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Fauna of a granite cave: first data from Britannia Creek Cave (3GP10-48), Wesburn, Victoria, Australia

Silvana Iannello, Penelope Greenslade and Grant Palmer

Centre for Environmental Management, School of Applied and Biomedical Sciences, Federation University, PO Box 663, Mt. Helen, Victoria 3350, Australia

Corresponding author: silvanaiannello@students.federation.edu.au

Abstract

There are few studies in Australia on the fauna of granite caves. Britannia Creek Cave is a granite cave heavily used for recreation yet it has never been mapped nor has the cave fauna been documented. We present here the cave system showing eight ecological zones, A to H, which we mapped, each with different light and moisture characteristics. The faunal diversity and composition in each zone is reported using data recorded from three surveys conducted in April, August and October 2015. For all fauna observed, the zone in which it occurred was noted. Taxa were identified to species level or to genus or family where species was unknown. The composition of fauna assemblages was investigated using Multi-Dimensional Scaling (MDS). Three taxa, the Raphidophoridae (cave crickets), Keroplatidae (glowworms) and Araneae (spiders), were most abundant and occurred in all eight zones. Known cave dwellers, such as *Arachnocampa (Campara) gippslandensis* (glowworm) were observed in small isolated clusters in three zones, C, E and H.

The highest number of taxa (7) were present in the transition zone B, followed by zone A (6) and a dark zone F (6). Fewest taxa (2) were present in transition zone D.

Because there are few publications on the biology of granite caves in Australia, our data can contribute to determining future conservation and land management priorities, especially in regard to recreational use which we also recorded.

Introduction

Most caves in Australia are formed by seepage of water into limestone and other calcareous rocks, or occur as lava tubes in basaltic rock (Northup & Lavoie 2001; Finlayson & Hamilton-Smith 2003) and there are several studies on the invertebrates of these caves (e.g. Hamilton-Smith 2001; Humphreys 2008; Eberhard and others 1991). However granite caves have been little studied, especially with regard to their fauna. In Victoria, several granite cave systems occur, one being the Britannia Creek Cave (BCC) (Figure 1). Like other granite caves, BCC is a boulder-filled stream channel. The origin of this type of cave is described by Finlayson (1981, 1986), who suggested that the effects of underground streams on acid igneous rocks may lead to rapid, mass failures on the valley side slopes, resulting in deposition of granite boulders and weathered materials into the stream beds. Subsequent and continuing movement of water (stream) through the material has caused the removal of weathered material (often termed *grus*), leaving cavities and fissures between the boulders (Figure 2).

Energy in most caves originates from the surface, from where debris and nutrients are carried underground and pass through various zones within the cave. There are typically five cave zones: entrance, twilight, transition, deep cave and stale air zones (Moulds 2006). The zones nearest the entrance vary in temperature and humidity because of variation in external environmental conditions. Plant and cryptogam species, such as mosses and ferns, adapted to cool conditions, inhabit the surface at and near cave entrances and may sometimes extend into the cave (INHSCFB 2011; Moulds 2006). The twilight zone occurs further into the cave beyond the entrance zone. This zone receives reduced sunlight and plants are unable to photosynthesise or grow there (Moulds 2006). Despite the lack of vegetation, this zone supports a range of insects, spiders and other cave dwelling invertebrates (INHSCFB 2011; Moulds 2006). The transition zone (sometimes called the "variable-temperature zone") (Mohr & Poulson 1966) exists beyond the twilight zone, where light is reduced to zero (INHSCFB 2011; Moulds 2006). Here the temperature and humidity are constant. These zones

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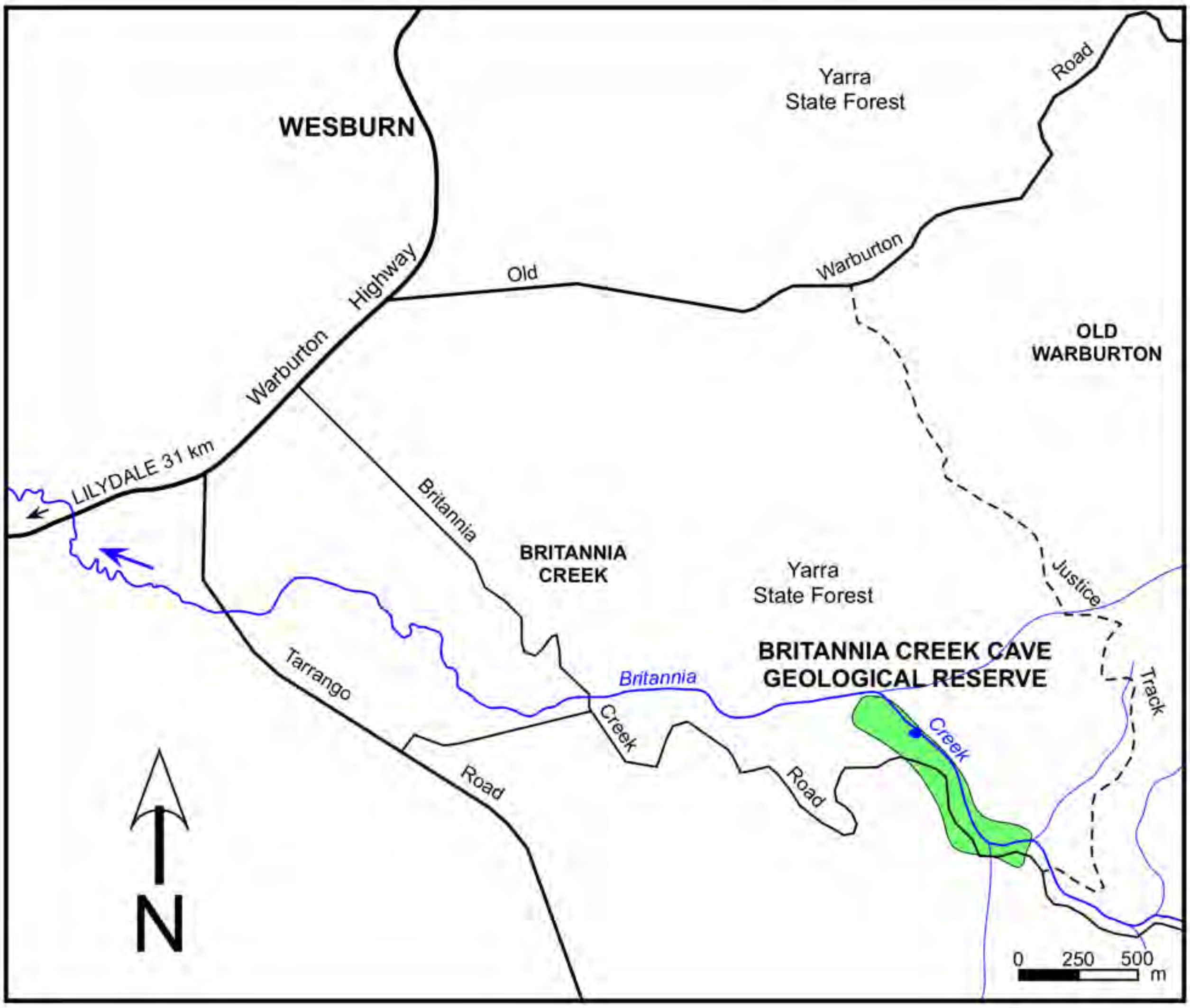

