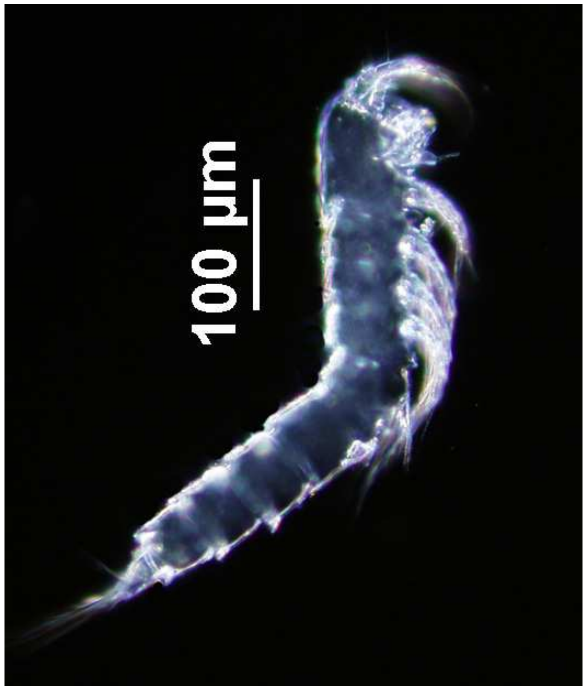
HARPACTICOID COPEPODS FROM THE YANCHEP NATIONAL PARK CAVES AND ELLEN BROOK VALLEY SPRINGS, WESTERN AUSTRALIA



Report prepared for
Department of Environment and Conservation

by

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1. EXECUTIVE SUMMARY

Harpacticoid fauna

A total of six harpacticoid species, classified in three families, were identified in this study from recent and historical samples obtained from eight Yanchep Caves and three Ellen Brook Valley Springs: Ameiridae n. gen. & n. sp., *Attheyella* (*Chappuisiella*) *hirsuta* Chappuis, 1951, *Australocamptus hamondi* Karanovic, 2004, *Elaphoidella bidens* (Schmeil, 1894), *Nitocra lacustris pacifica* Yeatman, 1983 and *Parastenocaris eberhardi* Karanovic, 2005.

The new ameirid taxon and *N*. *l*. *pacifica* were found in this study from the Yanchep Caves only. The remaining harpacticoids were found in both the Yanchep Caves and Ellen Brook Valley Springs. *Parastenocaris eberhardi* and the new ameirid were the most common taxa within the Yanchep Caves, whilst *N*. *l*. *pacifica* was rarely encountered as only one individual was collected from Fridge Grotto Cave during the entire sampling campaign. The most common taxon at the springs was *A*. *Ch*. *hirsuta*, which was present in two of the three springs.

Among individual sites, species richness was highest at Twilight Cave (5 taxa) followed by Boomerang Cave (4 taxa). A maximum of two taxa were recorded from the spring sites. Only one harpacticoid species was found in Cabaret Cave, Fridge Grotto Cave, Orpheus Cave, Spillway Cave and Sue's Spring.

Among the six harpacticoid copepod species found thus far from the Yanchep Caves and Ellen Brook Valley Springs, only Ameiridae n. gen. & n. sp. is endemic to the Gnangara Mound Region. This taxon occurs only in caves that contain submerged tuart root mats. The remaining copepod taxa are geographically widespread forms.

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

Recommendations

a) Ameiridae n. gen. & n. sp. should be listed as an Endangered Species under the Environment Protection and Biodiversity Conservation Act 1992. This is necessary as this species' habitat, namely the submerged tuart root mats of the Yanchep National Park Caves, have mostly dried up or are currently under threat of destruction.

b) Water flow must be restored and maintained permanently in the cave streams. This is essential for re-establishing the tuart root mats, which will in turn provide suitable habitats for Ameiridae n. gen. & n. sp. to recolonise should it still occur in some unknown groundwater refuge of the Gnangara Mound.

c) Biospeleological investigations should continue in the Yanchep National Park and surrounding karstic formations to find additional caves with tuart root mats.

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 some 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 harpacticoid copepods are presented herein; the cyclopoid copepods are dealt with in a separate report.

2.3 Scope

1. Document the harpacticoid 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 harpacticoid species.

3. METHODS

3.1 Study Sites

The specimens examined in this study were collected from a total of 11 sites (8 cave and 3 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.

