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The Darkness Beneath

Contents

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ABSTRACT

Bioluminescence in cave glow-worms

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Larval fungus gnats of the genus *Arachnocampa* are sit-and-lure predators that use bioluminescence to attract flying prey to their silk webs. Nine species are described in Australia and New Zealand. Some species are most common in rainforest habitat and others inhabit both caves and rainforest.

Time-lapse recording of light output in rainforest has shown that the light intensity varies through the night in a characteristic pattern with maximum brightness soon after dusk. The intensity of the colony and number of individuals glowing varies seasonally with the brightest displays in summer. Larvae are sensitive to rainfall, increasing their brightness when rain starts falling and are sensitive to moonlight, reducing their brightness on clear, moonlit nights. Laboratory experiments show that larvae douse in response to ultraviolet, blue and green light and are insensitive to red, suggesting they do not see red light. They are also sensitive to vibration, brightening when they sense physical disturbance.

The biological clock influences bioluminescence cycles, but with major differences between two of the studied species; one found in Queensland subtropical rainforest with no known cave populations (*Arachnocampa flava*), the other found in temperate rainforest with large populations in caves (*Arachnocampa tasmaniensis*). Larvae of *A. tasmaniensis* in the cave dark zone synchronize to each other, creating a daily sinusoidal rhythm of bioluminescence intensity in the many thousands of individuals making up a colony. This synchronization could provide a group-foraging advantage, allowing the colony to glow most brightly when the prey are most likely to be active. This is a novel adaptation of the circadian system to living in the constant darkness of caves. The New Zealand glow-worm (*Arachnocampa luminosa*) is also likely to be a synchronizing species: photographic monitoring of the population in the Glowworm Grotto of Waitomo Glowworm Cave has been ongoing since 2011. The daily synchronized cycle is similar to that of *A. tasmaniensis*.

Future research directions are also outlined.

Bioluminescence in cave glow-worms

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Introduction

The insects known as glow-worms in Australia and New Zealand are larval fungus gnats of the genus *Arachnocampa*. They are members of the Order Diptera, family Keroplatidae, subfamily Arachnocampinae (Matile 1981). They are sit-and-lure predators that use bioluminescence to attract flying prey to their silk webs.

Larvae are extremely susceptible to desiccation so even in rainforest habitats they are usually confined to moist areas near streams. From hatching to pupation (6–12 months) the larvae lie suspended from the substrate in a mucous tube from which they hang silk lines dotted with sticky mucus droplets to capture prey attracted by the larval bioluminescence. Adults are short lived (3–14 days) and do not feed (Richards 1960; Baker and Merritt 2003; Meyer-Rochow 2007).

The bioluminescence display produced by the high density of larvae in some suitable locations is a major tourist attraction at sites in Australia and New Zealand, making *Arachnocampa* a commercially valued insect associated with nature-based tourism (Baker 2002). Some sites where visitors experience glow-worm colonies in caves or rainforest include Natural Bridge at Springbrook National Park, Queensland, with approximately 100,000 visits per year (Baker 2002), Marakoopa Cave, Tasmania, and Waitomo Glowworm Cave in New Zealand.

Distribution and evolutionary history

Glow-worms are found only in Australia and New Zealand. In Australia, they are distributed through the wet forests of the Great Dividing Range and in Tasmania and southern Victoria. In New Zealand, the single species, *Arachnocampa luminosa*, is found in wet forests and caves of both the north and south islands.

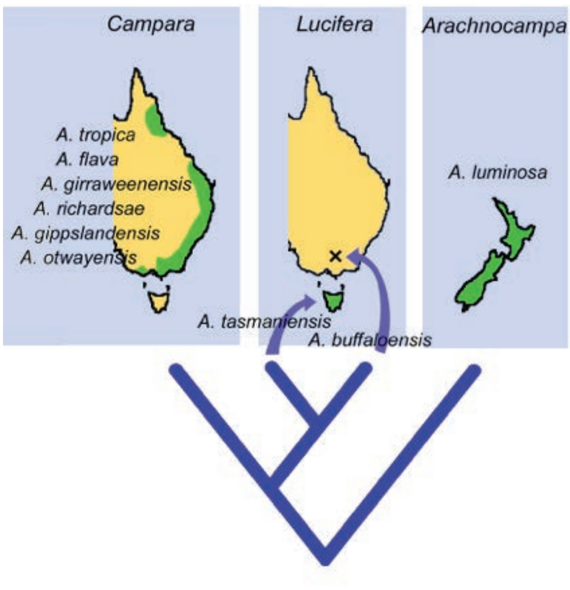


Figure 1. The distributions of glow-worm species and their phylogenetic relationships. The subgenus name is shown at the top of each panel.

