Subterranean Fauna of the Eneabba, Jurien and South Hill River (Nambung) Karst Areas, Western Australia

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A report prepared for the Department of Environment and Conservation, Western Australia – Midwest Region.

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Figures and Tables

1.1 Introduction

This project used volunteer speleologists to collect invertebrate fauna from a selection of major caves within the Eneabba, Jurien and Nambung Karst areas north of Perth, Western Australia. Collecting was conducted during daylight hours and used hand collecting techniques, primarily involving forceps, and paintbrushes dipped in ethanol. Specimens were predominately collected in 70% ethanol to allow morphological identification of material. Some specimens were also collected in 100% ethanol for future molecular studies of taxa. Additional collecting was only conducted when numerous individuals of target taxa were present.

Specimens have been identified to the lowest practical taxonomic level, commonly genus or subfamily. Species level identification is often unpractical due to poor taxonomic treatment of many groups within the literature. Available time has also been taken into account to provide a usable identification of all specimens collected to morpho-species level. The Araneae (listed as morpho-species) are currently being identified by the Western Australian Museum and these identifications will be available shortly. All accidentals have been excluded from species lists for specific karst areas as they do not represent true cavernicolous fauna, or a significant component of the cavernicolous ecosystem, but have been included in cave specific inventories for the sake of completeness.

This report identifies the invertebrate fauna collected during this recent fieldwork only and does not provide a complete historical species inventory for any of the caves examined. Historical collecting information and diversity is contained within Susac (in prep), which lists the known diversity of individual caves and degree of collecting previously undertaken. The current collecting will however undoubtedly provide new insights into the cavernicolous invertebrate fauna of the region, and also allow a comparison with historical population levels of previously known species to be undertaken. This historical comparison is critical in providing relevant conservation assessments of these karst areas with changing epigean land uses combined with climatic change over the past several decades since these caves were first assessed biologically.

1.2 Cave zones and ecological classification of invertebrates

Caves are divided into several distinct biological zones to aid interpretation (Figure 1). These correspond to the amount of available light and varying environmental conditions (Humphreys 2000). The Entrance Zone is the area directly around the cave entrance; it is generally well lit, often supports photosynthetic plants, and undergoes daily temperature and humidity fluctuations. The Twilight Zone is just beyond the entrance zone and is often dominated by lichen and algae that require low light conditions. The temperature and humidity are still variable but fluctuations are dampened compared with epigean variation.

Deeper into a cave, light is reduced to zero and the Dark Zone is entered, which is subdivided into three zones, the transition, deep cave and stale air zones. The Transition Zone is perpetually dark, but still fluctuates in temperature and humidity determined by epigean conditions. The Deep Cave Zone is almost constant in temperature and humidity conditions. The Stale Air Zone is only found in certain caves and is an area of the deep zone that is constricted, and commonly contains elevated levels of CO_2 and lower levels of O_2 (Howarth and Stone 1990).

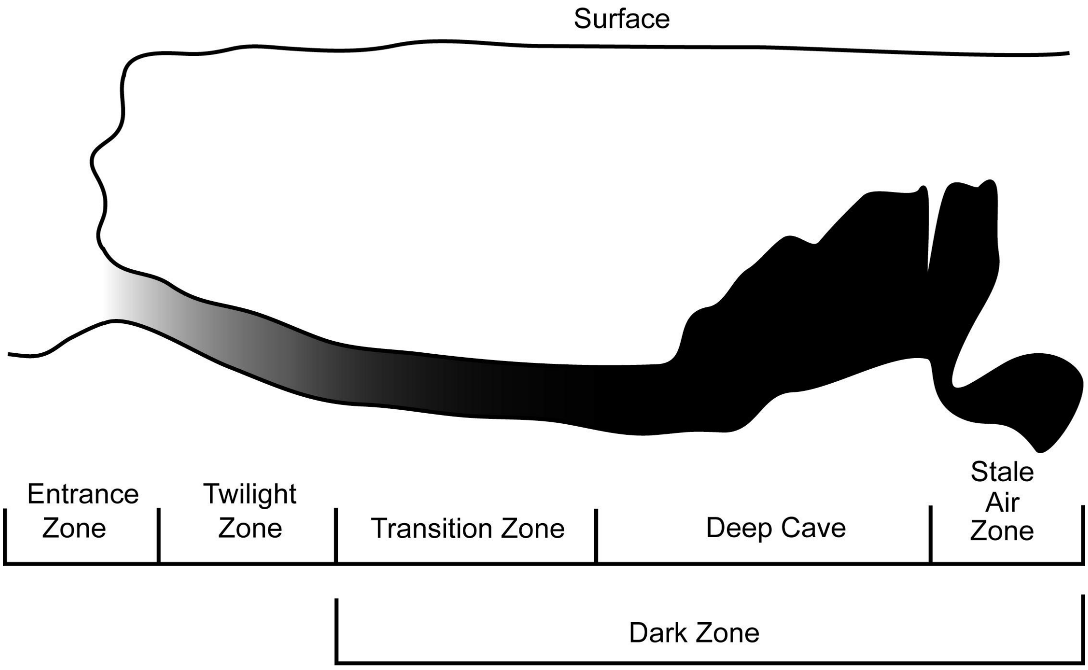

Figure 1. The environmental zones of a cave shown in cross section.

The following ecological classification of invertebrates used in this report is modified from Hamilton-Smith (1967), and Gnaspini and Trajano (2000), and is based on the degree of cave and guano dependence of taxa. The ecological classification of guano invertebrates is usually considered separately to an animal's degree of cave dependence. This is because guano is considered a substrate within the cave environment that attracts a range of cavernicolous and epigean species due to its high food value. Thus animals are categorised not only according to their degree of cave dependence (troglobite, troglophile trogloxene) but also according to their degree of guano dependence. This enables both an animal's degree of cave and guano dependence to be categorised, however, in practise detailed study of an animal is required to accurately determine its degree of guano dependence. This limits the effectiveness of this classification system and, without prior knowledge, most communities found in guano can only be referred to as 'guano associated' rather than guanobitic or guanophilic. Abbreviations are those used in the diversity tables.

Trogloxene: an organism that regularly uses the cave environment for part of its lifecycle or as shelter but must leave the cave to feed and or breed – **Tx**

Troglophile: an organism that can complete its entire lifecycle within a cave but possess no specific adaptations to the cave environment (troglomorphisms) – **Tp**

Troglobite: obligate cavernicolous organisms that possess specific adaptations to the cave environment – **Tb**

Guanoxene: an organism that may use guano for reproduction and/or feeding but requires other substrates to complete its life cycle - **Gx**

Guanophile: an organism that inhabits and reproduces both in guano piles as well as other substrates within a cave – **Gp**

Guanobite: an organism that requires guano deposits to complete its entire life cycle - **Gb**

Parasite: an animal that is an obligate parasite requiring animals to complete its lifecycle (e.g. fleas, ticks etc) - **P**

Accidental: an animal not normally associated with the cave environment and incapable of surviving within caves – **Acc**

Ecological classifications have been assigned to taxa wherever possible. These designations were made using available knowledge concerning behaviour, life history, and distribution within caves. However, information regarding species' ecology was found to be lacking or minimal in most cases.