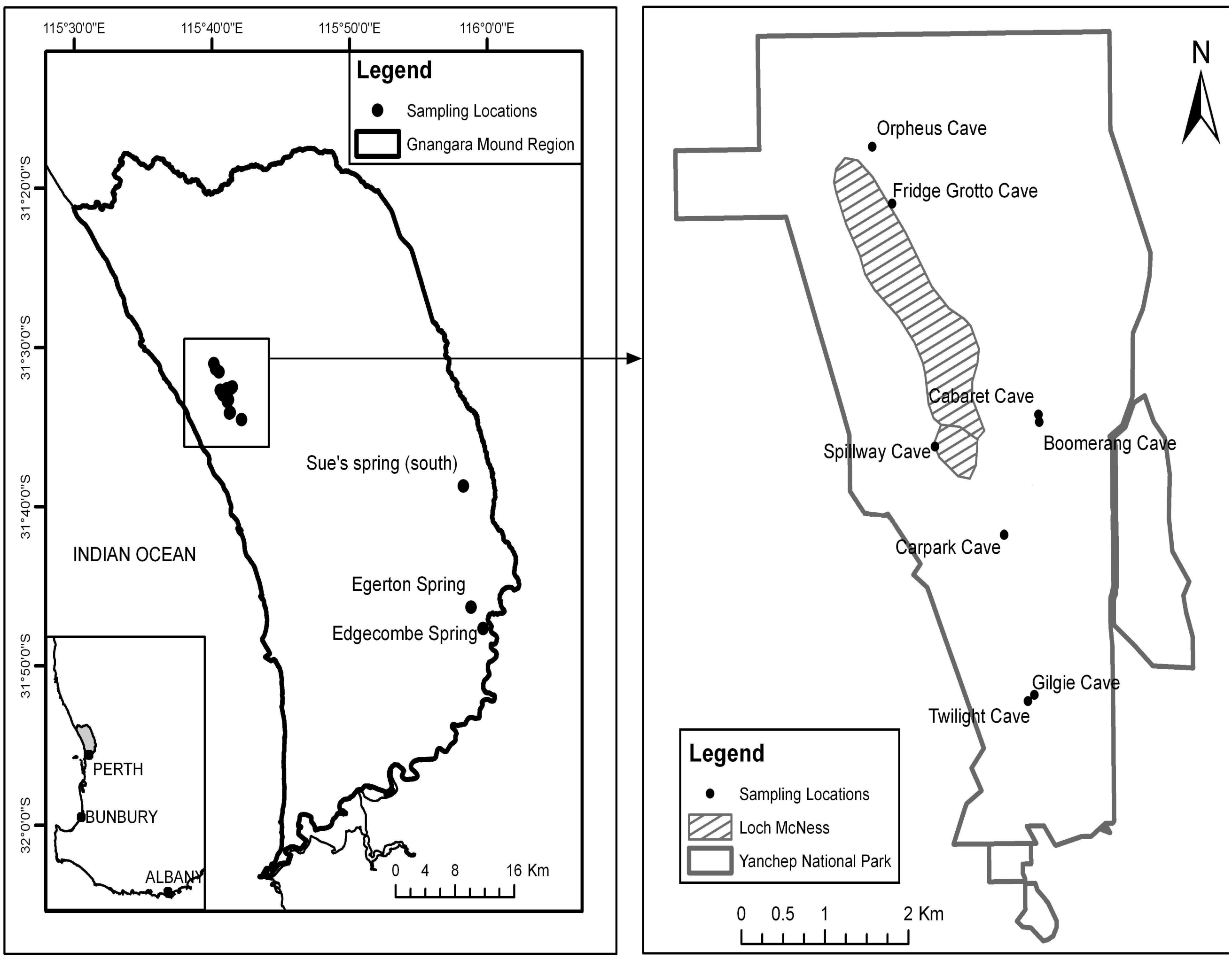

Figure 1. Map of the Gnangara Mound Region of Western Australia showing the 11 sampling locations.

Table 1. Cave and spring sites containing harpacticoid 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 vegetation cover, 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 harpacticoid 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 antenna 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 Harpacticoid copepod species identified

A total of six harpacticoid species, classified in three families, were identified in this study:

Family Ameiridae
Ameiridae n. gen. & n. sp.
Nitocra lacustris pacifica Yeatman, 1983

Family Canthocamptidae
Attheyella (*Chappuisiella*) *hirsuta* Chappuis, 1951
Australocamptus hamondi Karanovic, 2004
Elaphoidella bidens (Schmeil, 1894)

Family Parastenocarididae
Parastenocaris eberhardi Karanovic, 2005

Nitocra l. pacifica, *A*. *hamondi* and *P*. *eberhardi* specimens examined in this study matches the detailed descriptions provided in Karanovic (2004, 2005). Likewise, *A*. (*Ch*.) *hirsuta* and *E*. *bidens* material examined in this study agree in all respects with the descriptions given in Hamond (1987).

The ameirid harpacticoid collected from the Yanchep Caves shows a close resemblance to members of the genus *Nitocrella* Chappuis, 1923, *Novanitocrella* Karanovic, 2004 and *Abnitocrella* Karanovic, 2006 in having a 3-segmented endopod on leg 1, armature of I-0 on the proximal exopodal segment of legs 2 to 4, two outer spines on the distal exopodal segment of legs 1 to 4, bimerous endopod on legs 2 to 4, and sexually dimorphic leg 3. This ameirid also shares an apomorphic 1-segmented antennal exopod armed with an apical seta with *Nitocrella japonica* Miura, 1962 and *Abnitocrella halsei* Karanovic, 2006, armature of I-0 on the middle exopodal segment of legs 2 to 4 with *Nitocrella kunzi* Galassi & Pesce, 1997 and both *Novanitocrella* species, armature of 0-0; I on the endopod of legs 2 to 4 with *Nitocrella paceae* Pesce, 1980 and *N*. *africana* Chappuis, 1955, a plesiomorphic leg 5 in both sexes with *Novanitocrella* and some *Nitocrella* species, and sexually dimorphic leg 2 with *Nitocrella*. Despite these shared features, the cave ameirid copepod contains a suite of characters not known to occur in *Nitocrella*, *Novanitocrella* and *Abnitocrella*. The Yanchep Caves ameirid copepod, therefore, represents a new genus and new species.

4.2 Distribution of harpacticoid copepods among sites

All harpacticoids, except for the new ameirid species and *Nitocra l. pacifica*, were found in both the Yanchep Caves and Ellen Brook Valley Springs (Table 2). The new ameirid and *N*. *l*. *pacifica* were found in this study from the Yanchep Caves only. *Parastenocaris eberhardi* and the new ameirid were the most common taxa within the Yanchep Caves, whilst *N*. *l*. *pacifica* was rarely encountered as only one individual was collected from Fridge Grotto Cave during the entire sampling campaign. The most common taxon at the springs was *A*. *Ch*. *hirsuta*, which was present in two of the three springs.