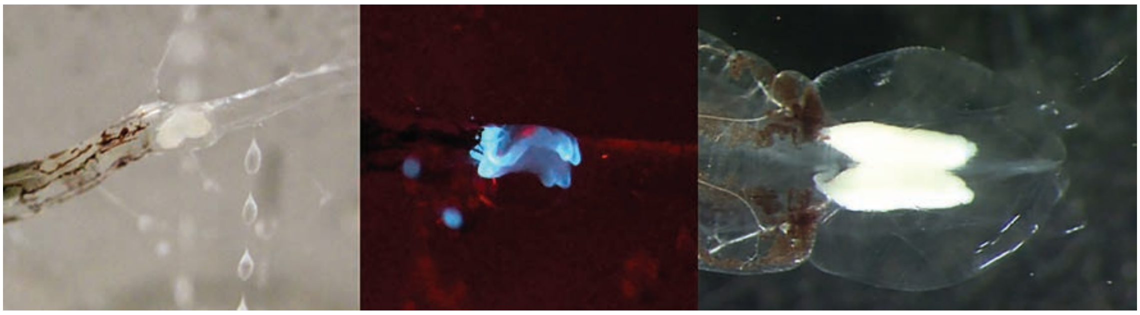


Figure 2. The light organ of *Arachnocampa flava*. The left panel shows the posterior region with the tracheal reflector appearing as a white mass. The central panel is a photograph of the light organ when it is releasing light. The right panel is a picture of the light organ region viewed from above, showing the tracheal mass that sits adjacent to the light-producing cells.

An Australia-wide examination of glow-worm species identity resulted in the naming of five new species (Baker 2010), bringing the total number of species to nine. Species tend to be clustered into geographic groups. The evolutionary relationships of the species were determined based upon mitochondrial gene sequence (Baker et al. 2008). Regarding phylogenetic relationships, the New Zealand species (*A. luminosa*) was placed as sister to all of the Australian taxa (Fig. 1). Within the Australian taxa, the Tasmanian species (*A. tasmaniensis*) was shown to be sister to a species from Mt Buffalo in Victoria (*A. buffaloensis*). A new subgenus (*A.* subgen*. Lucifera*) was named to encompass *A. tasmaniensis* and *A. buffaloensis* (Baker 2010). The remaining Australian species are placed within subgenus Campara.

Light production

The larval light organ, composed of modified cells of the four Malpighian tubules (Wheeler and Williams 1915; Gatenby 1959) is located in a swollen posterior segment. The air-filled trachea form a dense mass covering the light-producing photocytes (Green 1979). Externally, the tracheal mass is visible through the cuticle (Fig. 2). An ultrastructural investigation reported fine nerves containing opaque and clear synaptic vesicles, characteristic of the release of biogenic amines, running alongside the cells of the light organ (Green 1979).

Cave and rainforest populations

Rainforest glow-worm populations tend to be found in colonies in the vicinity of vegetation-sheltered streams, especially those with steep, excised stream banks; thus, they are present throughout much of the rainforests of the Great Dividing Range of eastern Australia, and wet forests of New Zealand (Baker 2010). The most likely dispersal scenario is that under favourable conditions of consistent rainfall (Merritt and Patterson 2017), populations grow and expand along such forest corridors. In rare cases, dispersing females encounter caves with stream inflow that are good habitat due to the sheltered, persistent, humid conditions. Under drying climates, such as the Pleistocene glacial cycles, fragmentation of populations through loss of favourable sites could have left relictual populations in isolated refugia such as caves. The sluggish flight behaviour and short lifespan of adults suggests that they do not disperse long distances under normal circumstances (Richards 1960; Baker et al. 2008) so it is possible that long-standing cave populations are genetically distinct. Morphologically, cave populations show reduced pigmentation of the epidermal cells, tend to make much longer snares than rainforest populations and produce larger adults than nearby forest populations (Richards 1960); however, these traits emerge from responses to different environments rather than being due to genetic differences. The population genetics of glow-worms is currently being studied by comparing nuclear and mitochondrial DNA sequence from many individuals in adjacent caves and forests using high through-put DNA sequencing.