2.1 Diversity of cave fauna in the Northern Agricultural Area

This sampling collected a diverse assemblage of invertebrate fauna from the three karst areas investigated, Eneabba, Jurien and South Hill (Nambung). Thirty eight species from 21 families, 14 orders and five classes were collected from five caves within the Eneabba karst area (Table 1), while 23 species from 13 families, 12 orders and five classes were collected from four caves in the Jurien karst area (Table 2). Twenty-six species from 16 families, 14 orders and six classes were collected from the seven Nambung caves examined during June 2007. These three karst areas share 11 common species (Table 4).

The majority of fauna collected during this sampling is classified as troglophiles (Tp) and predominately from the entrance and twilight areas of these caves. This is an expected outcome for a single sampling event within a relatively geologically young karst area, that lacks the evolutionary history for numerous troglobitic species to evolve. Troglobites are commonly collected only from using active trapping techniques over often successive and long trapping periods, due to the often intrinsic rarity of troglobites and very low populations.

Troglobitic species, including an eyeless, depigmented meenopliid planthopper have been collected in several caves in the South Hill karst region in the Nambung National Park. In Pulchella Cave (SH38), the troglobitic meenopliids were found in association with a troglomorphic reduviid near moist roots. This is an extremely important discovery for the invertebrate biodiversity of the Nambung region. The small entrances of the majority of caves within the South Hill karst results in the maintenance of high humidity which are favourable for troglobites. The collection of several blind silverfish specimens from the deep zone of Weelawadji Cave (E24) may prove significant to cavernicolous biodiversity of the area. This relies upon the outcome of an examination of the specimens by an appropriate taxonomic expert, as the entire subfamily (Nicoletiinae) are blind and reside in the deep soil biome, so the specimens may simply have invaded the karst space from subsurface soil, and not be ‘true’ *in situ* evolved troglobites.

Table 1. Invertebrate diversity from six caves sampled in the Eneabba Karst Area.

Class	Order	Family	Genus and Species	Cave adaption	Guano Dependence
Arachnida	Acarina	Cunaxidae	*sp2*		
	Acarina	Trombidiidae	*sp1*		
	Araneae	Theridiidae	*sp1*		
	Araneae		*sp1*		
	Araneae		*sp2*		
	Araneae		*sp3*		
	Araneae		*sp4*		
	Araneae		*sp5*		
	Araneae		*sp6*		
	Araneae		*sp7*	Tp	
	Opilionida		*sp1*	Tp	
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	Tp	Gp
Myriapoda	Chilopoda	Scolendropmorpha	*sp1*	Tp?	
	Chilopoda	Scutigeridae	*sp1*	Tp	
Crustacea	Isopoda	Armadillidae	*sp1*	Tx	
	Isopoda	Armadillidae	*sp2*	Tx	
	Isopoda	Philosciidae	*Laevophiloscia sp2*	Tp	Gx
	Isopoda	Philosciidae	*Laevophiloscia richardsae?*	Tp	
	Isopoda	Philosciidae	*Laevophiloscia sp1*	Tp	Gx
	Isopoda	Philosciidae	*sp1*		
	Isopoda	Philosciidae	*Laevophiloscia sp. 3*	Tp	
	Isopoda		*sp1*		
Hexapoda	Collembola	Entomobryidae	*sp1*	Tp	
Insecta	Blattodea	Blattellidae	*Neotemnopteryx douglasi*	Tp	Gb?
	Coleoptera	Anobiidae	*Ptinus exulans*	Tp	Gp
	Coleoptera	Carabidae	*Speotarus lucifugus*	Tp	Gp
	Coleoptera	Dermestidae?	*sp1* larvae	Tp?	
	Coleoptera	Tenebrionidae	*Brises acuticornis duboulayi*	Tp	Gp
	Hemiptera	Reduviidae	Emesinae *sp1*	Tp	Gx
	Hemiptera	Reduviidae	Harpactorinae *sp1*	Tp	Gx
	Hemiptera	Reduviidae	Harpactorinae *sp3*	Tp	Gx
	Lepidoptera	Teneidae	*Monopis crocicapitella?*	Tp	Gb
	Pscoptera	Trogiidae	*sp1*	Tp	
	Psocoptera	Trogiidae	*sp2*	Tp	
	Siphonaptera	Pucilidae	*Ctenocephalides sp1*	P	
	Thysanura	Lepismatidae	*sp1*	Tp?	Gx
	Thysanura	Nicoletiidae	*Nicoletiinae Trinemura novaehollandiae?*	Tp	
	Thysanura	Nicoletiidae	*Nicoletiinae Trinemura sp1*	Tb?	

Table 2. Invertebrate diversity from four caves sampled in the Jurien Karst Area.

Class	Order	Family	Genus and Species	Cave adaption	Guano Dependence
Arachnida	Acarina	Cunaxidae	*sp1*		
	Acarina	Cunaxidae	*sp2*		
	Acarina	Cunaxidae	*sp3*		
	Acarina	Trombidiidae	*sp1*		
	Araneae	Theridiidae	*Lactrodectus hasselti*	Tx	
	Araneae	Theridiidae	*sp1*		
	Araneae	Theridiidae	*sp2*		
	Araneae		*sp1*		
	Araneae		*sp2*		
	Araneae		*sp3*		
	Opilionida		*sp1*	Tp	Gx
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	Tp	Gp
Myriapoda	Chilopoda	*Allothereua lesueurii*	*sp1*		
Crustacea	Isopoda	Philosciidae	*Laevophiloscia sp1*	Tp	Gx
	Isopoda	Philosciidae	*Laevophiloscia sp2*	Tp	Gx
	Isopoda	Philosciidae	*Philosciidae sp1*	Tp	Gx
	Isopoda	Philosciidae	*Philosciidae sp2*	Tp	Gx
Hexapoda	Collembola	Entomobryidae	*sp2*	Tp	
Insecta	Blattodea	Blattellidae	*Neotemnopteryx douglasi*	Tp	Gb?
	Coleoptera	Anobiidae	*Ptinus exlunas*	Tp	Gp
	Coleoptera	Carabidae	*Speotarus lucifugus*	Tp	Gp
	Diptera	Phoridae	*sp1*	Tp	Gp
	Hemiptera	Reduviidae	*Harpactorinae sp2*	Tp	Gx
	Orthoptera	Rhaphidophoridae	*Gen. nov. and sp. nov.?*	Tx	Gx
	Pscoptera	Trogiidae	*sp1*	Tp	

Table 3. Invertebrate diversity from seven caves sampled in the Nambung Karst Area.

Class	Order	Family	Genus and Species	Cave adaption	Guano Dependence
Tubellaria	Unknown		sp	Tp?	
Arachnida	Acarina	Trombidiidae	sp1		
	Araneae	Stiphidiidae	*Baiami sp*	Tp	
	Araneae	Theridiidae	*Achaearanea? sp*	Tp	
	Araneae		*sp1*	Tp	
	Araneae		*sp2*	Tp	
	Araneae		*sp3*	Tp	
	Araneae		*sp4*	Tp	
	Araneae		*sp5*	Tp	
	Araneae		*sp6*	Tp	
	Araneae		*sp*	Tp	
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	Tp	Gp
Crustacea	Isopoda	Philosciidae	*Laevophiloscia sp*	Tp	
	Isopoda	Armadillidae	*sp*	Tp	
Myriapoda	Chilopoda	Scutigeridae	*Allothereua lesueurii*	Tp	
	Diplopoda	Polydesmidae		Tp	
Hexapoda	Diplura	Japygidae	*sp*	Tp	
Insecta	Blattodea	Blattellidae	*Neotomnopteryx douglasi*	Tp	Gx
	Blattodea	Blattellidae	*Neotomnopteryx sp cf. 'douglasi'*	Tb	Gx
	Coleoptera	Anobiidae	*Ptinus exulans*	Tp	Gp
	Coleoptera	Carabidae	*Lecanomerus ? sp*	Tp	Gp?
	Coleoptera	Carabidae	*sp*	Tp	
	Diptera	Sciaridae?	*sp*	Tp	Gp
	Hemiptera	Meenopliidae	sp1	Tb	
	Lepidoptera	Tineidae	*Monopis crocicapitella*	Tp	Gb?
	Orthoptera	Gryllidae	sp	Tp?	