Among individual sites, species richness was highest at Twilight Cave (5 taxa) followed by Boomerang Cave (4 taxa). A maximum of two taxa were recorded from the spring sites. Only one harpacticoid species was found in Cabaret Cave, Fridge Grotto Cave, Orpheus Cave, Spillway Cave and Sue's Spring.

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

		Caves								Springs		
Taxon	Ecology	Boomerang	Cabaret	Carpark	Fridge Grotto	Gilgie	Orpheus	Spillway	Twilight	Edgecombe	Egerton	Sue's (South)
Ameiridae n. g. & n. sp.	Sb	*	*	*		*			*			
Attheyella (*Ch.*) *hirsuta*	Sp	*							*		*	*
Australocamptus hamondi	Sb	*				*			*		*	
Elaphoidella bidens	Sp	*						*	*	*		
Nitocra lacustris pacifica	Sp				*							
Parastenocaris eberhardi	Sb			*		*	*		*	*		

Ecological codes: Sp = stygophile; Sb = stygobite.

4.3 Diagnostic features of harpacticoid copepods

4.3.1 Ameiridae n. gen. & n. sp.

1. Total body length is approximately 0.43 mm (Fig. 2A).
2. Each *antenna* is 3-segmented; a vestigial, 1-segmented *exopod* articulates with the first segment and bears a single apical *element* (Fig. 2B).
3. Legs 2 to 4 with 3-segmented *exopod* and 2-segmented *endopod* (Fig. 2C).
4. The second segment of the *endopod* of legs 2 to 4 bears one apical *element* (Fig. 2C)

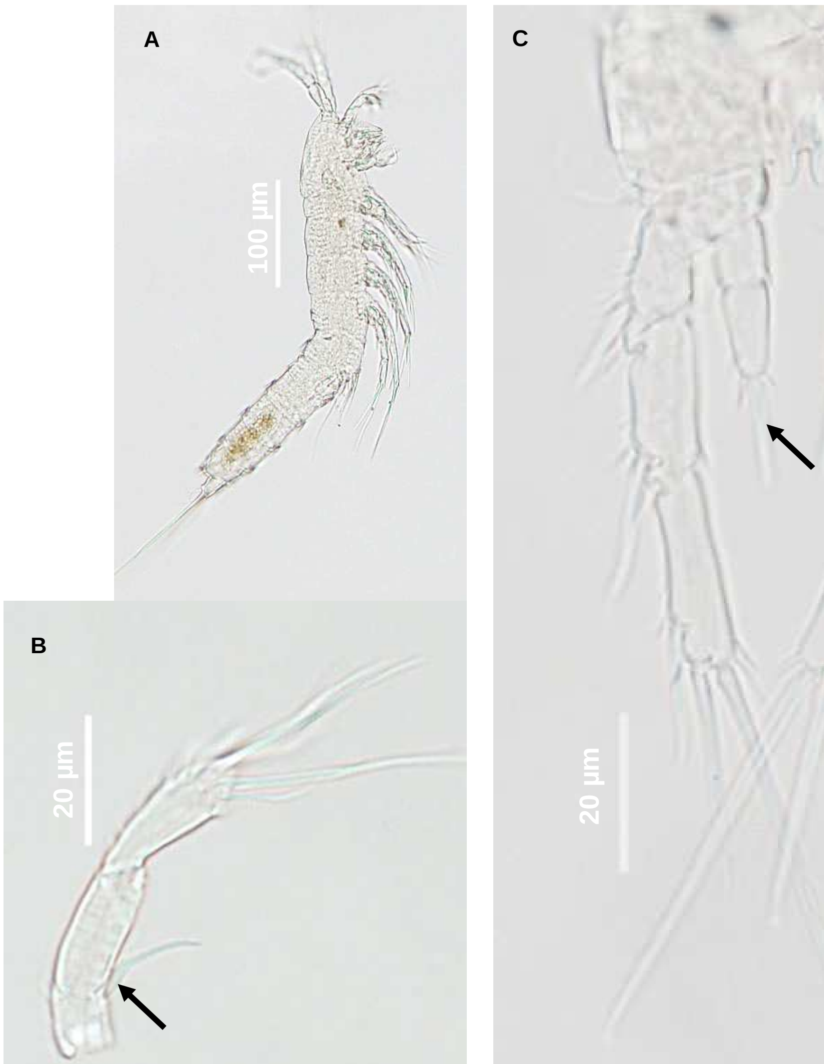

Figure 2. Ameiridae n. gen. & n. sp., adult female. a) habitus, lateral view; b) right antenna, showing 1-segmented exopod (arrowed) armed with one apical element; c) right leg 3 showing apical spine (arrowed) on second segment of endopod.

4.3.2 ***Attheyella* (*Chappuisiella*) *hirsuta***

1. Total body length is about 0.65 mm (Fig. 3A).
2. The lateral surface of the first *pedigerous somite* (= second leg-bearing somite as the first leg-bearing somite is fused to the *cephalic* region) bears an *integumental window* (Fig. 3B).
3. Each *antenna* is 3-segmented; a conspicuous 1-segmented *exopod* articulates with the <u>second</u> segment and bears <u>four</u> *elements* (Fig. 3C).
4. Legs <u>2 to 4</u> with 3-segmented *exopod* and 2-segmented *endopod* (Fig. 3D).
5. The second segment of the *endopod* of legs 2 to 4 bears <u>multiple</u> *elements* (Fig. 3D).