Natural bioluminescence cycles in forest

To see how larvae respond to natural environmental conditions, time-lapse digital photography using an SLR camera was set up in a rainforest gully in Springbrook National Park to image a glow-worm colony at 10 min intervals over x months of a year, at the same time recording temperature and rainfall with dataloggers (Merritt and Patterson 2017). On a typical night, larvae start glowing soon after dusk and rapidly rise to a peak intensity before their intensity decreases through the night (Fig. 3). At dawn they douse in response to the increase in ambient light levels. The intensity of larvae varies night-to-night. In winter, they generally glow more dimly than in summer. Rainfall has a large influence on glowing intensity. If rain fell through the night, the number of larvae glowing increased immediately and an increase in light intensity was seen among larvae in the field of view. After several days of rainfall the colony's bioluminescence output will remain elevated for several days. In forest settings, the best times to see glow-worms is after recent rainfall. The larvae are quite sensitive to low levels of ambient light, decreasing their own light output on strongly moon-lit, clear nights. Moonlight around the time of a full moon inhibited larval bioluminescence output (Fig. 3).

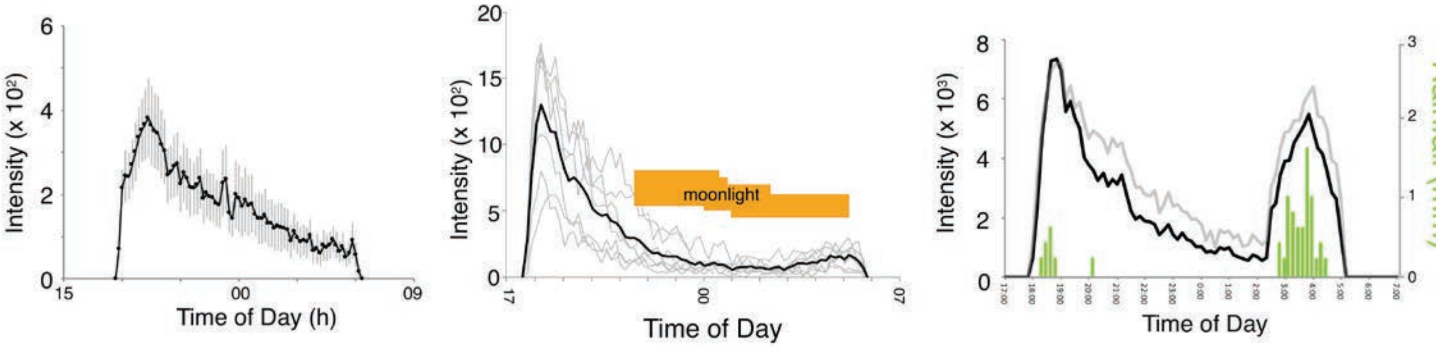


Figure 3. The light intensity profile of *Arachnocampa flava* in forest conditions The left panel shows the light output of larvae on a typical night. The central panel shows the light output over a period of exposure to a full moon. The black line is the average of the grey lines. The right panel is light output on a single night when rain fell after dusk and again at about 3 am.

It is well-known that larvae in forest glow only at night. Light suppresses bioluminescence; that is why visitors at tourism sites are requested not to shine torch-light directly on the glow-worm colonies. The dimming response was quantified in the laboratory (Mills et al. 2016). Exposure to a 5-min light pulse in the laboratory causes larvae to exponentially decrease their light output over 5–10 minutes until they completely switch off. Recovery of bioluminescence after light exposure is slow: once they have switched off, larvae took an average of 33 ± 6 min to resume bioluminescence and took an average of 70 ± 8 min to reach the pre-exposure level (Mills et al. 2016).

To obtain an idea of their spectral sensitivity, glowing larvae were exposed to different coloured light at equivalent photon fluxes (Mills et al. 2016). Larvae proved to be most sensitive to ultraviolet light, followed by blue, green and red. Like many insects, they are quite insensitive to red light so red LED sources are an alternative for safe lighting at night that allows visitors to see their way around without causing larvae to douse their own light. In caves, use of a red LED light source allows us to see the glow-worms' glows as well as the cave surroundings.