Table 4. Species common between karst areas of the NAR. All accidentals have been excluded from this comparison

Class	Order	Family	Genus and Species	Cave Adaption	Guano Dependence
Arachnida	Acarina	Trombidiidae	*sp1*		
	Araneae	Theridiidae	*sp1*		
	Araneae		*sp1*		
	Araneae		*sp2*		
	Araneae		*sp3*		
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	Tp	Gp
Myriapoda	Chilopoda	Scutigeridae	*Allothereua lesueurii*		
Crustacea	Isopoda	Philosciidae	*Laevophiloscia sp1*	Tp	Gx
Insecta	Blattodea	Blattellidae	*Neotemnopteryx douglasi*	Tp	Gb?
	Coleoptera	Anobiidae	*Ptinus exulans*	Tp	Gp
	Coleoptera	Carabidae	*Speotarus lucifugus*	Tp	Gp

2.2 Invertebrate diversity of Eneabba caves

Diversity of individual caves is shown in Tables 5 – 11. Significance of each cave and associated collections is discussed below. Several important genera and species will be discussed in detail in Section 3.1 and therefore will only be dealt with in passing within the following sections.

Collecting in Stockyard Tunnel produced minimal results (Table 5), possibly reflecting the heavy visitor impacts on this cave, especially tramping of floor habitats. The diversity of the Philosciidae isopods is however significant for the karst area. The presence of the troglophilic cockroach *Neotemnopteryx douglasi* also makes this an important cave in a regional context.

Table 5. Stockyard Tunnel E1, invertebrate diversity collected during April 2007.

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Myriapoda	Chilopoda	Scutigeridae	*Allothereua lesueurii*	1	Tp		Transition	70
Crustacea	Isopoda	Armadillidae	*sp2*	13	Tx		Twilight	70
	Isopoda	Philosciidae	*Laevophiloscia richardsae?*	5	Tp		Twilight	70
	Isopoda	Philosciidae	*Laevophiloscia sp1*	10	Tp	Gx	Twilight	70
	Isopoda	Philosciidae	*sp1*	3			Twilight	70
	Isopoda		*sp1*	1			Twilight	70
Hexapoda	Collembola	Entomobryidae	*sp1*	3	Tp		Transition	70
Insecta	Blattodea	Blattellidae	*Neotemnopteryx douglasi*	2	Tp	Gb?	Transition	70
	Thysanura	Nicoletiidae	*Nicoletiinae Trinemura novaehollandiae?*	1	Tp		Twilight	70

Aiyennu Cave shows considerable diversity at both an Order and Family level (Table 6), and also contains several important species significant to the area including *Neotemnopteryx douglasi* and *Protochelifer cavernarum* (refer to Section 3.1). The presence of two subfamilies of predatory reduviid ‘assassin bugs’ is an important feature of this cave in a regional biogeographic sense, as the distribution of this family in caves has shown to be significantly under-represented in collections (Moulds 2004). Further identification of these specimens will almost certainly confirm these records as range extensions, at a minimum into the hypogean environment. The current collection significantly adds to the invertebrate diversity known from this cave.

Table 6. Aiyennu Cave E9 invertebrate diversity collected during April 2007.

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Arachnida	Araneae		*sp1*	1			Twilight	100
	Opilionida		*sp1*	1	Tp	Gx	Transition	70
	Opilionida		*sp1*	2	Tp	Gx	Transition	100
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	6	Tp	Gp	Twilight	70
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	6	Tp	Gp	Twilight	100
Myriapoda	Chilopoda	Scolendropmorpha	*sp1*	1	Tp?		Entrance	70
Crustacea	Isopoda	Amaradillidae	*sp1*	6	Tp		Twilight	70
Insecta	Blattodea	Blattellidae	*Neotemnopteryx douglasi*	1	Tp	Gb?	Transition	70
	Coleoptera	Carabidae	*sp1*	1	Acc		Entrance	70
	Coleoptera		*sp1*	1	Acc		Entrance	70
	Dermaptera	Anisolabididae	*sp1*	1	Acc		Entrance	70
	Hemiptera	Reduviidae	Emesinae *sp1*	1	Tp	Gx	Transition	70
	Hemiptera	Reduviidae	Harpactorinae *sp1*	2	Tp	Gx	Transition	70
	Psocoptera	Trogiidae	*sp1*	1	Tp		Transition	70
	Thysanura	Lepismatidae	*sp1*	1	Tp?	Gx	Entrance	70

Beekeepers Cave contains a high diversity at family level and above, although the number of specimens collected are unlikely to represent the full diversity of the cave. The relatively restricted entrance to this cave will aid in maintaining humidity and thus it may prove an important cave for invertebrate biodiversity.

Table 7. Beekeepers Cave E10 invertebrate diversity collected during May 2007.

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Arachnida	Araneae	Theridiidae	*Achaearanea? sp*	1	Tp		Twilight	100
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	1	Tp	Gp	Twilight	100
Myriapoda	Chilopoda	Scutigeridae	*Allothereua lesueurii*	1	Tp		Transition	100
Crustacea	Isopoda	Philosciidae	*Laevophiloscia sp*	1	Tp		Transition	100
Insecta	Blattodea	Blattellidae	*Neotemnopteryx douglasi*	1	Tp	Gb?	Transition	70
			Neotemnopteryx douglasi	1	Tp	Gb?	Transition	100
	Coleoptera	Scaraboidea	*sp*	1	Tx?		Twilight	100

Collections from Arramall Cave (Table 8) show the presence of regionally significant species such as *Neotemnopteryx douglasi*, *Protochelifer cavernarum* and *Laevophiloscia* spp. Apart from these records the collection of a larval case of the moth *Monopis crocicapitella* is significant as it confirms historical unpublished records of *Monopis* sp. from Eneabba/Jurien karst areas (Moulds 2006). Dermestids are also a relatively common family associated with cave guano deposits overseas but are under-represented in Australian guano caves, possibly due to a lack of collecting in many karst areas.

Table 8. Arramall Cave E22 invertebrate diversity collected during April 2007.