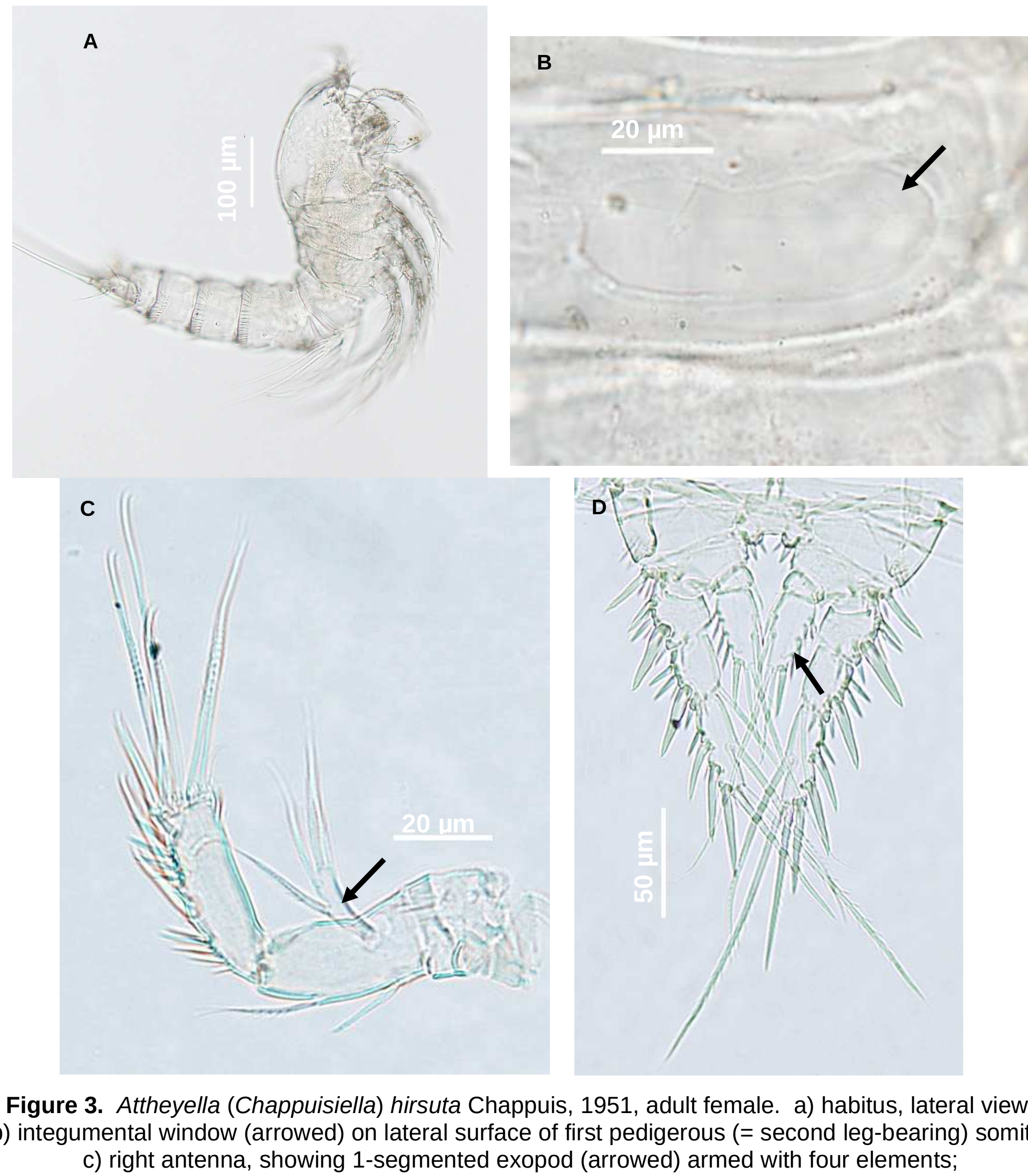

Figure 3. *Attheyella* (*Chappuisiella*) *hirsuta* Chappuis, 1951, adult female. a) habitus, lateral view; b) integumental window (arrowed) on lateral surface of first pedigerous (= second leg-bearing) somite; c) right antenna, showing 1-segmented exopod (arrowed) armed with four elements; d) leg 2 showing multiple elements on second segment of endopod (arrowed).

4.3.3 *Australocamptus hamondi*

1. Total body length is about 0.45 mm (Fig. 4A).
2. Each *antenna* is 3-segmented; a conspicuous 1-segmented *exopod* articulates with the second segment and bears three apical *elements* (Fig. 4B).
3. Legs 2 to 3 with 3-segmented *exopod* and 2-segmented *endopod*; second segment of endopod bears two apical *elements* (Fig. 4C).
4. Leg 4 with 3-segmented *exopod* and 1-segmented *endopod* (Fig. 4D).

Figure 4. *Australocamptus hamondi* Karanovic, 2004, adult female. a) habitus, lateral view; b) right antenna showing 1-segmented exopod (arrowed) armed with three elements; c) left leg 3 showing two elements on second segment of endopod (arrowed); d) left leg 4 showing one-segmented endopod (arrowed).