Figure 1. Map of part of Victoria, Australia, showing location of the Britannia Creek Cave Geological Reserve.

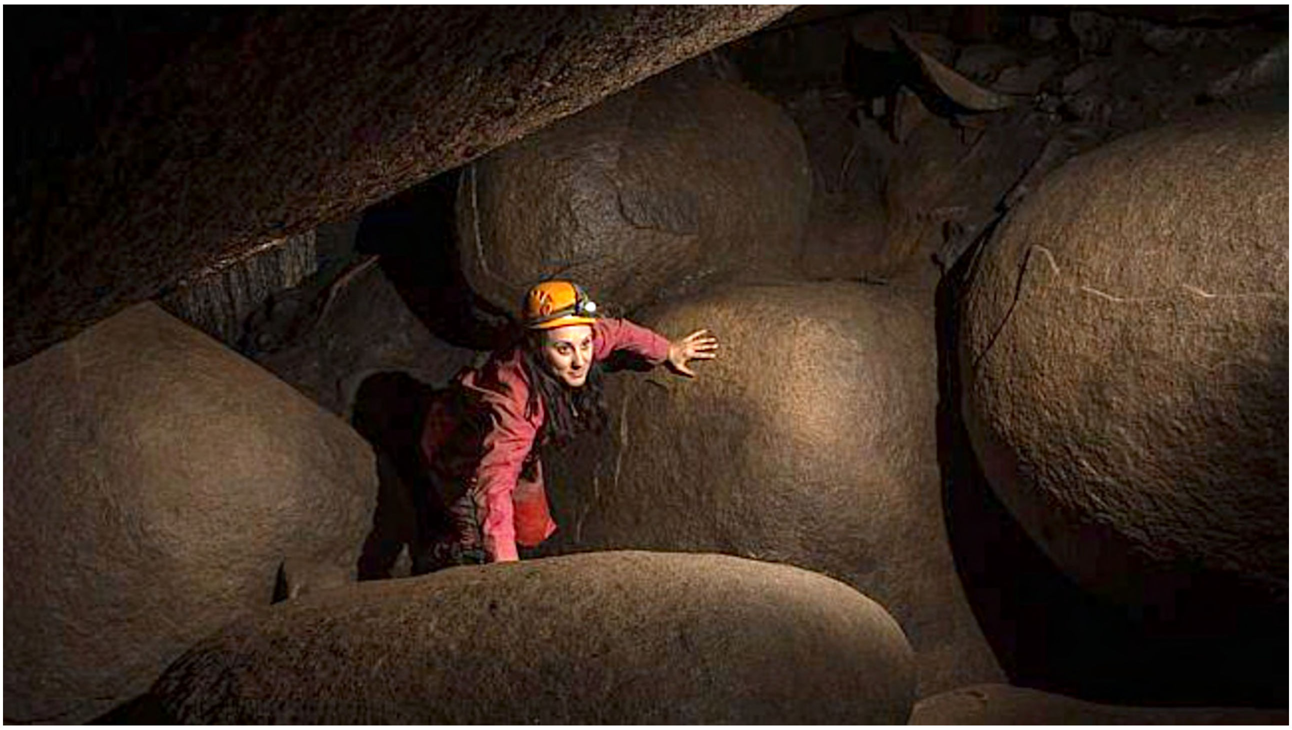

Figure 2. S.I. in typical passage, Britannia Creek Cave, with walls comprised of large weathered granite boulders. Photo: Jake Nowakowski

together are referred to as subterranean habitats and have similar characteristics to underground environments in karst (Culver & Pipan 2009; Clarke 1997), although the structure and composition of cave walls differ.

The fauna found in caves commonly includes species of conservation importance and some species may even be endemic to a single cave system (Culver and others 2000; Culver & Sket 2000). Invertebrates found in caves are generally described as cavernicoles (Clarke 1997; Hamilton-Smith 1967). Cavernicoles consist of accidentals (individuals having fallen or been carried into the cave but for which a cave is not a normal habitat), trogloxenes, troglophiles and troglobiont and their aquatic equivalents – stygoxenes, stygophiles, and stygobites (Moulds 2006; Clarke 1997; Eberhard and others 1991). The highest level of species endemism is found in the troglobites and stygobites (Gibert & Deharveng 2002).

Impacts on the cave fauna and flora must be considered. Recreational caving is one of the main negative impacts on the cave environment (Hamilton-Smith 2001; Poulter 2012). Visitors will impact the microclimate of the different cave zones by causing changes in humidity and carbon dioxide in the atmosphere. Structural damage can occur when visitors alter entrances to make access easier or mark routes through caves (Russell & MacLean 2008). Unintentional damage to fauna can be caused by trampling, bright lights from head torches and over-collecting (Eberhard 1999). Visitors can also cause damage to fragile cave decorations and deposit rubbish (Eberhard 2000).