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Arachnida	Araneae		*sp1*	4			Twilight	70
	Opilionida		*sp1*	1	Tp	Gx	Transition	100
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	15	Tp	Gp	Twilight	70
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	15	Tp	Gp	Twilight	100
Crustacea	Isopoda	Philosciidae	*Laevophiloscia sp1*	14	Tp	Gx	Transition	70
	Isopoda	Philosciidae	*Laevophiloscia sp2*	25	Tp	Gx	Transition	70
	Isopoda	Philosciidae	*Laevophiloscia sp2*	3	Tp	Gx	Transition	100
Insecta	Blattodea	Blattellidae	*Neotemnopteryx douglasi*	2	Tp	Gb?	Transition	70
	Coleoptera	Carabidae	*Speotarus lucifugus*	1	Tp	Gp	Twilight	70
	Coleoptera	Dermestidae?	*sp1* larvae	1	Tp?	Gp?	Twilight	70
	Coleoptera	Tenebrionidae	Tenebrioninae *sp1*	3	Acc		Twilight	70
	Lepidoptera	Teneidae	*Monopis crocicapitella?* Larval case	1	Tp	Gb	Twilight	70
	Pscoptera	Trogiidae	*sp1*	1	Tp		Transition	70

River Cave has the potential to contain a significant troglophilic fauna but due to the timing of the collecting during April the cave passage was extremely dry, thus severely limiting the diversity and amount of invertebrates collected (Table 9). The cave shows evidence of flood levels peaking at or near roof levels. Further collecting in this cave after rain may yield significantly more invertebrate fauna than presented here, although the current diversity was surprising to the author. The significance of the Harpactorinae reduviid is again significant and similar comments as made about the presence of these Hemiptera from Arramall Cave apply here.

Table 9. River Cave E23 invertebrate diversity collected during April 2007.

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Arachnida	Acarina	Trombidiidae	*sp1*	7			Transition	70
	Araneae	Theridiidae	*sp1*	4			Entrance	70
	Araneae	Theridiidae	*sp1*	1			Entrance	100
	Araneae		*sp1*	3			Transition	70
	Araneae		*sp2*	2			Transition	70
	Araneae		*sp3*	1			Twilight	70
	Araneae		*sp4*	1			Twilight	70
	Araneae		*sp5*	1			Transition	70
	Araneae		*sp6*	1			Twilight	70
	Opilionida		*sp1*	1	Tp	Gx	Transition	70
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	17	Tp	Gp	Twilight	70
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	12	Tp	Gp	Twilight	100
Crustacea	Isopoda	Armadillidae	*sp1*	1	Tx		Twilight	70
Hexapoda	Collembola	Entomobryidae	*sp1*	4	Tp		Transition	70
Insecta	Coleoptera	Carabidae	*sp1*	1	Acc		Entrance	70
	Coleoptera	Carabidae	*sp2*	1	Acc		Entrance	70
	Coleoptera	Carabidae	*sp3*	1	Acc		Entrance	70
	Coleoptera		*sp2*	1	Acc		Entrance	70
	Coleoptera		*sp3*	1	Acc		Entrance	70
	Hemiptera	Reduviidae	Harpactorinae *sp3*	1	Tp	Gx	Transition	70
	Hymenoptera	Braconidae	*sp1*	1	Acc		Entrance	70
	Psocoptera	Trogiidae	*sp2*	1	Tp		Transition	70
	Psocoptera	Trogiidae	*sp2*	1	Tp		Transition	100

Weelawadji Cave is perhaps the most significant caves examined during the current fieldwork, not only for its important and diverse invertebrate fauna (Table 10), but also for the diversity of habitats present both within the entrance areas (pre-gate) and those beyond the cave gate. The significant colony (~100) of bats (*Chalinolobus morio*?) roosting within the transition zone before the gate provide an important energy input for troglophilic and guano associated fauna such as *Neotemnopteryx douglasi*, *Protochelifer cavernarum* and *Monopis crocicapitella*. The collection of a potentially new species of troglobitic silverfish (Thysanura: Nicoletiidae) is highly significant as it may represent an entirely new record for this cave which has been the focus of extensive collecting efforts in the past (Lowry 1980). This cave was one of the most diverse sampled during the study. Repeat sampling over several months, including the use of artificially added leaf litter did not reveal significantly more diversity than was collected during the initial survey of the entrance areas. However, further sampling, deeper into the cave may prove productive, especially using such techniques.

Table 10. Weelawadji Cave E24 invertebrate diversity collected during April, May and June 2007.

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Arachnida	Acarina	Cunaxidae	*sp2*	14			Twilight	70
	Acarina	Trombidiidae	*sp1*	7			Transition	100
	Araneae		*sp7*	9	Tp		Deep	70
	Araneae		*sp7*	3	Tp		Deep	100
	Araneae		*sp8*	2	Tp		Transition	100
	Araneae		*sp9*	1	Tp		Transition	100
	Araneae		*sp10*	1	Tp		Transition	100
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	24	Tp	Gp	Twilight	70
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	13	Tp	Gp	Twilight	100
Crustacea	Isopoda	Philosciidae	*Laevophiloscia sp3*	7	Tp		Deep	70
	Isopoda	Philosciidae	*Laevophiloscia sp3*	9	Tp		Deep	100
Insecta	Blattodea	Blattellidae	*Neotemnopteryx douglasi*	17	Tp	Gb?	Transition	70
	Blattodea	Blattellidae	*Neotemnopteryx douglasi*	4	Tp	Gb?	Transition	100
	Coleoptera	Anobiidae	*Ptinus exulans*	23	Tp	Gp	Twilight	70
	Coleoptera	Anobiidae	*Ptinus exulans*	13	Tp	Gp	Twilight	100
	Coleoptera	Carabidae	*Speotarus lucifugus*	1	Tp	Gp	Twilight	70
	Coleoptera	Carabidae	*Speotarus lucifugus*	4	Tp	Gp	Twilight	100
	Coleoptera	Tenebrionidae	*Brises acuticornis duboulayi*	7, 2L	Tp	Gp	Twilight	70
	Coleoptera	Tenebrionidae	*Brises acuticornis duboulayi*	1, 1L	Tp	Gp	Twilight	100
	Diptera		*sp1*	1	Acc		Twilight	70
	Hymenoptera	Formicidae	*sp1*	1	Acc		Entrance	70
	Lepidoptera	Teneidae	*Monopis crocicapitella?*	1	Tp	Gb	Twilight	70
	Siphonaptera	Pucilidae	*Ctenocephalides sp1*	5	P		Twilight	100
	Thysanura	Nicoletiidae	*Nicoletiinae Trinemura sp1*	3	Tb?		Deep	70
	Thysanura	Nicoletiidae	*Nicoletiinae Trinemura sp1*	1	Tb?		Deep	100

Weelawadji West Cave shows similar fauna to the nearby Weelawadji Cave despite a considerably different entrance. The narrow solution pipe entrance results in a significantly reduced twilight zone and a greater transition zone. The smaller entrance compared with many of the Eneabba caves results in less organic matter near the entrance. The inflow of organic debris commonly serves as the most significant food source in the majority of caves. The presence of the predatory histerid beetle *Saprinus* sp. is an interesting biogeographical record for the area as this genus has been recorded intermittently across southern Australian caves and especially those associated with bat guano deposits.

Table 11. Weelawadji West Cave E52 invertebrate diversity collected during May 2007.