4.3.4 *Elaphoidella bidens*

1. Total body length is roughly 0.50 mm (Fig. 5A).
2. Each *caudal ramus* bears a large, dorsal process (Fig. 5B).
3. The posterior margin of each *prosomal somite* bears large tooth-like processes (Fig. 5C).
4. Each *antenna* is 3-segmented; a conspicuous 1-segmented *exopod* articulates with the <u>second</u> segment and bears <u>four</u> *elements* (Fig. 5D).
5. Legs <u>2 to 4</u> with 3-segmented *exopod* and 2-segmented *endopod*; the second segment of the endopod bears <u>multiple</u> *elements* (Fig. 5E).

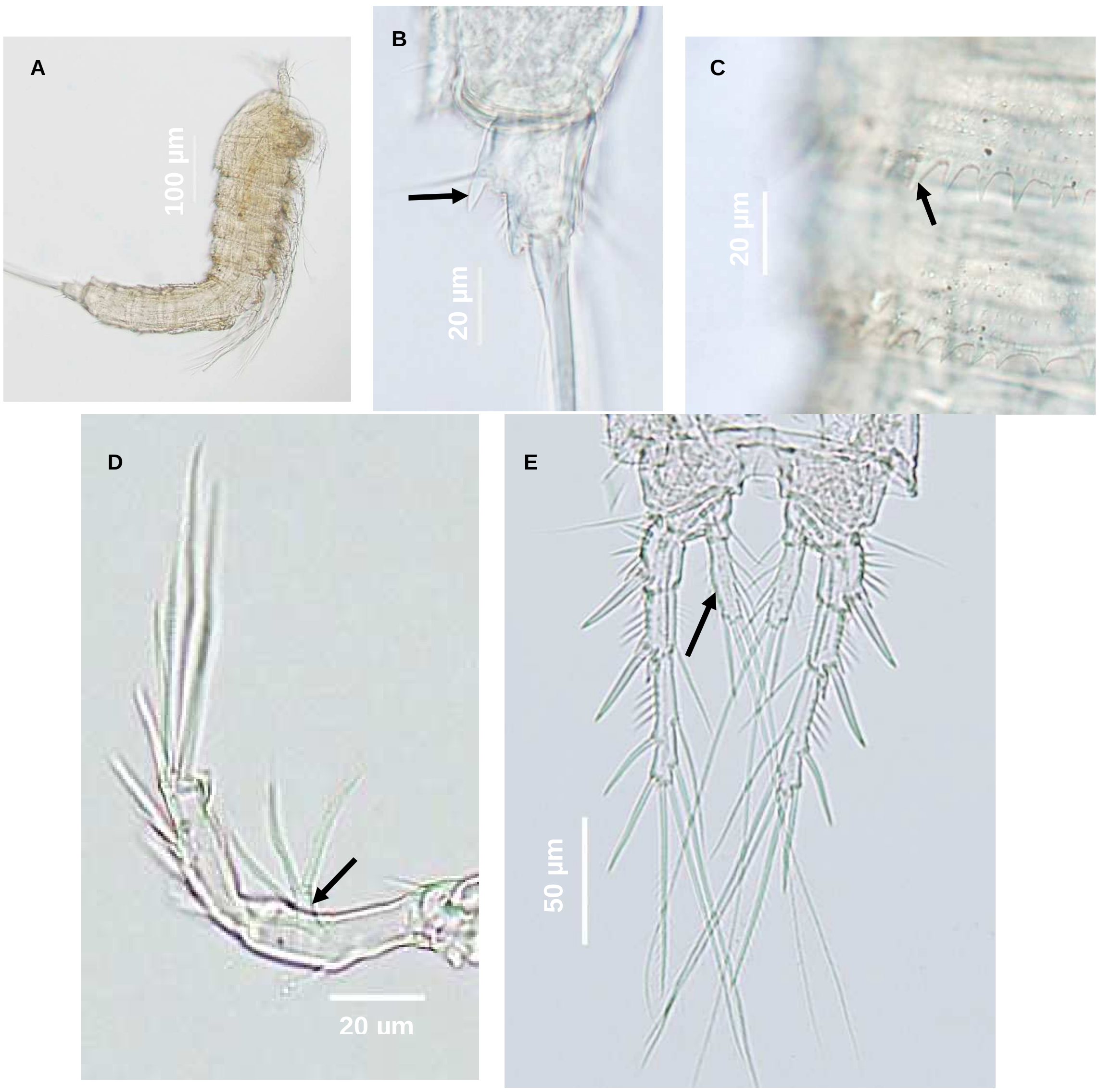

Figure 5. *Elaphoidella bidens* (Schmeil, 1894), adult female. a) habitus, lateral view; b) right caudal ramus showing dorsal process, lateral view; c) pedigerous somites 3 and 4 showing processes (arrowed) along posterior margin, lateral view; d) right antenna, showing 1-segmented exopod (arrowed) armed with four elements; e) leg 3 showing multiple elements on second segment of endopod (arrowed).

4.3.5 *Nitocra lacustris pacifica*

1. Total body length is roughly 0.40 mm (Fig. 6A).
2. The anal *somite* bears two long, posterior processes (Fig. 6B).
3. Each *antenna* is 3-segmented; a conspicuous 1-segmented *exopod* articulates with the second segment and bears three apical *elements* (Fig. 6C).
4. Legs 2 to 4 with 3-segmented *rami* (Fig. 6D).

