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Systematic composition and distribution of Australian cave collembolan faunas with notes on exotic taxa

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Abstract

Collembola (springtails) have been collected from caves in Tasmania, northwestern Western Australia, Victoria, New South Wales and Queensland more intensively in recent years than in the past. A sharp boundary in the composition of faunas of southern and northern Australia was found with the highest diversity of troglobitic forms in southeastern Australia and Tasmania. No extreme examples of troglobitic genera have yet been found in Western Australia. A single record of *Cyphoderopsis* was made from Christmas Island in the Indian Ocean, a common genus in caves in Sumatra. The Jenolan cave system has been most completely sampled with nearly 100 samples from fourteen caves. This system contains over twenty species of which three genera, *Adelphoderia, Oncopodura* and a new genus near *Kenyura*, are exclusively troglobitic with locally endemic species of conservation and phylogenetic interest. Compared with some Tasmanian caves, the Jenolan fauna appears to harbour more species that are likely to have been introduced.

Keywords: Collembola; caves; Australia; distribution.

Introduction

Australia has extensive cave-containing karst areas in carbonate rocks in all states. However, few karst areas have been systematically sampled for Collembola, Tasmania and eastern New South Wales being exceptions. Jenolan, in New South Wales, is currently the most intensively sampled cave system (Greenslade 1989) but Collembola have also been collected more widely from caves in New South Wales by Eberhard (1993a) Eberhard & Spate (1995) and from Tasmania by Eberhard *et al*. (1991) and Clarke (1997). In Western Australia, a number of collections from caves were made by Lowry in the 1970's but her records remain unpublished.

The first record of a springtail from Australian caves was made by Rainbow (1907) who described *Isotoma troglodytica* from the surface of pools in Yarrangobilly Caves in New South Wales. This species was subsequently shown to be a synonym of *Proisotoma minuta* (Axelson) by Womersley (1934). The first record from Jenolan was by Richards & Lane (1966) who recorded *Lepidosinella armata* Handschin, identified by J. T. Salmon, from the Indian Chamber of the Orient Cave. This species was otherwise known only from termite mounds in Java (Yosii, 1989). The Jenolan specimens seen by Salmon were subsequently identified as *Sinella* (*Coecobrya*) sp. (Greenslade, 1992). It is here recorded as *S.* (*C.*) *communis* Chen and Christiansen and is considered an exotic introduction. Richards & Lane (1966) also noted a record of what were probably Collembola on Lot's Wife, a stalagmite, also in Imperial Cave, but a few hundred metres from the site at which *L. armata* was found. Since then there have been no taxonomic studies on Australian cave Collembola although a number of collectors have been active, and produced several reports, notably Gibian, Smith & Wheeler (1988) and Eberhard (1993a, b), Eberhard and Spate (1995), Eberhard *et al.* (1991), Clarke (1997). Greenslade (1991) provides further information on the morphology, taxonomy, ecology and distribution of Australian Collembola. The ecology, adaptations and taxonomy of cave collembolan faunas from Europe, North America and Asia have been reported by Thibaud,1994, Christiansen, 1982 and Deharveng and Bedos, 2000 respectively.

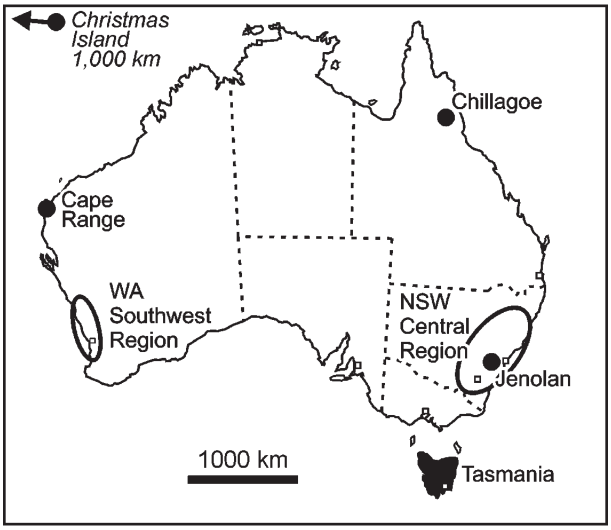

Figure 1. Map showing localities from which collections of cave Collembola are recorded.