Response to vibration and disturbance

So far, we have seen how larvae can modulate their light according to detection of moonlight and artificial light. Another form of light modulation has long been recognised — the ability to rapidly increase light levels on exposure to loud sounds, vibration or other disturbances.

A long-standing display used by tour operators in quiet cave chambers is the "inner tube slam" brightening response where glow-worms in a quiet chamber visibly brighten after an inflated rubber inner tube is slammed onto the rock or water surface. In other observations, pupae or larvae of some species brighten when their container is tapped (Sivinski 1998; Baker and Merritt 2003; Broadley 2012) and female *A. luminosa* pupae glow brightly when a male adult alights on them (Richards 1960). Lee (1976) reported that slight vibration would induce an increase in bioluminescence that falls back to a lower level over 10 minutes. *A. luminosa* larvae increase their glow intensity when prey is caught in their web (Stringer 1967) and when they aggressively fight with each other if their webs encroach in a densely-packed colony. In laboratory tests of controlled stimuli, *A. flava* larvae were found to respond to vibration of a single silk line at 100 Hz with an average 3-fold increase in light output over 20–30 sec, followed by a slow return to pre-exposure levels. Using haptic motors taped to an aquarium, vibration of many larvae individually housed in the aquarium resulted in a several-fold increase in bioluminescence over 20–30 sec, followed by an exponential return to pre-exposure levels over 1–30 min (Mills et al. 2016).

Biological clocks

All nine species of glow-worm are morphologically similar, with minor differences between them in size, pigmentation and other cuticular features. Consequently, we expected that their physiology and behavior would also be similar but were surprised to discover a fundamental difference in how the biological clock controls bioluminescence in two representative species. The background to this discovery was our testing of whether bioluminescence comes under the control of a biological clock in *Arachnocampa flava*, the south-east Queensland rainforest species. We found that the rhythm of glowing continues even when larvae are held in constant darkness for many weeks. In addition, individuals show different periodicities of the on-going cycle, meaning that they drift out of phase with each other over long periods in total darkness (Merritt and Aotani 2008). The dual control system — an internal clock and a switch-off response to light — was not, in itself, surprising because many animals combine direct response to lighting conditions with the internal clock to modulate the time of activity (Aschoff 1960; Rensing 1989; Mrosovsky 1999).

The between-species difference became apparent when we investigated another species, *A. tasmaniensis*. We wanted to know whether bioluminescence rhythms persist in caves in the dark zone where light:dark cycles are absent: caves could be seen as a natural experiment, replicating how we placed *A. flava* in constant darkness in the lab. Because *A. flava* does not have any known cave populations, *A. tasmaniensis* was chosen to test the question. Time-lapse imaging in caves showed that the intensity of larvae waxes and wanes in synchrony, with a period of close to 24 h and the peak occurring in late afternoon to early evening (Merritt and Clarke 2011; Merritt et al. 2012). This went against our prediction, so a series of cave- and laboratory-based experiments were undertaken to compare the clock control of bioluminescence in the two species.

But first, we analysed the synchronization phenomenon in more detail. The within-colony synchronization suggested that larvae detect and match others' bioluminescence cycles (Merritt and Clarke 2011). To confirm, experiments in caves showed that a cluster of individuals within a colony shifted phase in response to exposure to an artificial light pulse each day for several days and once the daily stimuli were stopped, the phase-shifted larvae gradually returned to synchrony with the rest of the colony (Maynard and Merritt 2013). In the laboratory, exposure of larvae to each other under controlled conditions also produced synchronization, confirming that individuals are able to detect the glows of others and change the phase of their daily cycle to synchronize.