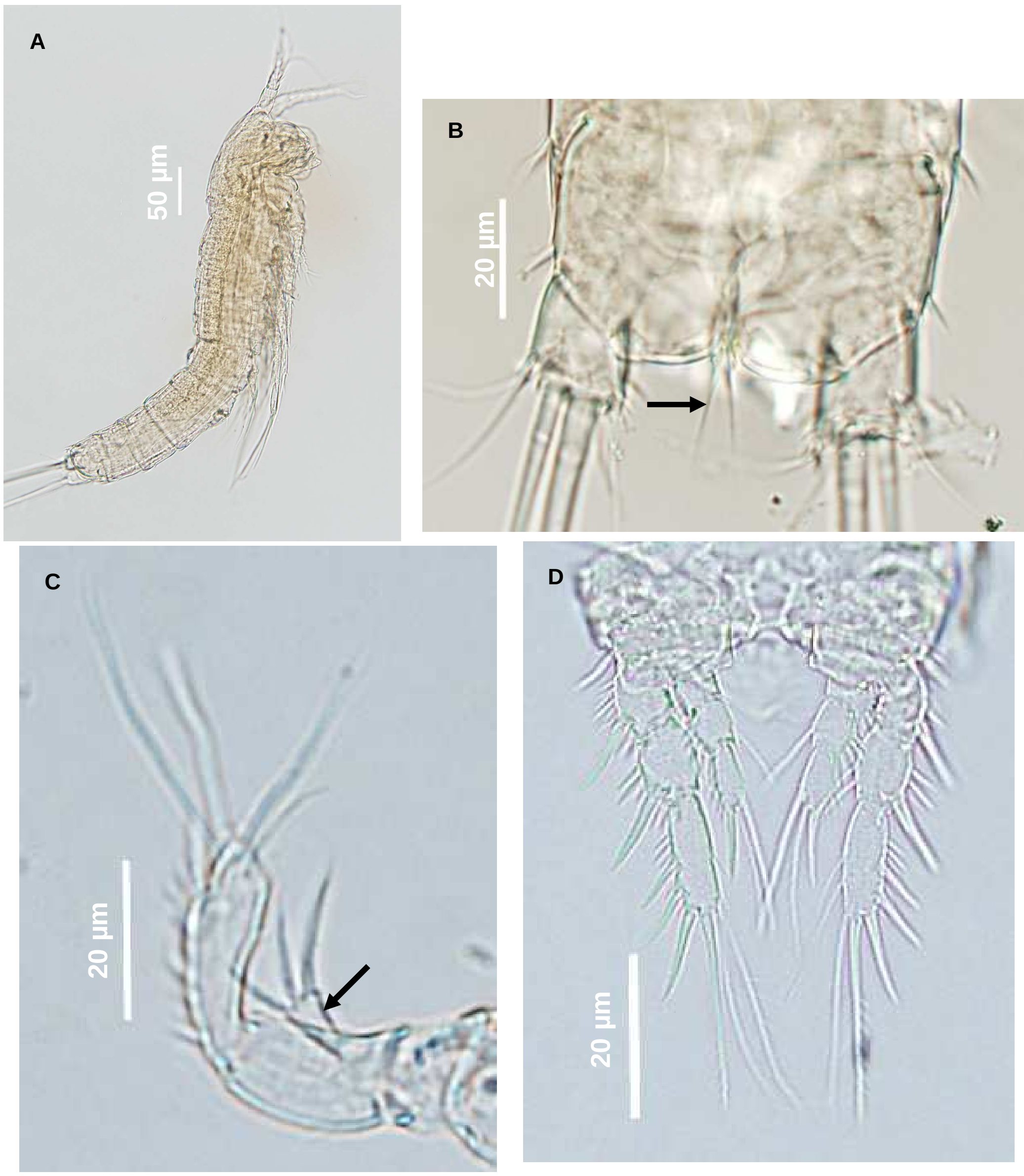

Figure 6. *Nitocra lacustris pacifica* Yeatman, 1983, adult female. a) habitus, lateral view; b) anal somite showing two long posterior processes (arrowed); c) right antenna showing 1-segmented exopod (arrowed) armed with three elements; d) leg 2 showing three-segmented rami (exopod and endopod).

4.3.6 ***Parastenocaris eberhardi***

1. Total body length is approximately 0.37 mm (Fig. 7A).
2. *Urosomites* 3 and 4 bears an *integumental window* on each side (Fig. 7B).
3. Each *antenna* is 3-segmented; a vestigial, 1-segmented *exopod* articulates with the second segment and bears one apical *element* (Fig. 7C).
4. Leg 2 and 4 with 3-segmented *exopod* and vestigial, 1-segmented *endopod* (Fig. 7D).
5. Leg 3 with 2-segmented *exopod* and vestigial, 1-segmented *endopod* (Fig. 7E).
6. Leg 5 is a triangular plate (Fig. 7F).