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Arachnida	Acarina	Cunaxidae?	*sp*	3	Tp		Transition	70
	Araneae	Lycosidae	*sp*	1	Acc		Twilight	70
	Araneae	Theridiidae	*Achaearanea sp*	1	Tp		Transition	70
Insecta	Blattodea	Blattellidae	*Neotemnopteryx douglasi*	7	Tp	Gb?	Transition	70
	Coleoptera	Histeridae	*Saprinus sp*	4	Tp	Gb	Transition	70
	Lepidoptera	Tineidae	*Monopis crocicapitella?*	2	Tp	Gb	Transition	70
	Lepidoptera		*sp*	1	Acc		Twilight	70

2.3 Invertebrate diversity of Jurien caves

Gooseberry Cave has been a very important cave historically for invertebrate biodiversity as it contains one of Western Australia's few significant bat maternity sites, and hence contains one of the states few guano associated invertebrate communities (Moulds 2006). Despite several collecting trips during the current study invertebrate diversity is low, despite significant undisturbed guano deposits. However, the relative abundance of several species including *Ptinus exulans*, *Speotarus lucifugus* and *Protochelifer cavernarum* show that the community is unlikely to be in decline and sampling after rain and/or after (but not during) birthing of bats in late October may show greater diversity (Table 12). It is strongly recommended that additional collecting/observation is conducted in this cave over several months to accurately represent the diversity that is historically recorded from this cave in published literature (Moulds 2004).

Drovers Cave shows few significant fauna (Table 13), although further collecting or an examination of historical collections may reveal the presence of such species. The most significant record from the present study is that of the Rhaphidophorid cave cricket. These obvious inhabitants of cave entrances and twilight areas through southern Australia and New Zealand show distinct regional speciation as described by Richards (1964; 1966a; 1966b; 1968; 1969; 1971) and it is reasonable to assume that records of the family from coastal western Australia represent a new species and/or genus.

Table 12. Gooseberry Cave J1 invertebrate diversity collected during April and June 2007.

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Arachnida	Acarina	Cunaxidae	*sp1*	1			Transition	70
	Acarina	Cunaxidae	*sp2*	4			Transition	70
	Acarina	Trombidiidae	*sp1*	1			Transition	70
	Acarina	Trombidiidae	*sp1*	1			Transition	100
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	8	Tp	Gp	Twilight	70
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	3	Tp	Gp	Twilight	100
Insecta	Coleoptera	Anobiidae	*Ptinus exulans*	33	Tp	Gp	Twilight	70
	Coleoptera	Carabidae	*Speotarus lucifugus*	5, 1L	Tp	Gp	Twilight	70
	Coleoptera	Carabidae	*Speotarus lucifugus*	3	Tp	Gp	Twilight	100
	Diptera	Phoridae	*sp1*	1	Tp	Gp	Transition	100
	Pscoptera	Trogiidae	*sp1*	1	Tp		Transition	70

Table 13. Drovers Caver J2 invertebrate diversity collected during April 2007.

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Arachnida	Acarina	Cunaxidae	*sp1*	1			Transition	70
	Araneae		*sp3*	1			Twilight	70
	Opilionida		*sp1*	1	Tp	Gx	Transition	70
Myriapoda	Chilopoda		*sp1*	1			Transition	70
Hexapoda	Collembola	Entomobryidae	*sp2*	3	Tp		Transition	70
Insecta	Blattodea	Blattellidae	*Neotemnopteryx douglasi*	5	Tp	Gb?	Transition	70
	Hemiptera	Reduviidae	Harpactorinae *sp2*	1	Tp	Gx	Transition	70
	Orthoptera	Rhaphidophoridae	*Gen. nov. and sp. nov.?*	1F	Tx	Gx	Twilight	70

Moorba Cave shows low invertebrate diversity (Table 14), although it does contain at least two species of Philosciid isopod that are relatively diverse and locally endemic throughout the region. The complete lack of insects collected during the current fieldwork suggest that collecting effort was not great enough to provide a reasonable assessment of this cave using the current data alone.

Table 14. Moorba Cave J3 invertebrate diversity collected during April 2007.

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Arachnida	Acarina	Cunaxidae	*sp2*	6			Transition	70
	Araneae	Theridiidae	*sp1*	2			Transition	70
	Araneae	Theridiidae	*sp2*	1			Twilight	70
	Araneae		*sp1*	1			Twilight	70
	Opilionida		*sp1*	1	Tp	Gx	Transition	70
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	4	Tp	Gp	Twilight	70
Crustacea	Isopoda	Philosciidae	*Laevophiloscia sp1*	4	Tp	Gx	Twilight	70
	Isopoda	Philosciidae	*Laevophiloscia sp2*	1	Tp	Gx	Twilight	70

The final cave examined during April 2007 was Old River Cave and the collection from this site show significant diversity of isopods and a further record of the Rhaphidophorid cave cricket making it potentially important in a local diversity sense and also potentially at a regional scale (Table 15).

Table 15. Old River Cave J7 invertebrate diversity collected during April 2007.

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Arachnida	Acarina	Cunaxidae	*sp3*	2			Transition	70
	Araneae	Theridiidae	*Lactrodectus hasselti*	1	Tx		Entrance	70
	Araneae		*sp3*	2			Twilight	70
Crustacea	Isopoda	Philosciidae	*Laevophiloscia sp1*	6	Tp	Gx	Transition	70
	Isopoda	Philosciidae	*Laevophiloscia sp2*	2	Tp	Gx	Twilight	70
	Isopoda	Philosciidae	*Philosciidae sp1*	2	Tp	Gx	Twilight	70
	Isopoda	Philosciidae	*Philosciidae sp2*	3	Tp	Gx	Twilight	70
Insecta	Orthoptera	Rhaphidophoridae	*Gen. nov. and sp. nov.?*	1	Tx	Gx	Twilight	70

2.4 Invertebrate diversity of South Hill (Nambung) caves

The South Hill River karst area is located within the Nambung National Park, south of Cervantes. The nature of the caves examined during the present study is significantly different to those from the Jurien and Eneabba karst areas to the north with small solution pipe entrances, commonly leading to large single chamber caves. This results in much greater proportions of the caves being in the deep and transition zone, with much reduced entrance and twilight zones (Figure 1). This leads to greater environmental stability within much of the dark zone of the caves in the Nambung area and commonly higher humidity. The presence of tree roots entering the deep zone of many of the caves in this karst area also adds an important food source to these caves, which combined with stable humidity and temperature provides a favourable habitat for troglobites.

The invertebrate diversity of Weston Cave (Table 16) is significant for the area, with several spider genera present. The genus *Baiami* Lehtinen is an important record as this genus is found in caves from the south-west of WA and is closely related to the troglobitic genus *Tartarus* Gray on the Nullarbor Plain. *Baiami* spp are recorded from the twilight and transition zones of many caves within the Nambung region, although the species level diversity is presently unknown.