Methods

Material from collections made available to me by J.K. Lowry (from Western Australia), A. Clarke (from Tasmania), S. Eberhard (both Tasmania and New South Wales), G. Smith, M. Gibian (both from New South

Table 1. Genera recorded from Australian caves per State

Including troglobites, troglophiles, and trogloxenes (terminology of Massoud and Thibaud, 1973). Genera with exotic species are in **bold** and ★ denotes exclusively troglobitic genera or those known to contain troglobitic species

WA – Western Australia; NSW – New South Wales; TAS – Tasmania; QLD – Queensland.

Neanuridae				
Subclavontella		NSW		
Odontella		NSW		
Ceratrimeria		NSW		
Lobellini	WA	NSW		
Australonura		NSW	TAS	
Pseudachorudina			TAS	
Pseudachorutes			TAS	
Megalanura			TAS	
Womersleymeria			TAS	
★n. gen. nr *Kenyura*		NSW		
Brachystomellidae				
Setanodosa	WA			
Brachystomella	WA			
n. gen.			TAS	
Hypogastruridae				
Triacanthella		NSW		
Ceratophysella		NSW		
Hypogastrura			TAS	
Mesogastrura		NSW		
Xenylla			TAS	
Onychiuridae				
Tullbergia	WA	NSW	TAS	
Mesaphorura		NSW	TAS	
Onychiurus		NSW		
Dinaphorura		NSW		
Isotomidae				
Folsomina	WA			
Folsomia		NSW		
Cryptopygus	WA	NSW		
Isotoma (*Isotoma*)	WA	NSW		
Isotoma (*Parisotoma*)		NSW	TAS	
Isotomodes	WA			
Folsomides	WA	NSW		
Entomobryidae				
Entomobrya	WA			
Drepanura	WA			
★*Sinella (Coecobrya)*	WA	NSW	TAS	QLD
Lepidosira	WA			
★*Pseudosinella*	WA		TAS	QLD
Willowsia	WA			
Lepidocyrtoides	WA	NSW		
Lepidocyrtus	WA	NSW		
Ascocyrtus		NSW		
Tomoceridae				
Lepidophorella			TAS	
Novacerus			TAS	
Paronellidae				
cf. Salina		NSW		
Paronellides		NSW		
★*Cyphoderopsis*	WA			
★n. gen. nr *Troglopedetes*			TAS	
Oncopoduridae				
★*Oncopodura*		NSW	TAS	
Sminthuridae				
★***Arrhopalites***		NSW	TAS	
★*Adelphoderia*		NSW	TAS	
Neelidae				
Temeritas		NSW		
Megalothorax		NSW	TAS	
Neelides			TAS	

Wales) and F. Howarth (from Queensland) have been used in this study. Collecting methods and sites were predominantly made by hand from the surface of pools, from rock walls, stalagmites and other surfaces, but some Tullgren funnel extractions were also taken from guano and flood debris—mainly leaf litter. A few pitfall traps, baited with arthropod remains, were operated briefly. All specimens were identified to genus and, where possible to species, but many species that have been collected remain undescribed.

Collections from seven karst areas, representing a latitudinal transect across Australia from north to south, were selected for comparison. These localities with their latitudes are listed in Table 3 and shown on Figure 1. All genera that contained endemic, troglobitic species likely to be locally endemic in these seven karst areas were noted.

The most complete information on any single karst area is that from Jenolan caves, which was intensively sampled between 1986 and 1989 by G. Smith, M. Gibian and other collectors and by S. Eberhard in 1993. The Jenolan collections, which consist of nearly 100 samples from fourteen caves, and the Collembola identified from them, are listed in detail in an unpublished report (Greenslade 1989) and a summary of that report is given here (Table 2).

All the material, including most of the material from Jenolan, is lodged in the collections of the South Australian Museum, Adelaide, and in the Australian National Insect Collection. A small amount of material, collected before 1970, is deposited in the Te Papa Museum (Wellington) or in the Australian Museum (Sydney).

Table 2. Species list of Collembola from Jenolan Caves

Abundance of individuals: + = 1-5, ++ = 6-20, +++ = 21-50, ++++ = 51-200, +++++ = >200.
Ecological type: Tb = troglobite (troglobiont), Tp = troglophile, Ta = transient.
★Both *Ceratophysella* species were recorded but not distinguished in most collections. The data for the two species is therefore combined.