Insecticides may seep into caves via streams and have been found in the upper layers of bat guano. Changes in stream flow because of vegetation clearing in catchments are examples of human impacts on caves leading to degradation (Poulter 2012; Hamilton-Smith 2001; Eberhard 2000). These impacts can occur in any type of cave (Poulter 2012; Russell & MacLean 2008, Eberhard 2000; Hamilton-Smith 2001).

The first aim of the project was to map the cave and identify zones based on light intensity and climate. The only cavernicole previously recorded from BCC was the troglophilic glowworm, *Arachnocampa* (*Campara*) *gippslandensis* (Baker 2010). Consequently, the second aim was to compile, as comprehensively as practical, an inventory of the fauna of the BCC and its distribution within the cave. The impacts of recreational visitors were also assessed during the fauna survey.

Methods

Site

The cave is located in the Britannia Creek catchment, in the parish of Warburton, Upper Yarra Shire, east of Melbourne, Victoria (37°47' S and 145°39' E) (Figure 1). The catchment is 6 km long from east to west and approximately 3 km wide from north to south (Master & Wise 1980). Current land use in the catchment is nature conservation, timber harvesting, recreation and water storage. Britannia Creek flows from east to west in the centre of the catchment where it intercepts and flows through the cave (Master & Wise 1980), which is located on the west side of the catchment. Mean annual rainfall is 1460 mm and mean temperature from April to September is 13.8°C (BCWS 2015).

The underlying basement rock is the acid granodiorite, named the Warburton Granodiorite, of upper to middle Devonian age (Finlayson 1981; Master & Wise 1980) and comprises granite boulders (core stones). The boulders are of irregular shape and varying sizes. Similar geological formations are found in a number of underground streams in Victoria (Finlayson 1981).

The surface vegetation overlying the cave belongs to the Ecological Vegetation Class #29 Damp Forest and #30 Wet Forest, Highlands Southern Fall Bioregion (DSE 2004) which is dominated by a tall eucalypt overstorey of mountain ash (*Eucalyptus regnans*), mountain grey-gum *(Eucalyptus cypellocarpa),* and messmate stringybark *(Eucalyptus obligua)* with scattered understorey trees over a tall broad-leaved shrub tree-fern understorey of rough tree-fern (*Cyathea australis*), soft tree-fern (*Dicksonia antarctica*) along the creek line and some "wet ferns" such as mother shield-fern (*Polystichum proliferum*) and hard water-fern (*Blechnum wattsii*) (DSE 2004). The vegetation around the entrances of the cave comprises a variety of species mainly composed of mosses, liverworts and prickly currant-bush (*Coprosma quadrifida*), as well as fungi.

Mapping Method

The upper chambers, lower chambers and entrances (daylight holes) of the cave were all surveyed and mapped[1] (Figure 3). Mapping was undertaken using a line survey and a forward

1 The cave is referred to as GP10-48 due to the convention of giving the lowest entry number first. However GP10 is not shown in the survey; it is believed to be connected to the surveyed passages through passages which are inaccessible due to water.

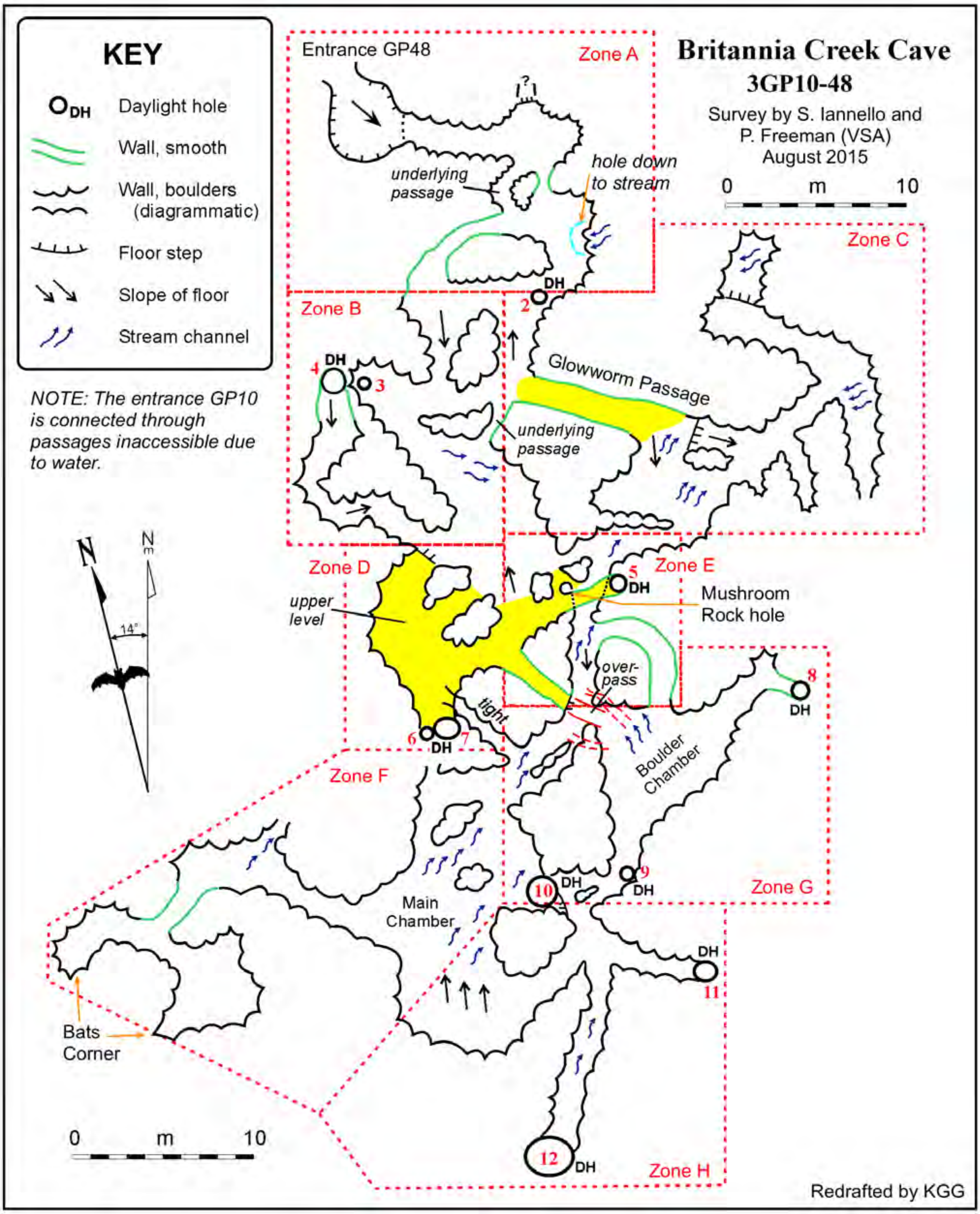

Figure 3. Map of Britannia Creek Cave with boundaries of zones A-H delineated in red. Entrances 1 to 12 depicted by a number in red. Yellow shaded areas show the upper levels of the cave.