Table 16. Weston Cave (SH2) invertebrate diversity collected during June 2007

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Arachnida	Acarina	Trombidiidae	sp1	1				70
	Araneae	Stiphidiidae	Baiami	3	Tp		Transition	70
	Araneae	Stiphidiidae	Baiami	2	Tp		Transition	100
	Araneae	Theridiidae	sp1	2	Tp		Transition	70
	Araneae		*sp*	6	Tp		Transition	70
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	2	Tp	Gp	Twilight	70
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	2	Tp	Gp	Twilight	100
Myriapoda	Chilopoda	Scutigeridae	*Allothereua lesueurii*	1	Tp		Transition	70
Insecta	Diptera	Sciaridae?	sp	1	Tp	Gp?	Transition	70
	Lepidoptera	Tineidae	*Monopis crocicapitella*	1	Tp	Gb?	Transition	70

Table 17. Thousand Man Cave (SH7) invertebrate diversity collected during June 2007

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Arachnida	Araneae		*sp*	2	Tp		Transition	70
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	7	Tp	Gp	Twilight	70
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	2	Tp	Gp	Twilight	100
Crustacea	Isopoda	Philosciidae	*Laevophiloscia sp*	8	Tp		Twilight	70
	Isopoda	Philosciidae	*Laevophiloscia sp*	3	Tp		Twilight	100
	Isopoda	Armadillidae	*sp1*	1	Tx		Twilight	70
Insecta	Coleoptera	Elatridae	sp	1	Acc		Twilight	70
	Hymenoptera	Formicidae	sp	1	Acc		Twilight	70
	Lepidoptera		*sp*	1	Acc		Twilight	70

The large single chamber of Thousand Man Cave (SH7) is dominated by a wide sediment floor as a result of flood inflow from the cave entrance. This is the dominant energy input for this cave. The solid gate presently on the cave, combined with the significant alteration of the cave mouth, originally low and wide at the break of slope in a large doline, has resulted in considerably reduced organic input into this cave. This is undoubtedly having an impact on the populations of invertebrate fauna within the deep zone of Weston Cave (Table 17).

Pretty Cave is one of the most diverse caves within the Nambung area (Table 18) reflecting the presence of organic inflows and large amounts of roots penetrating the roof. The most significant record from this cave is the troglobitic cockroach similar to *Neotemnopteryx douglasi*, but completely lacks eyespots. This almost certainly represents an undescribed species, most probably endemic to the Nambung karst. A detailed morphological and/or molecular study would determine the relationship between this species and *Neotemnopteryx douglasi* which occurs throughout the NAR karst areas examined during the present survey (Table 4).

The invertebrate diversity of Quandong Cave (Table 19) is low, with the majority of specimens collected from the twilight area directly below the gate. The lack of humidity and drips within the deep zone of the cave restricts the amount of fauna. This is also the case for Brown Bone Cave (Table 20) although the presence of several species of stygofauna within the permanent stream at the end of the cave makes this cave significant in a regional context. Stygofauna specimens have not been examined as part of this report but are likely to be regionally significant with a possible range extensions of an amphipod species, and the presence of syncarids, copepods and dytiscids (R. Susac, pers. comm. June 2007).

Table 18. Pretty Cave (SH9) invertebrate diversity collected during June 2007

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Arachnida	Araneae	Theridiidae	*sp*	2	Tp		Transition	70
	Araneae		*sp1*	2	Tp		Transition	70
	Araneae		*sp2*	1	Tp		Transition	70
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	7	Tp	Gp	Twilight	70
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	2	Tp	Gp	Twilight	100
Myriapoda	Chilopoda	Scutigeridae	*Allothereua lesueurii*	2	Tp		Deep	70
Gastropoda	Pulmonata		*sp* (shell only)	4	Acc		Twilight	70
Crustacea	Isopoda	Philosciidae	*Laevophiloscia sp*	12	Tp		Transition	70
	Isopoda	Philosciidae	*Laevophiloscia sp*	1	Tp		Transition	100
	Isopoda	Armadillidae	*sp1*	1	Tx		Twilight	70
Insecta	Blattodea	Blattellidae	*Neotomnopteryx sp cf. 'douglasi'*	3	Tb	Gx	Deep	70
	Blattodea	Blattellidae	*Neotomnopteryx sp cf. 'douglasi'*	1	Tb	Gx	Deep	100
	Orthoptera	Gryllidae	sp	1	Tp?		Twilight	70
	Lepidoptera		*sp*	1L	Acc?		Twilight	70

Table 19. Quandong Cave (SH12) invertebrate diversity collected during June 2007

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Arachnida	Araneae	Stiphidiidae	Baiami	1	Tp		Transition	70
	Araneae		sp1	2	Tp		Transition	70
	Araneae		*sp3*	4	Tp		Transition	70
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	5	Tp	Gp	Twilight	70
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	5	Tp	Gp	Twilight	100
Crustacea	Isopoda	Philosciidae	*Laevophiloscia sp*	5	Tp		Transition	100

Table 20. Brown Bone Cave (SH17) invertebrate diversity collected during June 2007

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Arachnida	Araneae	Stiphidiidae	Baiami	1	Tp		Transition	70
Myriapoda	Chilopoda	Scutigeridae	*Allothereua lesueurii*	1	Tp		Deep	100
Crustacea	Isopoda	Philosciidae	*Laevophiloscia sp*	3	Tp		Transition	100
Insecta	Blattodea	Blattellidae	*Neotomnopteryx douglasi*	1	Tp	Gx	Deep	100
	Diptera	Sciaridae?	*sp*	1	Tp	Gp	Deep	70

Cadda Cave (SH18) is another diverse cave for the Nambung area, although it contains a similar to fauna to that found in nearby caves such as Weston and Quandong (Table 21). One significant aspect of Cadda Cave is the troglobitic meenopliid planthopper. These small (1-3 mm) white planthoppers are found near drip holes and roots, upon which they feed on sap. Troglobitic planthoppers have been found in many karst areas in Australia and this undescribed species will have interesting evolutionary significance from a national context. Troglobitic meenopliids are known from the Cape Range WA (Humphreys 1998), Chillagoe QLD (Hoch and Howarth 1989; Soulier-Perkins 2005), Bullita Cave NT (T. Moulds unpublished data) and Yarrangobilly Caves NSW (Hoch and Asche 1988).

Table 21. Cadda Cave (SH18) invertebrate diversity collected during June 2007

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Arachnida	Araneae	Stiphidiidae	*Baiami sp*	8	Tp		Deep	70
	Araneae	Stiphidiidae	*Baiami sp*	2	Tp		Deep	100
	Araneae	Theridiidae	*Achaearanea? sp*	2	Tp		Transition	100
	Araneae	Theridiidae	*sp*	4	Tp		Deep	100
	Araneae		*sp*	13	Tp		Transition	70
	Pseudoscorpionida	Cheliferidae	*Protochelifer cavernarum*	4	Tp	Gp	Transition	70
Myriapoda	Chilopoda	Scutigeridae	*Allothereua lesueurii*	1	Tp		Deep	100
Crustacea	Isopoda	Philosciidae	*Laevophiloscia sp*	7	Tp		Deep	100
Insecta	Blattodea	Blattellidae	*Neotomnopteryx douglasi*	3	Tp	Gx	Deep	100
	Coleoptera	Carabidae	*sp*	1	Tp		Transition	70
	Diptera	Sciaridae?	*sp*	1	Tp	Gp	Deep	100
	Hemiptera	Meenopliidae	sp1	6	Tb		Deep	70

Table 22. Tick Cave (SH20) invertebrate diversity collected during June 2007

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Arachnida	Araneae	Stiphidiidae	*Baiami sp*	8	Tp		Deep	70
	Araneae		*sp*	5	Tp		Deep	100
Crustacea	Isopoda	Philosciidae	*Laevophiloscia sp*	3	Tp		Deep	100
		Armadillidae	*sp*	5	Tp		Deep	70
		Armadillidae	*sp*	15	Tp		Deep	100
Hexapoda	Diplura	Japygidae	*sp*	1	Tp		Deep	70
Insecta	Blattodea	Blattellidae	*Neotomnopteryx douglasi*	1	Tp	Gx	Deep	100
	Coleoptera	Carabidae	*Lecanomerus ? sp*	1	Tp	Gp?	Deep	70
	Coleoptera	Carabidae	*sp*	2	Acc		Transition	70
	Hemiptera	Meenopliidae	sp1	6	Tb		Deep	70
	Hemiptera	Meenopliidae	sp1	1	Tb		Deep	100

Tick Cave (SH20) also contains the troglobitic meenopliid species found in Cadda Cave and Pulchella Cave (Table 22). This cave also contains a potentially important record of the carabid beetle *Lecanomerus*? sp. that is recorded across southern Australia, including a cave dwelling species *L. speluncaris* from the Nullarbor Plain and *L. flavocinctus* from Eneabba, although this specimen appears distinct and possibly troglomorphic. Tick Cave is an important fauna cave due to its restricted entrance, high humidity and large volume of root material deep into the cave. This cave would benefit from further collecting including active trapping as further troglomorphic species are likely to be collected.

