....
.... *Macrocyclops albidus* [Ueda *et al*. (1996)]

— Second segment of leg 5 bears two *elements* ....
.... *Mesocyclops brooksi* [Holyńska *et al*. (2003)]

6. DISCUSSION

6.1 Cyclopoid copepod fauna

Examination of numerous copepod samples from 12 Yanchep Caves and five Ellen Brook Valley Springs revealed a total of eight cyclopoid copepod species, of which four are new to science. We have submitted a manuscript to an international journal describing these new forms.

The cyclopoid copepod assemblages from the Yanchep Caves and Ellen Brook Valley Springs are comprised mostly of widespread stygophilic taxa. *Australoeucyclops* n. sp. occurs further south and north of the Gnangara Mound Region. Eberhard (2004) found this undescribed species from a dam and several springs in the Margaret River Region, and we have examined specimens of this species from Beekeepers Cave, located west of Eneabba (*ca*. 200 km north of Yanchep National Park). *Macrocyclops albidus* and *P*. *chiltoni* are cosmopolitan species, occurring primarily in surface waters but also occasionally in subsurface habitats (Karaytug, 1999; Dussart and Defaye, 2006; Lewis and Reid, 2007). *Mesocyclops brooksi* occurs throughout Western Australia in both epigean and hypogean habitats (Hołyńska & Brown, 2003; Karanovic, 2006).

Although *Tropocyclops confinis* is recorded herein from Australia for the first time, this species has been reported previously in the Ethiopian, Palaearctic, Oriental, Neotropical and South Pacific Regions (Dussart and Defaye, 2006). The collection of *T*. *confinis* from the hypogean environment is highly unusual as this species typically inhabits rivers, lakes and ponds (Defaye, 1988). The occurrence of this species in Lot 51 Cave is interpreted to be artificial as evidenced by the collection of only two individuals concurrently from this single cave during the entire sampling campaign. The source of these individuals remains unknown. This species is most likely widespread in Australia, as Morton (1977) described a species, designated *Tropocyclops* sp. A, from surface waters in Victoria, Tasmania, New South Wales and Queensland that resembles the material upon which our description is based. This would not be unexpected considering *T*. *confinis* has a relatively broad distribution pattern as mentioned previously. Nonetheless, Morton's record must be verified as his taxonomic account was brief and lacked illustrations. Extensive sampling of surface waters within Australia is needed to determine the distribution pattern and preferred habitat(s) of this species on this continent.

Mixocyclops n. sp. is not restricted to the cave and spring environments within the Gnangara Mound Region, as we have examined conspecific material from Boranup Creek located in the Margaret River Region (Tang & Knott, unpublished data) and Three Springs tumulus spring and Melaleuca Swamp in the northern and central section, respectively, of the Wheatbelt Region (DEC stygofauna collection). Indeed, this species may be widespread in the southern half of Australia, as Morton (1977) also described a species, named *Mixocyclops macaulae*, collected from *Sphagnum* bogs on Mt. Baw Baw and Mt. Buffalo in Victoria that is very similar to the Western Australian material. Morton's record, however, must be confirmed as his description was not supported by a complete set of illustrations.

Paracyclops n. sp. may also occur in other Australian States, as Morton (1977) also described a species, named *Paracyclops myallensis*, from a swamp near Newcastle, New South Wales, that is similar to the Gnangara Mound material. Morton's record, however, must be confirmed as his description was based on only two female specimens and was not supported by a complete set of illustrations. Nonetheless, we anticipate that further collections will reveal that *Paracyclops* n. sp. is: a) more widespread than the present collection indicates; and b) a stygophile rather than a stygobite, particularly considering that other members of this genus occur in epigean habitats (Karaytug, 1999).

Eucyclops n. sp. is the only cyclopoid species identified in this study that is considered a stygobitic form and, more importantly, endemic to the Gnangara Mound Region.

The abundance of copepod individuals was generally low (< 15 individuals) for most species. This may be due to the fact that a limited number of root mat and sediment sweeps were taken at the caves and springs, respectively, during each sampling period in order to minimise the ecological impacts on these threatened habitats.