method (Day 2002). Survey stations were set up at convenient positions along the cave passage allowing for line of sight from one station to the next. Station 1 was placed at the main entrance. A red laser pointer (Distometer X), modified to measure distance, compass bearing, angle and inclination was used at the first station to sight onto a target at the second station. Each station was referenced with a letter and number. The results were entered into COMPASS cave mapping software, which generated a skeleton map. The map was completed using CorelDraw 8 (Davis 1998) to show the shape of the cave (Figure 3). [The final version was redrafted by Ken Grimes to try to better show the nature of the majority of the walls –Ed.]

Survey method

Once mapping was complete, the map was used to design a plan to systematically survey the fauna of the cave. This allowed comparison of species richness throughout the cave in wet areas, dry areas and areas without a direct surface opening into a cave chamber. The cave was divided into eight zones A, B, C, D, E, F, G and H (Table 1) and the 12 daylight holes were numbered 1 through 12 (Figure 3). Zones F and C were both in dark areas away from any daylight hole. The other six zones were close to surface habitats accessible via either horizontal or vertical entrances. These six zones are on routes heavily used by visitors. Zones F and C have the highest stream flow passing through them and commonly flood.

Faunal survey

Each zone was surveyed for a period of 20 minutes during three survey visits (18 April, 22 August and 11 October 2015). For each survey in a zone, cave floors, walls, roofs, penetrating tree roots, cracks, fissures and voids in the rock were visually inspected for the presence of fauna. The cave fauna observed was identified to species where possible, otherwise to genus or other higher taxon. This allowed a comparison of taxon richness and composition in each zone. Collection of specimens was not permitted.

Analysis

A multi-dimensional scaling (MDS) was undertaken to examine the composition of fauna assemblages occurring in each zone (A-H). MDS is a non-parametric regression and ordination technique that indicates the rank orders of the samples and plots sample data two dimensionally. Those samples that are closer together on the plot are more similar in composition than samples plotted further apart. The 'fit' of the ordination or 'stress' measures the concordance in rank order of the observed distances that are closer together with those predicted from the samples further apart and is an indication of how reliably the ordination matches the observed data. A stress factor of <0.1 indicates high reliability with little chance of a misleading interpretation (Clarke and Gorley 2015). The MDS was based on a Bray-Curtis similarity matrix using presence/absence data. The presence/absence data was based on the three sample times combined.

Results

A map showing zones A through H and entrances 1 through 12 of the cave was constructed (Figure 3). Each zone of BCC is comprised of various granite boulder configurations, light levels, moisture and size of cavity. The most common characteristics of the cavities are low roofs and small narrow passages – the narrowest passage being the exit from zone E, approximately 600 mm x 800 mm.

A histogram showing the total number of taxa recorded in each zone for the months of April, August and October combined is given in Figure 4. Altogether 15 taxa were observed and photographs of some of the invertebrates are given in Figures 5 and 6. Zones A (6 taxa), F and C (6 taxa each) and B (7 taxa) have similar numbers of taxa compared to zone E (4 taxa). Zone G and H have the same number (3). Zone D contained the lowest (2). Table 2 lists all taxa identified in each zone.

Zone	Type	Stream flow	Cave entrance	Use Level	Level
A	Twilight	Yes	Yes	High	Lower
B	Transition	Yes	Yes	High	Lower
C	Transition	Yes, floods	No	High	Upper/lower
D	Transition	Yes	Yes	High	Upper
E	Twilight	Yes	Yes	High	Lower
F	Dark	Yes, floods	No	High	Upper
G	Twilight	Yes	Yes	High	Lower
H	Twilight	Yes	Yes	High	Lower

Table 1. Characteristics of zones recognised in Britannia Creek Cave.