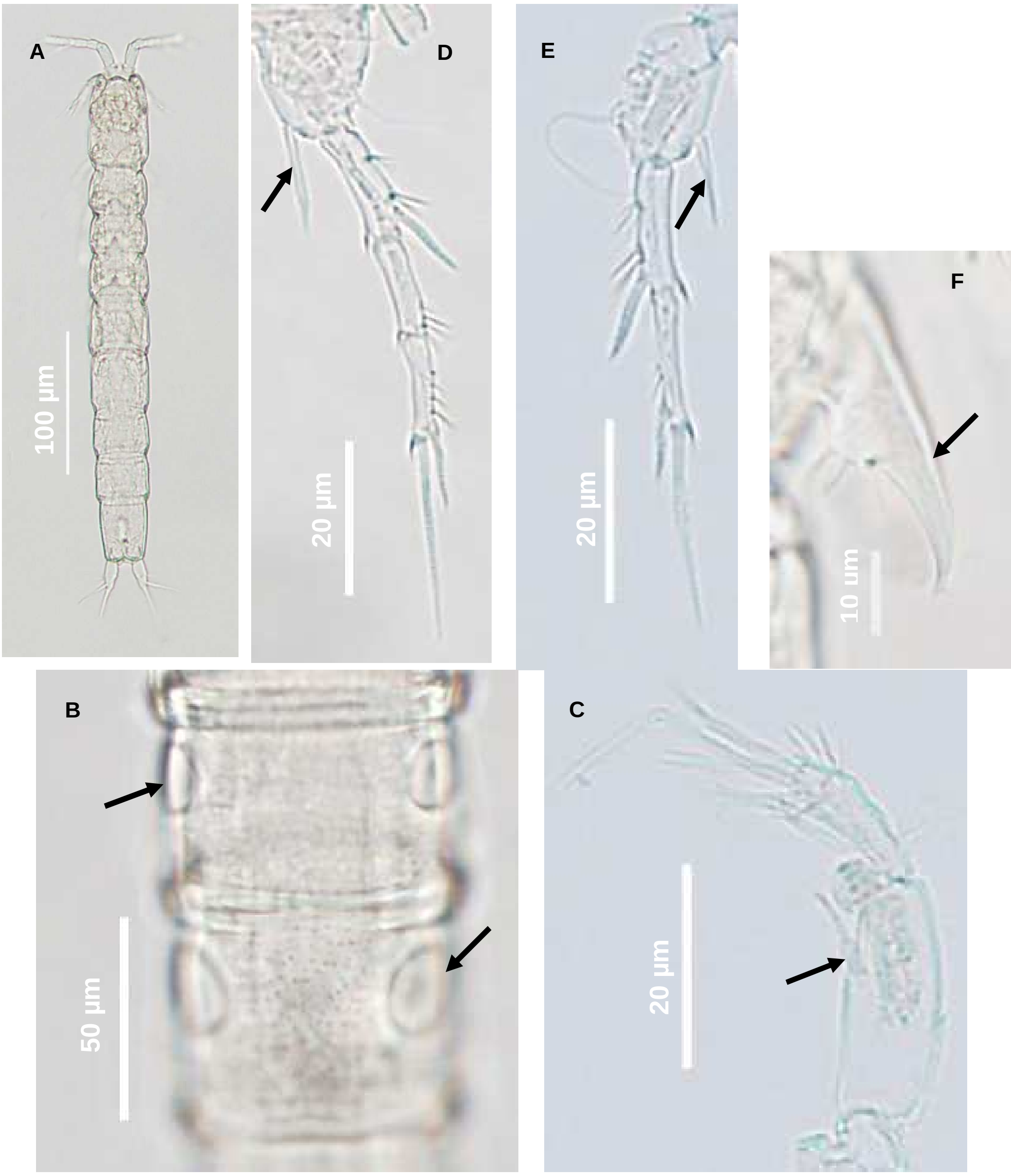

Figure 7. *Parastenocaris eberhardi* Karanovic, 2005, adult female. a) habitus, dorsal view; b) urosomites 3 and 4 showing integumental windows (arrowed), ventral view; c) left antenna showing vestigial exopod (arrowed); d) left leg 4 showing 2-segmented exopod and vestigial 1-segmented endopod (arrowed); e) right leg 3 showing 3-segmented exopod and vestigial 1-segmented endopod (arrowed); f) leg 5 (arrowed).

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 leg 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. *Exopod* of a*ntenna* rudimentary, 1-segmented, bears 1 apical *element* 2

— *Exopod* of a*ntenna* well developed, 1-segmented, bears 3 to 4 apical *elements* 3

2. *Urosomites* 3 and 4 with lateral *integumental windows*; leg 3 *exopod* 2-segmented; leg 3 *endopod* vestigial, 1-segmented.....................*Parastenocaris eberhardi* [Karanovic (2005)]

— *Urosomites* 3 and 4 without lateral *integumental windows*; leg 3 *exopod* 3-segmented; leg 3 *endopod* well developed, 2-segmented.................................. Ameiridae n. gen. & n. sp.

3. *Exopod* of a*ntenna* bears 3 apical *elements*...4

— *Exopod* of a*ntenna* bears 4 apical *elements* 5

4. Legs 2 to 4 with 3-segmented *exopod* and 3-segmented *endopod*..................................... ....*Nitocra lacustris pacifica* [Karanovic (2004)]

— Legs 2 to 3 with 3-segmented *exopod* and 2-segmented *endopod*; leg 4 with 3-segmented *exopod* and 1-segmented *endopod* .... *Australocamptus hamondi* [Karanovic (2004)]

5. Each *caudal ramus* bears a large, dorsal process; the posterior margin of each *prosomal somite* bears large tooth-like processes ....*Elaphoidella bidens* [Hamond (1987)]

— Each *caudal ramus* lacks a large, dorsal process; the posterior margin of each *prosomal somite* is smooth ....*Attheyella* (*Chappuisiella*) *hirsuta* [Hamond (1987)]

6. DISCUSSION

6.1 Harpacticoid copepod fauna

Examination of copepod samples from eight Yanchep Caves and three Ellen Brook Valley Springs revealed a total of six harpacticoid copepod species, of which only one is new to science. We have submitted a manuscript to an international journal describing this new taxon.