A. flava do the opposite; they do not synchronize to each other, they just synchronise to the light:dark cycle. Thus, the two species respond differently to the same entrainment cues. In *A. flava,* entrainment to light reinforces the nocturnal glowing rhythm while in

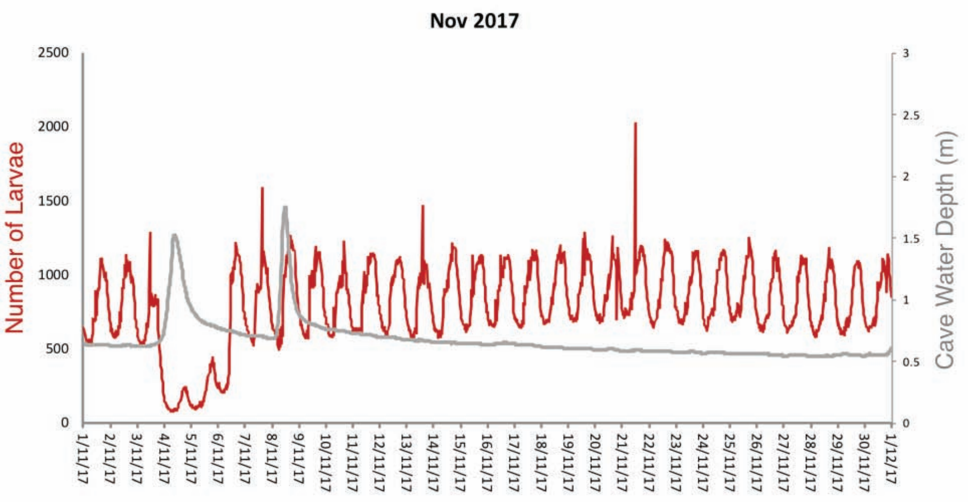
A. tasmaniensis entrainment induces synchronization to the low light levels of other larvae. *A. tasmaniensis* are also found in forest colonies, so it seems that the synchronization response is overwhelmed by the switch-off response to ambient light, meaning that they switch off under daylight and switch on at night (Berry et al. 2017).

The masking response is the same in both species of *Arachnocampa* so the phase response to entrainment appears to be key (Berry et al. 2017). A phase-response curve (PRC) to photic entrainment is a graphical depiction of the degree and direction of phase change shown by individuals exposed to a light pulse according to the subject's phase when the stimulus is applied (Johnson 1992). Analysis of the published PRCs of a diverse group of nocturnal and diurnal animals shows that their PRCs are similar, with slight but consistent differences (Refinetti 2016). This, along with comparisons of the PRCs of related species with different nocturnal/diurnal tendencies, indicates that differences between nocturnal and diurnal animals lie not so much in the nature of their phase-responses as through processes downstream of the clock (Refinetti 2016). However, *A. tasmaniensis* and *A. flava* do not fit this scenario: they show very different PRCs (Berry et al. 2017).

There are indications that the New Zealand glow-worm, *A. luminosa*, is also a synchronizing species. Time-lapse monitoring cameras installed in the Glowworm Grotto in 2011 have provided a continuous record of the bioluminescence intensity and number of glowing larvae since that time. They show ongoing, synchronized, daily cycles in the cave (Fig. 4), just like *A. tasmaniensis*. The cycles show some disruption due to floods and occasional, momentary increases in the count due to noise disturbance (Fig. 4). They also show strong seasonal cycles, with the most intense display and greatest population density in December and January. While it has not been experimentally proven, *A. luminosa* appears to have the same synchronization capability as *A. tasmaniensis*, suggesting that it shares the same type of biological clock and PRC.

The substantial difference between two species of same genus is very unusual. One hypothesis is that the biological clock of *A. tasmaniensis* is representative of species adapted to cave environments and that of *A. flava* to forest-adapted species. We hope to follow up the species differences through several avenues; (1) establish the synchronization ability of all species and see if the *flava*-like and *tasmaniensis*-like traits can be matched against the evolutionary tree of Fig. 1, (2) sequence some of the clock-associated genes in both species to see if there are obvious differences and (3) carry out a population genetics study of representative species covering both forest and cave habitats where available, looking for signs of genetic isolation by distance or isolation by habitat.

Figure 4. The number of *Arachnocampa tasmaniensis* larvae visible in the field of view of a monitoring camera in Waitomo Glowworm Cave through November 2017. Images were recorded at 30 min intervals. The cave water depth shows floods on 4 and 9 November.



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ABSTRACT

Naracoorte Caves: a critical window on faunal extinctions and past climates

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Naracoorte Caves National Park in South Australia was inscribed onto the UNESCO World Heritage list in December 1994 in recognition of its outstanding Quaternary vertebrate fossil deposits. Listed as a serial nomination with Riversleigh in Queensland, the sites reveal much about the evolution of Australia's unique mammals including the extinct megafauna. Importantly, they provide insight into how vertebrate communities have responded to environmental change over the past 20 million years.