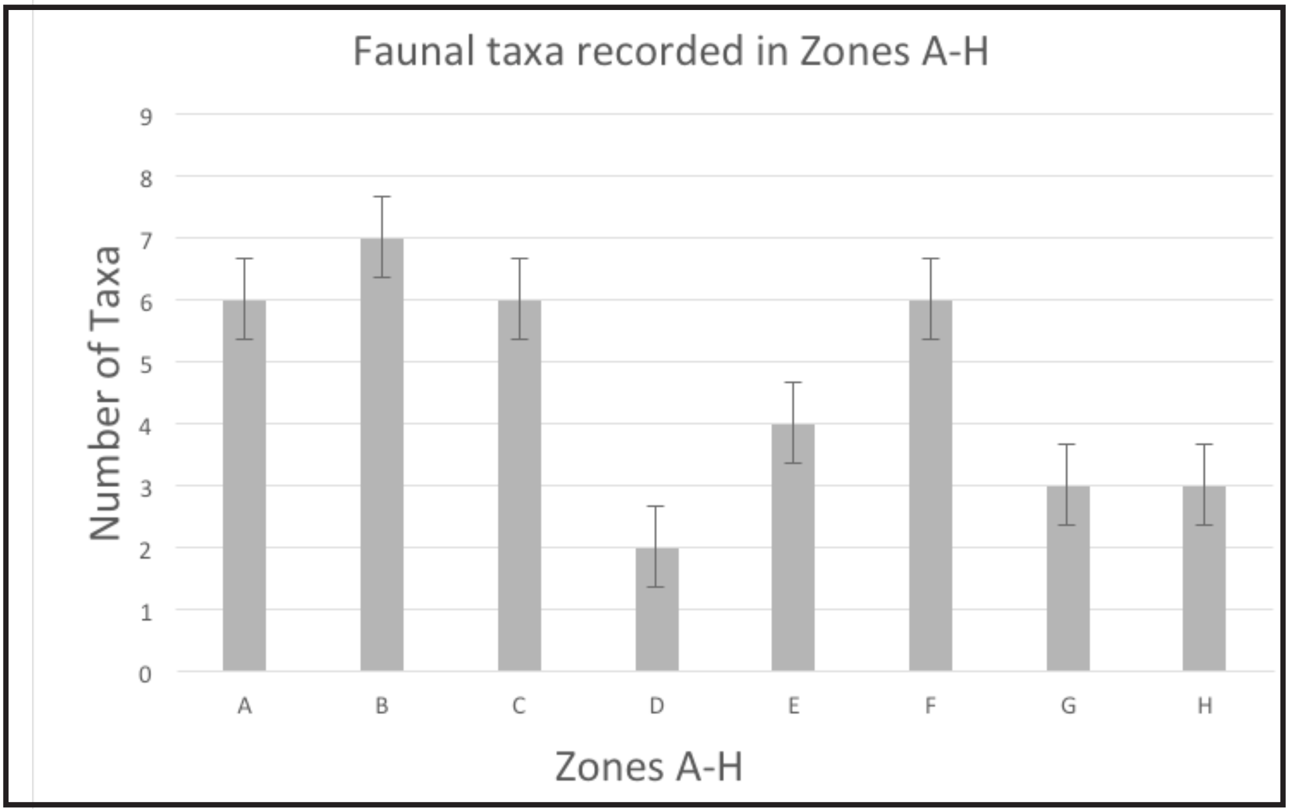

Figure 4. Number of taxa recorded in each zone of Britannia Creek Cave for the months of April, August and October combined. Total number of different taxa recorded was 15.

The MDS ordination (Figure 7) shows that zones E, B, D and F are less similar in community composition than are zones A, C and H overall. Zone pairs with similar community compositions include zones H and C, zones A and E, zones A, H, and C, and zones D and G.

Discussion

The numbers of invertebrate taxa recorded from the BCC is fewer than might be expected, even for a granite cave. Limestone caves in Australia have been recorded as having over 50 species of invertebrates (see Moulds and Bannik 2012). The reason for the low species richness is partly explained by the limited sampling method. The use of pitfall trapping, debris collection and extraction and bait traps were not permitted in the current study. In particular, this is likely to be the explanation for the lack of records of Collembola. By contrast, over 30 species of Collembola have been recorded from the (limestone) Jenolan Caves, but collections there were made over a longer period, in numerous caverns, on many occasions and using several methods (Greenslade 2002). The low taxon richness in the main passage can also be explained by the heavy use of this passage by recreational cavers. Nearly 50 visitors a day in five or six groups have been recorded (S. Iannello, unpublished data). Passages used by recreational groups are likely to be avoided by invertebrates. In addition, the numerous small cavities and narrow fissures between the granite blocks in the BCC are more likely to harbour invertebrates; it was not possible to observe these in the current survey.

Another feature likely to influence the poor taxa richness observed is the numerous entrances to the BCC. Karst caves typically have few, and often only one, entrance (together with some minute entrances). Where there are multiple entrances, they can be tens to hundreds of metres, to kilometres, apart from each other. In contrast, BCC has numerous entrances. Twelve penetrable entrances were identified; no more than 11 metres apart. Multiple entrances mean that the dark zone is limited and this is where most cave fauna typically live (Romero 2009).

Typical karst fauna in Australia and in New Zealand, the Rhaphidophoridae, Araneae and Leiodidae, are predominately located in the entrance zone, twilight zone and transition zone (Richards 1958, 1970; Eberhard 1999). They require access to prey from the surface and some taxa may exit the cave to forage (Richards 1958; Eberhard 1999). Most taxa recorded in this study were located in the twilight zone and transition zone.