Pulchella Cave is one of the most important caves in the Nambung area for invertebrate biodiversity as it contains at least two troglobitic species, the meenopliid planthopper and a Harpactorinae reduviid assassin bug (Table 23). The reduviid bug is pale yellow to white and shows elongation of appendages and reduced eyes. This is almost certainly an undescribed species and most likely restricted to the stable temperature and humidity of Pulchella Cave. Specimens of both the planthopper and reduviid were collected in association on or near moist root masses growing form the floor of the cave in the main chamber near active dripping stalactites. Specimens of *Baiami* were also found in association with these species, and husks of planthoppers and *Laevophiloscia* spp. Isopods were observed in the webs of these spiders. The highly constricted entrance of Pulchella aids in maintaining high humidity within the main chamber that supports this diverse troglomorphic invertebrate community. This community is susceptible to disturbance by cavers and access to this cave should continue to be restricted to protect this highly significant invertebrate community and to avoid damage to the highly decorated chamber itself.

Table 23. Pulchella Cave (SH38) invertebrate diversity collected during June 2007

Class	Order	Family	Genus and Species	Number	Cave adaption	Guano Dependence	Cave Zone	Ethanol percentage
Tubellaria	Unknown		sp	10	Tp?		Twilight	70
Arachnida	Araneae	Stiphidiidae	*Baiami sp*	1	Tp		Transition	70
	Araneae	Stiphidiidae	*Baiami sp*	1	Tp		Transition	100
	Araneae		*sp1*	4	Tp		Transition	70
	Araneae		*sp2*	3	Tp		Deep	70
	Araneae		*sp3*	3	Tp		Deep	70
	Araneae		*sp4*	3	Tp		Deep	70
	Araneae		*sp5*	2	Tp		Deep	70
	Araneae		*sp6*	1	Tp		Deep	70
	Araneae		*sp*	1	Tp		Deep	100
Crustacea	Isopoda	Philosciidae	*Laevophiloscia sp*	11	Tp		Deep	70
	Isopoda	Philosciidae	*Laevophiloscia sp*	8	Tp		Deep	100
	Isopoda	Armadillidae	*sp*	1	Tp		Transition	70
Gastropoda	Pulmonata		*sp*	2	Acc		Twilight	70
Myriapoda	Chilopoda	Scutigeridae	*Allothereua lesueurii*	1	Tp		Transition	70
	Diplopoda	Polydesmidae		1	Tp		Transition	70
Insecta	Blattodea	Blattellidae	*Neotomnopteryx douglasi*	2	Tp	Gx	Deep	100
	Coleoptera	Anobiidae	*Ptinus exulans*	1	Tp	Gp	Transition	70
	Coleoptera	Carabidae	*sp*	1	Acc		Transition	70
	Coleoptera	Carabidae	*sp*	1	Acc		Transition	100
	Hemiptera	Meenopliidae	sp1	11	Tb		Deep	70
	Hemiptera	Meenopliidae	sp1	4	Tb		Deep	100
	Hymenoptera	Formicidae	sp	1	Acc		Twilight	70

3.1 Comments on specific taxa collected from NAR Karst Areas

Pseudoscorpionida: *Protochelifer cavernarum*

The Cheliferid pseudoscorpion *Protochelifer cavernarum* shows a distribution across southern Australia and up the eastern seaboard (Moulds 2004; Moulds *et al.* 2007). This species is commonly associated with cave guano deposits. The type locality for this species is Cliefden Caves. Recent molecular investigations (Moulds *et al.* 2007) of several populations of *P. cavernarum* on the Nullarbor Plain have shown that separate caves contain genetically distinct "species" although no formal designations were made. Preliminary morphological investigations also revealed distinct differences between populations across southern Australia. It is therefore highly likely that the populations of *P. cavernarum* from the caves of Eneabba and Jurien Karst areas represent a distinct undescribed species of *Protochelifer*. This is highly significant as until further detailed investigations are undertaken into the many populations present in the study area it can not be ruled out that each cave population may represent a separate, possibly locally endemic species.

Crustacea: *Laevophiloscia* spp.

Diversity of Philosciid isopods is high within the Eneabba and Jurien karst areas as shown by Vandel (Vandel 1973). Vandel identifies numerous locally endemic species of *Laevophiloscia* that have been collected from almost every cave examined in the present study. These specimens have nominally been identified as morpho-species as dissections of pleuropods are required to accurately identify many of these taxa to species level and it was considered counter productive and unnecessary to attempt this in the time available for this study as the distribution of these species has been accurately accounted for in historical records such as (Lowry 1980; Lowry 1996).

Blattodea: Neotemnopteryx douglasi

The distribution of the troglophilic cockroach *Neotemnopteryx douglasi* shows a significant disjunction, with records from the Eneabba/Jurien karst areas on the west coast of Western Australia and records from karst in northern New South Wales on Australia’s east coast. This may represent a true distribution for the species or it may actually comprise two species or even genera. The local populations in Eneabba and Jurien are healthy with numerous individuals being collected and many more observed, especially in the transition zone of Weelawadji Cave associated with fresh bat guano. The populations of this species in Eneabba and Jurien must be considered to be genetically distinct from those of the east coast and therefore require maintained conservation attention to ensure their continued populations as they may prove locally endemic and thus significant from a biodiversity perspective.

Hemiptera: Meenoplidae

This small troglobitic species of planthopper found in Cadda, Tick and Pulchella caves is highly significant for the NAR karst areas. This species will show extremely interesting relationships with other meenopliid planthoppers in Australia and represents a major range extension for subterranean records of this family in Australia, with the closest subterranean relative being in the Cape Range WA. Further examination of this species will determine its position within the evolution of this family in Australia and molecular data will possibly provide an estimate of time since subterranean colonisation of the Nambung karst.

Hemiptera: Reduviidae: Harpactorinae

The presence of Harpactorinae reduviids in all three areas examined is significant as they are almost certainly all new troglophilic/troglobitic records and also likely to be range extensions. The troglobitic species collected from Pulchella Cave is a very important record for the cave and the region at large as very few troglobitic reduviids are known in Australia, although this is likely to increase with further investigation.

Tenebrionidae: *Brises acuticornis duboulayi*

The large and conspicuous tenebrionid beetle *Brises acuticornis duboulayi* represents a subspecies of this generally central Australian, arid associated species (Mathews 1986). The presence of *B. a. duboulayi* in Weelawadji Cave is a range extension from more arid and inland records (Cue, Western Australia), although it has been recorded from undisclosed coastal areas near Shark Bay (Mathews 1986).