Spanning the last 500,000 years of this long record, the vast fossil deposits of Naracoorte Caves allow scientists to reconstruct high resolution records of biodiversity and past climate. The caves contain the most diverse and abundant deposits of Quaternary vertebrates in Australia with over 130 species from dozens of sites within the park. The exceptional preservation of the Naracoorte fossils is well known, with complete skeletons and delicate specimens preserved in all of their detail.

The first fossils were reported from Naracoorte by the Reverend Julian Tenison-Woods in 1858; but it was a discovery made by cave explorers in the Victoria Cave in 1969 that set the stage for World Heritage listing. Research has been ongoing since then and in the last ten years knowledge has increased tenfold as new scientific discoveries are re-writing the story of Naracoorte's fossil caves. From fossil plants to ancient DNA, new insights are providing a more complete understanding of Naracoorte's role in reconstructing the wonders of ancient Australia.

KEY WORDS: Naracoorte Caves, World Heritage, palaeontology, Quaternary, megafauna, vertebrate fossils, caves.

Naracoorte Caves: a critical window on faunal extinctions and past climates

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Introduction and history of fossil discoveries at Naracoorte Caves

Naracoorte Caves World Heritage Area is situated in the Limestone Coast region of South Australia, approximately 350 km southeast of the city of Adelaide. The locality is widely renowned for its extensive fossil record of Quaternary vertebrates preserved within deep sediment deposits in a network of limestone caves (Reed & Bourne, 2000). The caves formed during the early Pleistocene within the late Eocene to middle Miocene aged Gambier Limestone (White & Webb, 2015). The largest of the caves are concentrated along the East Naracoorte Range, which is an early Pleistocene stranded coastal dune range that has contributed much of the cave sediment infill deposits. Animals accumulated in the caves via several mechanisms including pitfall entrapment, predator accumulation and deaths of cave-dwelling species. The resultant vertebrate fossil assemblages reflect a rich late Quaternary fauna and flora in the Naracoorte region, spanning at least the past 500,000 years (Reed & Bourne, 2000).

The earliest report of fossil material discovered at the Naracoorte Caves comes from a paper published in the *South Australian Register* by Reverend Julian E. Woods (later Tenison-Woods) in March 1858 (Woods, 1858; Reed & Bourne, 2013). In this article, Woods describes his visit to the 'Mosquito Plains Caves' in 1857 and his interpretation of the geology and vertebrate remains he found in Blanche Cave. Woods discovered a wealth of bone material at the base of large columns within the cave and attributed these bones to small mammals such as rodents and bandicoots (Woods, 1858). He did not find remains of extinct Pleistocene megafauna at

Figure 1 – A. Reverend Julian Tenison-Woods in 1860 (from the collection of the State Library of South Australia B33699). B. Illustrations of rodent fossils found by Woods in Blanche Cave in 1857 (Woods, 1862).