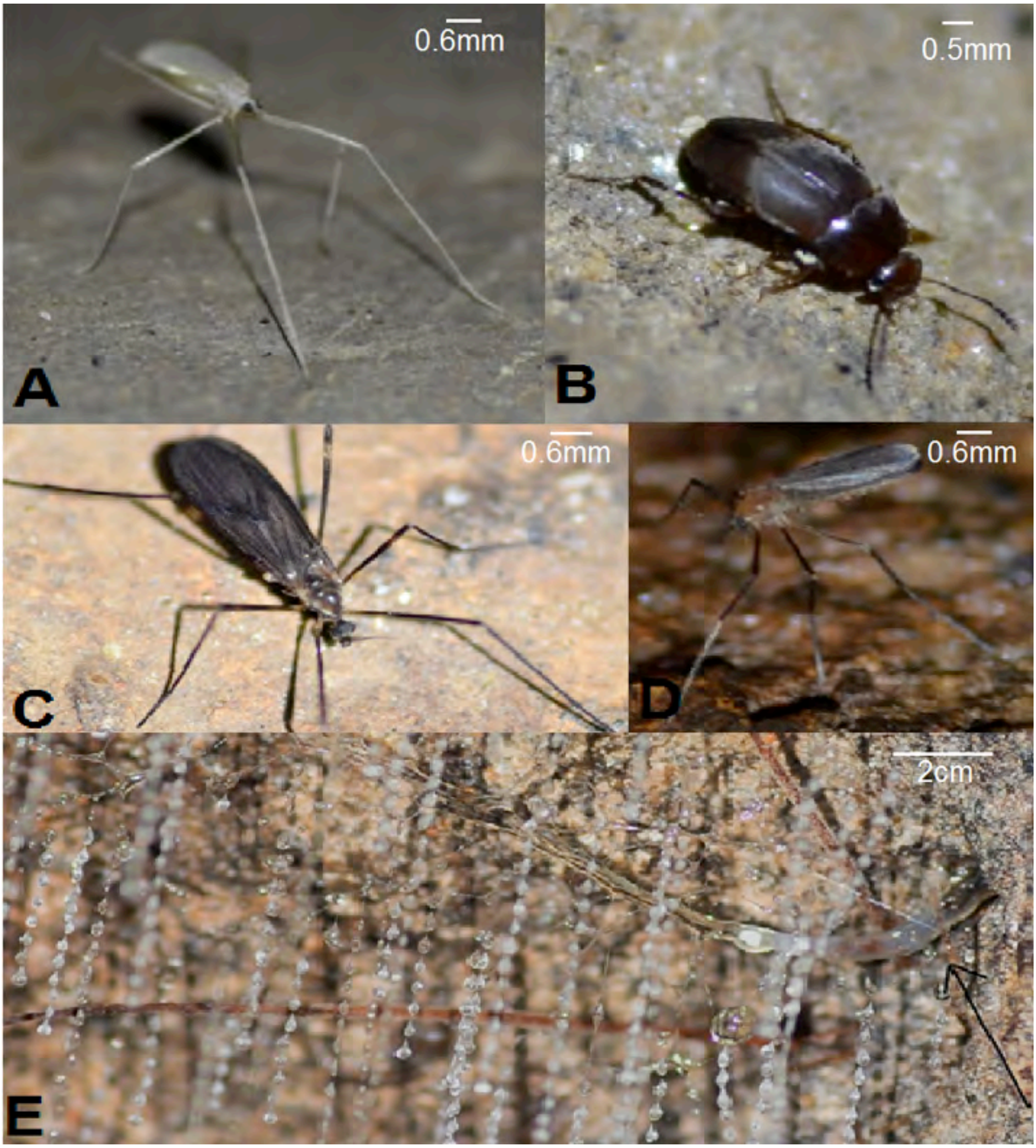

Figure 5. Photographs of live invertebrates taken in Britannia Creek Cave. A. Diptera gen. and sp. unknown; B. Coleoptera gen. and sp. unknown, Leiodidae (small carrion beetle or round fungus beetle); C. Keroplatidae, cf. Arachnacantha gippslandica *(glowworm); D. Diptera gen. and sp. unknown; E. Diptera,* Arachnacantha gippslandica *larva (glowworm). Photographs: Silvana Iannello.*

Accidentals are defined as those whose habitat is normally on the surface, rather than underground (Hamilton-Smith 1967). They may be washed in via the pathway of streams that flow through caves or may fall or roam in from the surface (Hamilton-Smith 1967). The accidental taxa observed in BCC were located in close proximity to the entrance zones and in the streams running through the cave. These included *Rhytidoponera metallica* (green-headed ant), and *Ornithorhynchus anatinus* (platypus). Britannia Creek Cave sits in a deep gully with the Britannia Creek running through it. The stream flows through the cave in several different directions before it exits via a small resurgence, so the likelihood of accidental fauna, such as the platypus, occurring in the cave stream is high.

One troglophile observed in Britannia Ck Cave is the glowworm *Arachnocampa gippslandensis*. This species is also known from the nearby