Thysanura: Nicoletiinae: *Trinemura sp*.

The collection of blind silverfish specimens from the deep cave zone of Weelawadji Cave is one of the most significant outcomes of the current fieldwork. All known Australian members of the Nicoletiinae belong to the genus *Trinemura* whose species are all depigmented and blind as they inhabit the subsoil biome (Smith 1988). Several other *Trinemura* species have been recorded from the deep cave zone in New South Wales (Bungonia Caves) and South Australia (Kelly Hill Caves, Kangaroo Island), although only the species from Bungonia is regarded as a troglobite. Detailed morphological examination of these specimens by an appropriate taxonomic expert (e.g. G.B. Smith) will determine if they are indeed a cavernicolous evolved species. Regardless of this, the presence of this genus is an important addition to the invertebrate diversity of the local region.

4.1 Future work and recommendations

The current study has provided a current assessment of population levels of previously recorded invertebrate species as well as increasing the diversity of some lesser collected caves in the area. The collection of specimens in 100% ethanol will also allow for future genetic assessment of taxa.

Future assessments should focus on collecting in some of the lesser collected caves in the area. Comparing the distribution of species from literature records with the current collecting will also enable identification of new species records and local range extensions within karst areas. Further collaboration with the Western Australian Museum including the provision of seed funding to enable detailed investigation of target groups for morphological and/or molecular analysis will yield significant results, and ultimately a greater understanding of the invertebrate diversity of these important karst areas in a state and national context. Groups which would benefit from more detailed examination are the pseudoscorpion *Protochelifer cavernarum*, the spider *Baiami*, the isopod *Laevophiloscia* and the meenoplid species.

The style of gates, and general entrance modification associated with the installation of gates should also be considered in future cave management. Installation of solid gates restrict natural inflow of water and associated organic sediments that provide the energy base for invertebrate communities. The maintenance of cave gates is also important as considerable amounts of rust were found in the deep zone of several caves that could potentially have an adverse impact on fragile invertebrate communities. In future, the use of materials such as stainless steel should be considered for cave gate construction to avoid potential impacts.

The use of trapping, both active and passive, should also be considered for assessing the potential for previously unknown troglobitic in the deep zone of the larger caves. This could include the use of pitfall traps, leaf litter traps and samples extracted through tullgren funnels. The use of trapping in the deep zone will provide a significantly more thorough assessment of these habitats where hand collecting is extremely opportunistic due to the very low populations of most troglobitic species. Future collecting should also take into account seasonal variation in populations, especially those linked to large scale rain events as many of the caves sampled are semi active streams.

5.1 References

Gnaspini, P. and Trajano, E. (2000). Guano communities in tropical caves. *Ecosystems of the world. Subterranean ecosystems*. Wilkens, H., Culver, D. C. and Humphreys, W. F. Amsterdam, Elsevier. **30:** 251-268.

Hamilton-Smith, E. (1967). The Arthropoda of Australian caves. *Journal of the Australian Entomological Society* **6**: 103-118.

Hoch, H. and Asche, M. (1988). Cave-dwelling planthoppers of Australia (Insecta: Homoptera: Fulgoroidea). *Proceedings of the 17th Australian Speleological Federation Tropicon Conference*, Lake Tinaroo, Far North Queensland, Australian Spelological Federation.

Hoch, H. and Howarth, F. G. (1989). Reductive evolutionary trends in two new cavernicolous species of a new Australian cixiid genus (Homoptera: Fulgoroidea). *Systematic Entomology* **14**: 179-196.

Howarth, F. G. and Stone, F. D. (1990). Elevated carbon dioxide levels in Bayliss Cave, Australia: Implications for the evolution of obligate cave species. *Pacific Science* **44**(3): 207-218.

Humphreys, W. F. (1998). *Phaconeura* (Homoptera: Meenoplidae) attended by ants of the genus *Paratrechina* (Hymenoptera: Formicidae) in caves. *The Australian Entomologist* **25**: 23-27.

Humphreys, W. F. (2000). Background and glossary. *Ecosystems of the world. Subterranean ecosystems*. Wilkens, H., Culver, D. C. and Humphreys, W. F. Amsterdam, Elsevier. **30:** 3-14.

Lowry, J. W. J. (1980). Ecological Relationships of Western Australian Cavernicoles. School of Zoology. Sydney, University of New South Wales**:** Vol. 1 pp367, Vol. 362 204 pp. + appendices.

Lowry, J. W. J. (1996). Fauna found in Arramall River, Weelawadji and the Stockyard Gully Caves., http://wasg.iinet.net.au/eneabba.html. **2003**.

Mathews, E. G. (1986). A revision of the troglophilic genus *Brises* Pascoe, with a discussion of the Cyphaleini (Coleoptera: Tenebrionidae). *Records of the South Australian Museum* **19**(6): 77-90.

Moulds, T. A. (2004). Review of Australian cave guano ecosystems with a checklist of guano invertebrates. *Proceedings of the Linnean Society of New South Wales* **125**: 1-42.

Moulds, T. A. (2006). The seasonality, diversity and ecology of cavernicolous guano dependent arthropod ecosystems in southern Australia. Department of Environmental Biology. Adelaide, The University of Adelaide**:** 260.

Moulds, T. A., Murphy, N., Adams, M., Reardon, T. B., Harvey, M. S., Jennings, J. and Austin, A. D. (2007). Phylogeography of cave pseudoscorpions in southern Australia. *Journal of Biogeography* **34**(6): 951-962.

Richards, A. M. (1964). The Rhaphidophoridae (Orthoptera) of Australia 1. Tasmania. *Pacific insects* **6**: 217-223.

Richards, A. M. (1966a). The Rhaphidophoridae (Orthoptera) of Australia 3. A new genus from south-eastern Australia. *Pacific insects* **8**: 617-628.

Richards, A. M. (1966b). The Rhaphidophoridae (Orthoptera) of Australia 4. A new genus from South Australia. *Proceedings of the Linnean Society of NSW* **91**(2): 109-113.

Richards, A. M. (1968). The Rhaphidophoridae (Orthoptera) of Australia. Part 7. A new genus from the Nullarbor Plain, south-western Australia. *Proceedings of the Linnean Society of New South Wales* **93**(1): 46-51.

Richards, A. M. (1969). The Rhaphidophoridae (Orthoptera) of Australia. Part 8. Two new species of Parvotettix Richards. *Pacific insects* **12**(1): 1-8.

Richards, A. M. (1971). The Rhaphidophoridae (Orthoptera) of Australia. Part 10. A new genus from southeatern Tasmania with New Zealand affinities. *Pacific insects* **13**(3-4): 589-595.

Smith, G. (1988). New species of *Trinemura* Silvestri (Thysanura: Nicoletiidae) from Australia. *Journal of the Australian Entomological Society* **27**: 47-52.

Soulier-Perkins, A. (2005). Phylogenetic evidence for multiple invasions and speciation in caves: the Australian planthopper genus *Solonaima* (Hemiptera: Fulgoromorpha: Cixiidae). *Systematic Entomology* **30**: 281-288.

Vandel, A. (1973). Les Isopodes terredtres de l'Australie etude systematique et biogeographique. *Mem. Mus. Natl. Hist. Nat. Paris* **82**: 1-171.