Family Species	No. of Records	No. of Individuals	Ecological Type
Neanuridae			
Neanura muscorum Templeton	3	++	Ta
Brachystomella sp.	3	++	Ta
Subclavontella sp.	1	+	Ta
Odontella sp. 1	1	+	Ta
Odontella sp. 2	1	+	Ta
Odontella sp. 3	1	+	Ta
n.gen. nr *Odontella* sp.	1	++	Ta
Ceratrimeria sp.	1	++	Ta
Australonura nr *meridionalis* Stach	3	++	Tp
Lobellini sp.	2	+	Tp
n. gen nr. *Kenyura* n.sp.	2	++	Tb
Onychiuridae			
Onychiurus sp.	13	+++++	Tp
Tullbergia sp.	4	++	Tp
Mesaphorura krausbaueri Börner group	5	+++	Tp
Dinaphorura sp	3	+	Tp
Hypogastruridae			
Triacanthella sp.	3	+	Ta
Ceratophysella denticulata (Bagnall) *Ceratophysella gibbosa* (Bagnall)	13★	+++++	Ta
Mesogastrura libyca (Caroli)	1	+	Tp
Isotomidae			
Isotoma sp.	1	+	Ta
Parisotoma sp.	1	+	Ta
cf. *Cryptopygus* sp.	1	+	Ta
Folsomides exiguus Folsom	1	+	Ta
Folsomia candida Willem	22	+++	Tp
Cryptopygus caecus Wahlgren	1	+	Ta
Entomobryidae			
Sinella (Coecobrya) communis Chen and Christiansen	6	++	Tb
Lepidocyrtus sp. imm.	3	+	Ta
Ascocyrtus cinctus (Schäffer)	1	+	Ta
Oncopoduridae			
Oncopodura sp.	11	+++	Tb
Neelidae			
Megalothorax sp.	1	+	Tp
Sminthuridae			
Temeritas imm	1	+	Ta
Adelphoderia sp.	30	+++	Tb
Arrhopalites sp.	1	+	Tp
Indet. imm. Sminthuridae	1	+	Ta

Results

Table 1 lists all genera, or tribe in one case, found in Australian collections from caves that have been studied so far from four States. Many of the genera also occur in ground-surface habitats such as leaf litter or more commonly in soil (Greenslade, 1994). Several troglobitic genera of interest have been recorded. As in the northern hemisphere, species of *Oncopodura* are common in caves but in Australia this genus is only found in the south eastern part of the continent and in Tasmania. Species in this genus have also been found in leaf litter in temperate *Nothofagus* rainforests (Greenslade, unpubl.). Two troglobitic genera of Paronellidae have been found. One is a new genus near *Troglopedetes* with two species in Tasmanian caves, one of which is highly cave adapted. The other is a species of *Cyphoderopsis* from a cave on Christmas Island which is a Commonwealth Territory in the Indian Ocean. This genus is common in caves of south east Asia including Sumatra (Deharveng, 1987; pers. comm.). A number of undescribed cave-adapted species of *Adelphoderia* have been collected from caves in southeastern Australia including Tasmania. This genus is currently only known from one described species, again from temperate *Nothofagus* rainforest, although another undescribed species has recently been collected from montane tropical rainforest litter in Queensland (P. Greenslade, unpubl.). Palacios-Vargas (1999) recently described a new genus and species belonging to the same small subfamily, the Spinothecinae, from caves in Argentina. No troglobitic genera have yet been collected from Western Australia and all genera recorded from that State also occur in eastern Australia (Greenslade, 1994). In the Northern Hemisphere, the genus *Arrhopalites* is relatively common in caves but it is very rarely encountered in Australia but it is not currently known whether troglobitic species occur here although two cosmopolitan species have been recorded, *Arrhopalites caecus* (Tullberg,1871) and *Arrhopalites pygmaeus* (Wankel,1860) (Greenslade, 1994). It appears that *Arrhopalites* is replaced by *Adelphoderia* in the southern hemisphere.

In Table 2, the species recorded from all collections from Jenolan caves are listed together with their ecological type using the classification of Massoud & Thibaud (1973) and Vannier & Thibaud (1986) where transient equates to accidental species. The number of records and approximate number of individuals of each species is given. Genera which are believed to have exclusively or predominantly introduced species in Australian faunas are marked in Table 1. The Jenolan species of most conserva-

Table 3. Distribution of troglobitic genera of Collembola in selected karst regions in Australia along a latitudinal gradient

Location	**Christmas Is.**	**Chillagoe**	**Cape Range**	**WA southwest**	**NSW central.**	**Jenolan**	**Tasmania**
Latitude	**10°30'**	**17°09'**	**22°05'**	**30°-32°**	**28°-38°**	**33°49'**	**40°-44°**
Genus							
Cyphoderopsis	★						
Sinella (Coecobrya)		★		★	★	★	★
Pseudosinella		★		★			★
Adelphoderia					★	★	★
Arrhopalites					★	★	★
Oncopodura					★	★	★
n. gen. nr *Kenyura*						★	
n. gen. nr *Troglopedetes*							★

tion and phylogenetic interest belongs to a new genus near *Kenyura* and is currently only known from a single cave. When the Jenolan fauna is compared with the Tasmanian fauna (Table 1), it appears to include a noticeably larger number of genera with exotic species (Figure 2). These genera were more common in caves open to the public (Greenslade, 1989).