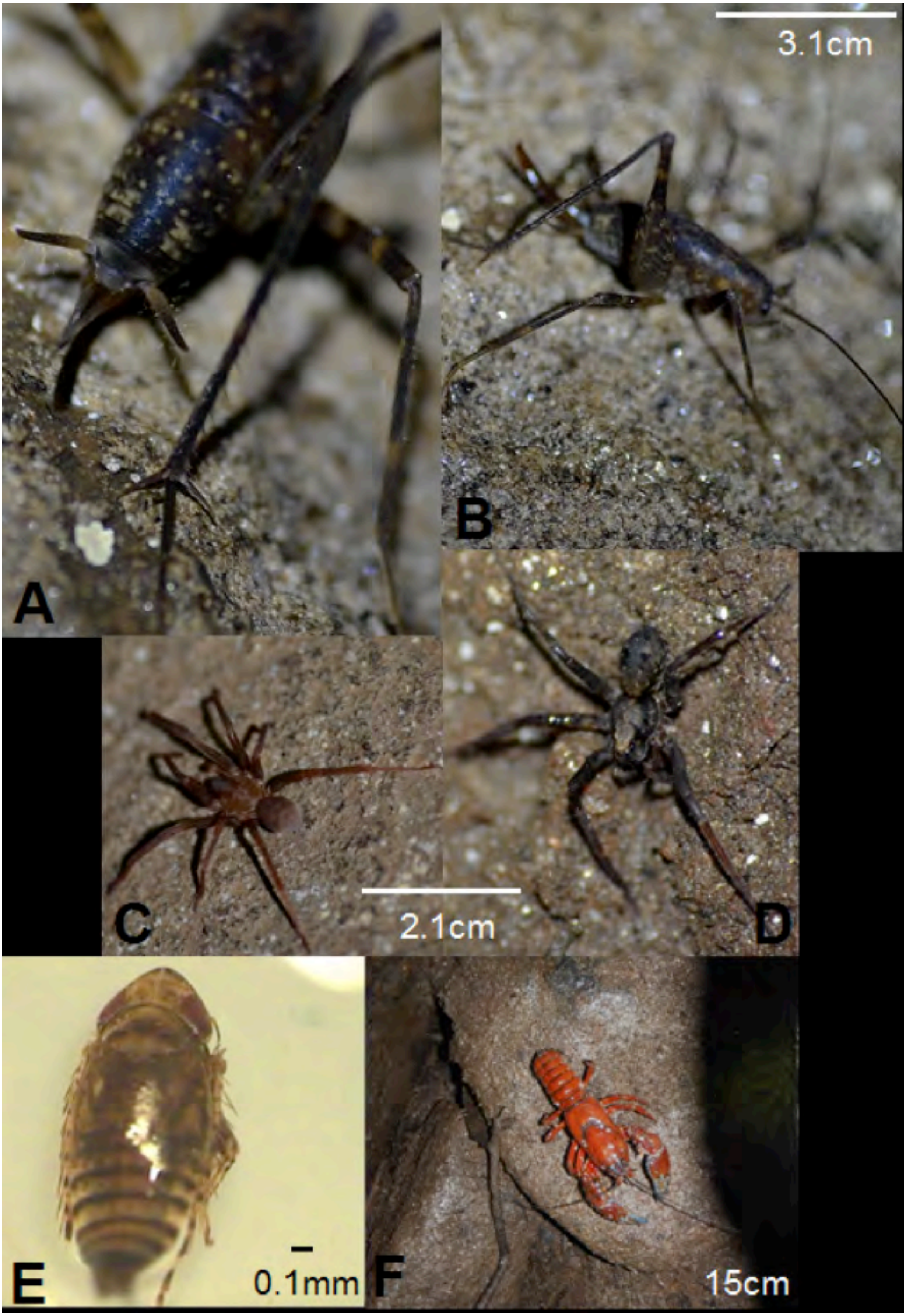

Figure 6. Photographs of live invertebrates taken in Britannia Creek Cave.
A. & B. Insecta, Orthoptera, Rhaphidophoridae, new species (cave cricket); C. & D. Araneae gen. and sp. unknown; E. Insecta, Hemiptera, Cicadellidae, Horouta *sp. (leaf hopper); F. Crustacea, Parastacidae,* Euastacus woiwuru *(freshwater crayfish). Photographs: Silvana Iannello.*

Higher taxon		Species	Family	Common name	Zones recorded
Arachnida	Araneae			spider	A to H
Arachnida	Acari			mite	B
Crustacea	Decapoda	*Euastacus woiwuru* Morgan	Parastacidae	freshwater crayfish	B
Crustacea	Isopoda			slater	E
Insecta	Diptera		Culicidae	mosquito	B
Insecta	Diptera	*Arachnocampa gippslandensis* Richards	Keroplatidae	glowworm	Clusters C, E & H A, B, G
Insecta	Diptera			fly	C
Insecta	Coleoptera		Leiodidae, (Cholevinae)	small carrion beetle or round fungus beetle	F
Insecta	Ephemeroptera			mayfly	C
Insecta	Hymenoptera	*Rhytidoponera metallica* F. Smith	Formicidae	green-headed ant	A
Insecta	Hemiptera	*Horouta* sp.	Cicadellidae	leaf hopper	F
Insecta	Neuroptera	*Kempynus millgrovensis*	Osmylidae	lacewing	A, C
Insecta	Orthoptera	**New Species**	Rhaphido-phoridae	cricket	A to H
Mollusca	Gastropoda			snail	A
Myriapoda	Diplopoda			millipede	F
Mammalia	Monotremata	*Ornithorhynchus anatinus*	Ornithorhyn-chidae	platypus	B
Mammalia	Microchiroptera			microbat	F

Table 2. List of taxa observed and photographed in the Britannia Creek Cave. The new undescribed species is indicated in bold.

Labertouche Cave and at Shiprock Falls (Baker and others 2008). The genus *Arachnocampa* is only found in Australia and New Zealand (Baker and others 2008). The larvae are bioluminescent and their main habitats are rainforest gullies and wet caves (Baker and others 2008; Baker 2010). *Arachnocampa gippslandensis*, being a cave dwelling species, has less pigmentation, produces longer snares and grows larger in comparison to its relatives that inhibit surface habitats (Baker and others 2008).

Three main *A. gippslandensis* population clusters were identified in BCC. The first one was located in zone C (Glowworm Passage) (Figure 2). Zone C (a transition zone) provides a direct visitor route to the other zones of the cave. This zone is a small narrow seven metre long passage with a low ceiling. The passage has multiple tree roots growing between the granite boulders and in the cave floor. The upper sides of the passage are where *A. gippslandensis* was located. The second population is in zone E (near an entrance). The cluster is situated in a small bell chamber at Mushroom Rock where visitor groups squeeze past to get to zone C. The third population is in zone H, also near an entrance. Here the glowworm population is located high in the roof above a shelf of granite boulders and is directly out of the main thoroughfare.

Relatively high abundance of troglophile cave cricket (Rhaphidophoridae) was observed in all zones surveyed. Rhaphidophoridae are known scavengers, but primarily prey upon arthropods (Richards 1958, 1970). A damaged and fallen specimen was compared with every described species in the Australian National Insect Collection and found to be a new, undescribed