Six of the eight copepod species (*Australoeucyclops* n. sp., *M*. *albidus*, *P*. *chiltoni*, *T*. *confinis*, *M*. *brooski* and *Mixocyclops* n. sp.) were found in caves containing tuart root mats as well as in habitats lacking root mats, which indicates that the occurrence of most *cyclopoid copepod* taxa in the Yanchep Caves is not dependent on the tuart root mat system.

6.2 Conservation

Based on the distribution and habitat records given above for the eight Gnangara Mound cyclopoid copepod taxa, *Australoeucyclops* n. sp., *Macrocyclops albidus*, *Mesocyclops brooksi*, *Mixocyclops* n. sp., *Paracyclops chiltoni*, *Paracyclops* n. sp. and *Tropocyclops confinis* are regarded as species of low conservation value as they are geographically widespread taxa. On the other hand, we consider *Eucyclops* n. sp. to be a species of high conservation value as it was found thus far in four of five Ellen Brook Valley Springs (Bevan Peter's, Egerton, Mrs. King's and Sue's) as well as just one of the 12 Yanchep Caves (Cabaret Cave). Currently, the water level in Cabaret Cave is at an all-time historic low, leading to the reduction in extent and quality of root mats (Knott *et al*. 2008). Similarly, the habitat and associated aquatic fauna of Egerton Spring is under immediate threat of destruction by the recent land clearance and development of residential properties to within *ca*. 20 m west of this spring (Knott *et al*., 2008). Local recharge will likely cease at this spring as the residential homes were constructed uphill from the discharge point. The present condition of Bevan Peter's and Mrs. King's springs is unknown, as these habitats have not been visited in recent times. In contrast to Egerton Spring, the recently discovered Sue's Spring appears relatively undisturbed and, according to the landholder, flows constantly throughout the year (Knott *et al*., 2008). As such, this spring should be conserved to protect the local flora and fauna, especially the endemic *Eucyclops* n. sp.

7. RECOMMENDATIONS

a) As *Eucyclops* n. sp. is endemic to the Gnangara Mound Region and several of the habitats in which it was found (i.e. Cabaret Cave and Egerton Spring) are currently under threat of destruction, this taxon should be listed as a Vulnerable Species under the Environment Protection and Biodiversity Conservation Act 1992.

b) Sue's Spring should be conserved to protect the local flora and fauna, particularly the endemic *Eucyclops* n. sp. Further, a more intensive sampling of this spring should be carried out in August/Septermber, 2008, to fully document its fauna.

c) Sampling of bores and other springs in the Gnangara Mound Region should be conducted to determine the geographical range of *Eucyclops* n. sp.

d) Bevan Peter's Spring and Mrs. King's Spring must be re-investigated to assess their habitat condition and aquatic fauna diversity.

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10. APPENDIX 1 – DEFINITIONS OF MORPHOLOGICAL TERMS [FROM BOXSHALL AND HALSEY (2004)]

Antenna: the second cephalic appendage.

Antennule: the first cephalic appendage.

Caudal rami (singular = ramus): the paired articulated structures carried on the anal somite.

Cephalic: the head.

Cephalothorax: the anterior region of the copepod body in which the first leg-bearing somite is incorporated into the first 5 cephalic somites.

Element: the seta or spine on an appendage.

Endopod: the inner ramus (branch) of a biramous appendage.

Exopod: the outer ramus (branch) of a biramous appendage.

Intercoxal sclerite: a flat chitinous plate connecting the base of a pair of swimming legs.

Maxilla: the fifth and last pair of cephalic appendages.

Prosome: anterior body region comprising the cephalothorax and second to fourth leg-bearing somites.

Rami (singular = ramus): the two branches (exopod and endopod) of an appendage.

Seta (plural = setae): a slender, flexible armature element with internal tissue connection through the integument.

Somite: a segment or division of the body.

Spine: a stout, rigid armature element with internal tissue connection through the integument.

Spinules: pointed epicuticular ornamentation, without tissue connection through the integument.

Urosome: posterior body region consisting of the fifth leg-bearing somite plus the genital and abdominal somites.