The harpacticoid copepod assemblages from the Yanchep Caves and Ellen Brook Valley Springs are comprised mostly of widespread taxa. *Nitocra lacustris pacifica* has been reported from Fiji, Western Samoa and Tonga by Yeatman (1983), Papua New Guinea by Fiers (1986) and the Murchison Region of Western Australia by Karanovic (2004). This subspecies is indeed relatively widespread in Western Australia, as we have examined five adult specimens collected from one bore locality in the Shark Bay Region (Tang & Knott, unpublished data). There is a distinct possibility that *N*. *l*. *pacifica* occurs in other Australian States given that the nominate species *N*. *lacustris* (Schmankevitsch, 1895) was recorded previously, without descriptions or illustrations, from springs in South Australia by Mitchell (1985) and Zeidler (1989). Whether these authors' specimens represent *N*. *lacustris* s. str. or *N*. *l*. *pacifica* requires further investigation. The collection of just one female *N*. *l*. *pacifica* during the study period supports Karanovic's (2004) supposition that this species "is only an occasional guest in the subterranean waters of Western Australia."

Attheyella (*Chappuisiella*) *hirsuta* has been collected from moss samples obtained in Tasmania by Chappuis (1951) and Victoria by Hamond (1987). As *A*. (*Ch*.) *hirsuta* was hitherto known only from Tasmania and Victoria, its collection in Western Australia represents a large range extension for this freshwater taxon. Furthermore, this is the first record of this species from the hypogean environment.

Australocamptus hamondi was hitherto known only from boreholes in the Murchison Region of Western Australia (Karanovic, 2004). The occurrence of *A*. *hamondi* in several caves and a spring in the Gnangara Mound Region extends its known distribution to the south-west of Western Australia and supports Karanovic's (2004) premise that this species is stygobitic.

Elaphoidella bidens is a cosmopolitan species that typically inhabits the littoral zone of large waterbodies (Gurney, 1932; Lewis, 1972). In Australia, this species is known to occur commonly in slow-moving streams or lakes in South Australia, Victoria, New South Wales and Queensland (Hamond, 1987). The presence of *E*. *bidens* from the Gnangara Mound Region, accordingly, represents the first record of this species in Western Australia. Although the occurrence of this species in the hypogean environment of Western Australia is unusual, it is certainly not unique as it has been reported previously from caves in the Ryukyu Islands of Japan (Miura, 1962) and North America (Reeves *et al*., 2000).

Parastenocaris eberhardi was hitherto known only from Strongs Cave and Kudjal Yolgah Cave located in the Margaret River Region of Western Australia (Karanovic, 2005). The discovery of this species in the caves and spring of the Gnangara Mound Region, therefore, extends its known distribution northwards.

Ameiridae n. gen. & n. sp. is the only harpacticoid species identified in this study that is considered to be endemic to the Gnangara Mound Region; it occurs only in caves that contain submerged tuart root mats.

6.2 Conservation

Based on the distribution and habitat records given above for the six Gnangara Mound harpacticoid copepod taxa, *Attheyella* (*Chappuisiella*) *hirsuta*, *Australocamptus hamondi*, *Elaphoidella bidens*, *Nitocra lacustris pacifica* and *Parastenocaris eberhardi* are regarded as species of low conservation value as they are geographically widespread taxa. In contrast, we consider Ameiridae n. gen. & n. sp. to be a species of high conservation value as it was found exclusively in Yanchep Caves containing submerged tuart root mats (i.e. Boomerang, Cabaret, Carpark, Gilgie and Twilight Caves). Although pumps, sumps and black plastic liners are currently used in Cabaret, Boomerang and Carpark Caves to prevent the dehydration of the root mats, these artificial measures have proven to be ineffective due to frequent mechanical failure of the pumps and, more importantly, the unabated decline of the water table in the Gnangara Mound. As a result, Boomerang and Carpark Caves, along with Fridge Grotto and Gilgie Caves, have completely dried up. The water level in Cabaret Cave is also at all-time historic lows, leading to the reduction in extent and quality of root mats as well as a decrease in abundance and diversity of aquatic fauna at these sites (Knott *et al*., 2008). The continual degradation of these groundwater-dependent habitats is cause for concern, particularly for Ameiridae n. gen. & n. sp. as it occurs only in caves that contain submerged tuart root mats. Indeed this species has not been found in the Yanchep Caves since the 1990s, which suggests that it may have already gone extinct. Clearly, alternative and effective management strategies need to be developed and implemented promptly to re-establish the natural environment of the caves. We anticipate that Ameiridae n. gen. & n. sp. will recolonise the Yanchep Caves, should it still occur in some unknown groundwater refuge of the Gnangara Mound, once root mats are restored and sufficient water levels are maintained permanently.

7. RECOMMENDATIONS

a) Ameiridae n. gen. & n. sp. should be listed as an Endangered Species under the Environment Protection and Biodiversity Conservation Act 1992. This is necessary as this species' habitat, namely the submerged tuart root mats of the Yanchep National Park Caves, have mostly dried up or are currently under threat of destruction.

b) Water flow must be restored and maintained permanently in the cave streams. This is essential for re-establishing the tuart root mats, which will in turn provide suitable habitats for Ameiridae n. gen. & n. sp. to recolonise should it still occur in some unknown groundwater refuge of the Gnangara Mound.

c) Biospeleological investigations should continue in the Yanchep National Park and surrounding karstic formations to find additional caves with tuart root mats.

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

Antenna: the second 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.

Integumental window: a thinner, membranous portion of the outer cuticle layer.

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

Pedigerous: somites bearing swimming legs.

Prosome (*Prosomal*): 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.

Somite: a segment or division of the body.

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

Urosomite: component somite of *urosome*.