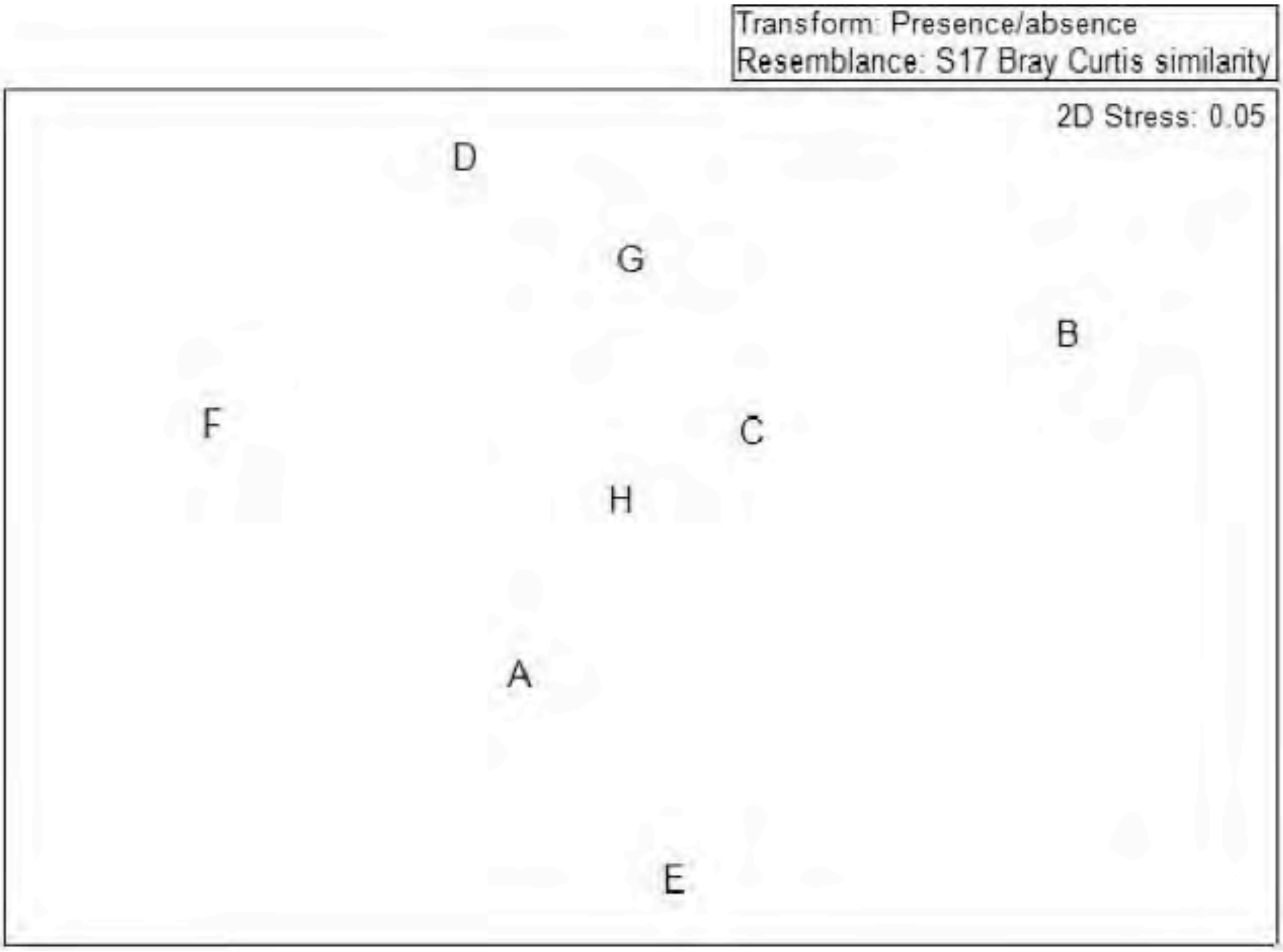

Figure 7. MDS analysis of the community composition of invertebrates recorded in zones A to H combined, at three sample times (April, August and October) in Britannia Creek Cave.

species (Youning Su pers. comm.). The only genus of Rhaphidophoridae, (Rhaphidophorinae, Macropathini) known in Victoria is *Cavernotettix* Richards comprising three species, the closest being *C. buchanensis* Richards, from Buchan Caves located approximately 250 km east of BCC. The species from BCC should be described, its genetic composition ascertained, analysed and compared with those of the other species in Victoria. This would enable construction of a phylogenetic tree so that relationships between species, their origins and the evolution and timing of cave faunas in the region could be established.

Tree roots are the exclusive habitat for some hemipterans, such as the nymphs of plant hoppers (Fulgoroidea), which feed on root sap (Eberhard 1999). One Hemiptera cicadellid, *Horouta* sp. was identified in the dark zone of zone F. Throughout the cave, multiple tree roots were observed located in zones A, C, D and G.

Another troglophile taxon identified was a cholevine beetle (Leiodidae) in zone F. Its common name is round fungus beetle (Peck 1981; Seago 2008). The tribe is a member of the largest subfamily in the Leiodidae, comprising 3000 species (Seago 2008). All cholevines are believed to be saprophagous on carrion, dung or other decaying organic matter (Seago 2008). The BCC species is related to several other species that are endemic to caves. Examples of other cave species are *Ptomaphaginus chapmani* (Peck 1981) from Sarawak, *Platycholeus horn* (two species) from North America (Seago 2008) and *Anophthalmus* and *Adelops* species from Mammoth Cave, Kentucky, USA. Other relatives are found in southern Europe (Packard 1876). The *leiodid* has not confirmed as a cave dwelling species. Zone F is a small and narrow passage similar to zone C. The beetle was only observed on granite boulders on the main route through to Bats Corner (see Figure 3). Decaying food dropped by visitors was found on the granite boulders in this zone that may explain the beetle's presence.

The trogloxenes identified at BCC were *Euastacus woiwuru* Morgan, (Freshwater Crayfish) and an unidentified Microchiroptera (bat). The fresh water Crayfish, *Euastacus woiwuru* was recorded twice in the same zone (zone B) and the microbat was recorded once in zone F. *Euastacus woiwuru* inhabits streams in central Victoria from the Dandenong Mountains east of Melbourne, north-east to Eildon and Dandongadale, east to Woods Point and Erica and south-east to the region of Thorpdale. Included in this range, as well as the Yarra, are tributaries of the Murray and Latrobe rivers and some small coastal streams. The species usually occurs at altitudes above 200 m a.s.l., occasionally at lower elevations. (Crandall 2001; Morgan 1986).

Management of recreational visitors and use

During the survey, zone C was a heavily used route by visiting tour groups. Much disturbance to the cave was observed such as soil compaction, engraving of initials on the walls, white spray painted arrows along the entire passage roof, glowworm lures disturbed, splinter breakages in the tree roots and polished tree roots, due to visitors holding onto the tree roots to support their weight while manoeuvring through the passage. It is clear that a lack of active management of the cave use poses a significant threat to the unique cave fauna. It should be noted that a natural flooding event changes use by visitor groups.

Management responsibility needs to be clearly identified for the cave system. Currently the Department Environment Land Water and Planning (DELWP) has responsibility for management of BCC. The appropriate body should, as a priority, develop an appropriate plan and implement it. The main aim of the plan should be to preserve and protect Britannia Creek Cave and its natural flora and fauna by protecting sensitive habitat, reducing human disturbance and providing a monitoring protocol, the results of which should inform management strategies, especially for the two cave-dependent species. The management plan should also aim to improve public safety and ensure the provision of information to visitors on the biological and physical features as well as the conservation values of the cave.

Conclusion

Britannia Creek Cave supports three main groups of cave fauna, found to be distributed across the different cave zones. Accidental species, such as *Rhytidoponera metallica,* were commonly found near cave entrances. The troglophiles, *Arachnocampa gippslandensis*, and the undescribed species of cave cricket were present throughout the cave system. Two trogloxene species, a microbat species (sub-Order Microchiroptera) and the freshwater crayfish *Euastacus woiwuru* were each observed in a single zone in the cave system, zone F (dark zone) and zone B (transition zone) respectively. The rarity of the cave fauna contributes to its high conservation value and there is a clear need to develop an appropriate management plan that includes management of recreational visits, to ensure conservation values are not further degraded.

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