Eight genera which are exclusively or nearly exclusively troglobitic or deep soil living occur in the seven karst areas from the latitudinal transect and are listed in Table 3 together with the karst areas in which they occur. They include three endemic genera, *Adelphoderia*, n. gen. nr *Kenyura* and n. gen. nr *Troglopedetes*, that appear to be restricted to Tasmania and the extreme south east of Australia. The data indicates that there appears to be a trend of increasing diversity of troglobitic, relict taxa from north to south. It is probable that the seven genera of exotic taxa (Table 1) originate mainly from the northern hemisphere.

Discussion

Eberhard & Spate (1995) and Thurgate *et al.* (2001a) note that the karst areas of New South Wales support a diverse invertebrate subterranean fauna that compares favourably in taxon richness to other karst regions in Australia. A rich stygofauna has also been identified (Thurgate *et al.,* 2001b). These authors found that Jenolan is one of five karst areas in New South Wales that could be considered biodiversity 'hotspots' although to some extent this may reflect intensity of collecting. As well as high taxon richness and endemism, they note that relictual distributions and ancient lineages characterise the significance of the New South Wales invertebrate cave fauna in general (Eberhard and Spate, 1995; Hamilton-Smith and Eberhard, 2000; Thurgate et al., 2001b). As far as the collembolan fauna is concerned, Jenolan seems to reflect these characteristics since it harbours several species of *Oncopodura, Adelphoderia* and the new genus near *Kenyura*.

Latitudinal gradients in taxon composition across Australia are frequently encountered and reflect both the major dual origins of the fauna and differences in climate. On one hand there is a cool, moisture loving fauna of Gondwanan origin in the south, and on the other, a tropical, later incursion of Asian origin in the north (CSIRO, 1991). The higher diversity of southern cave faunas shown here by the Collembola, is therefore not surprising since Collembola are most diverse and have most endemic taxa in cooler moister climates of southern regions. However, it is possible that the low diversity in the north of the continent may only be reflecting less collecting effort there since Howarth (1988) and Humphreys (1993) found, unlike Collembola, there was a rich fauna of troglobitic arthropods in some tropical karst areas of tropical Australia.

The question as to whether the exotic species are impacting on the indigenous species in caves cannot be answered without more research. The only example of native Collembola being adversely effected by exotics in Australia is in faunas of fungal fruit bodies (Greenslade, Simpson and Grgurinovic, unpublished results). However, the introduced *Sinella* (*Coecobrya*) has only been found in a concrete drain at Jenolan, a site unlikely to be colonised by native species. The higher number of exotic taxa in the most frequently visited and

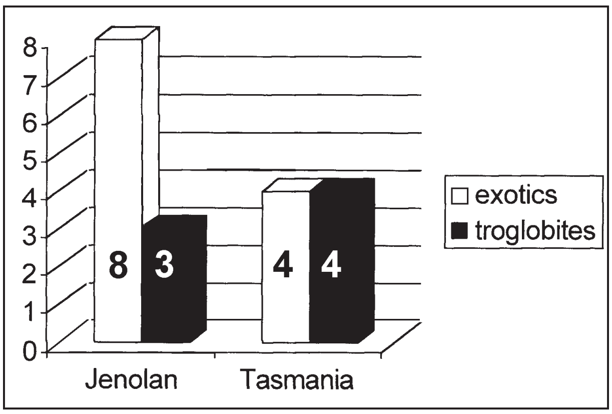

Figure 2. Comparison of exotic and troglobitic genera in Jenolan (NSW) and Tasmanian caves

earliest used tourist cave indicates a possible linkage that requires further investigation. However, there is clearly a need to control and monitor the impact of tourism and also scientific visits to caves of high conservation value especially as regards the possible human translocation of taxa within cave systems. Risk management strategies based on those used in current Australian border quarantine procedures could be applied to all such visits.

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