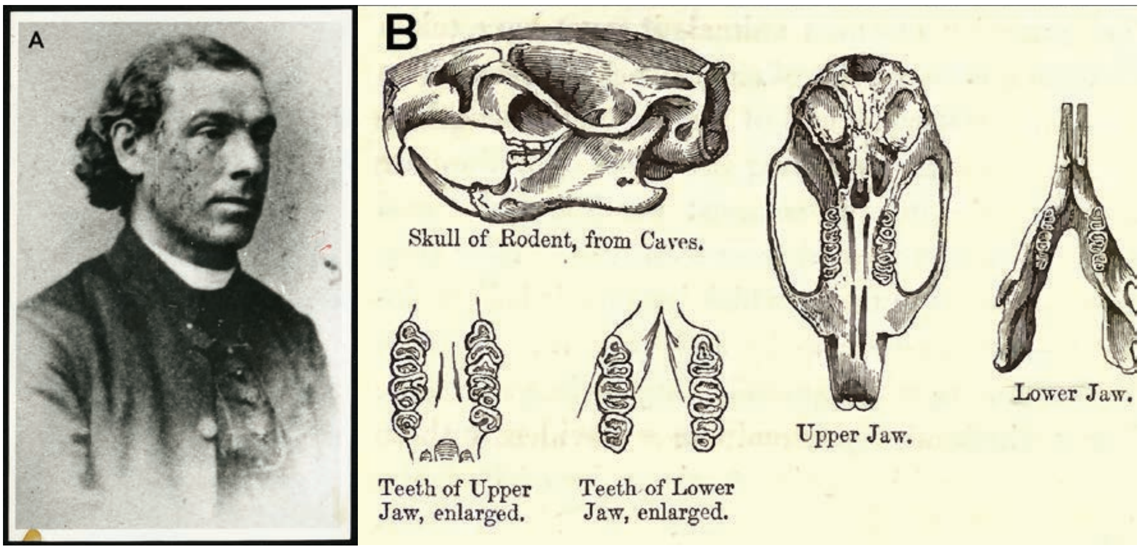

Figure 2 – Megafauna fossils scattered over the cave floor in the Upper Ossuary, Victoria Fossil Cave (photo Steve Bourne).

Naracoorte but was well aware of the discovery of these fossils at other localities, notably the Wellington Caves in New South Wales (Woods, 1862).

Megafauna fossils were first reported from the Naracoorte Caves in 1908, when the Director of the South Australian Museum Edward Stirling and preparator Friedrich Zietz visited Naracoorte. The caretaker of the caves William Reddan had uncovered megafauna bones in Alexandra Cave and Specimen Cave and reported his findings to the museum. This prompted the visit by Stirling and Zietz who recovered fossils of the extinct marsupial predator *Thylacoleo carnifex* (Reed & Bourne, 2000).

The formation of the Cave Exploration Group of South Australia in 1955 initiated a new era of exploration and scientific investigation at the Naracoorte Caves. Fossil material was recovered by cavers during systematic exploration of the cave system and these finds were reported to the South Australian Museum (Reed & Bourne, 2000). In 1956 a partial skeleton of *Thylacoleo carnifex* was uncovered during quarrying operations in James Quarry. Similar activities led to the discovery of a large fossil deposit in a cave at Henschke's quarry in Naracoorte township in 1969 (Reed & Bourne, 2000).

The most significant discovery at Naracoorte Caves was made in 1969 when previously unknown areas of Victoria Cave were discovered by cave explorers. Within this new extension was a large sediment floored chamber containing thousands of bones of Pleistocene vertebrates including exceptional specimens of megafauna species. The discovery led to the first ongoing research project at the caves, led by Rod Wells and colleagues (Wells et al., 1984). Opportunities for tourism and education were soon recognised and the cave became an important site for visitors and researchers alike. The focus of interpretation at the Naracoorte Caves shifted towards explanation of the scientific values of the park rather than focussing just on aesthetic values (Reed & Bourne, 2013).

Heritage values and recognition

In December 1994, around 300 hectares of the Naracoorte Caves Conservation Park (now National Park) were listed as a UNESCO World Heritage site. A serial nomination with Riversleigh in northwest Queensland, it is inscribed as the Australian Fossil Mammal Sites (Riversleigh/Naracoorte). The sites are considered of outstanding universal value, meeting two of the ten criteria for World Heritage listing:

> Criterion (viii): to be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features.
>
> Criterion (ix): to be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals.

The World Heritage values relate specifically to the Quaternary vertebrate fossil deposits and their associated values (Bourne & Reed, 2009). The park also has other values that are significant at a state and national level including biological, historical, scientific, geological and cultural. These values are recognised in additional heritage listings including National and State heritage (Reed & Bourne, 2013). In 1984, Blanche Cave and Victoria Fossil Cave were registered on the South Australian Heritage Register. The sites demonstrate evolving attitudes towards natural history, moving from the 'Victorian' attitude of nature as a curiosity to conservation and appreciation of scientifically important values. In 2016, an expanded State Heritage nomination recognised a broader range of the park's values (South Australian Heritage Council, 2016). The Australian Fossil Mammal Sites were added to the National Heritage List of Australia in May 2007.

Why is Naracoorte an exceptional vertebrate fossil locality?

The Naracoorte Caves World Heritage Area provides an extraordinary window into late Quaternary biodiversity and environment. It is unrivalled among Quaternary localities in Australia for the diversity of fossil species, quality of preservation, continuity of the fossil record and association of multiple palaeoenvironmental proxies. The caves contain finely resolved, deep sediment sections which have had minimal disturbance from dynamic process such as high energy water flow. Vast accumulations of sediment within the caves are largely derived from Quaternary dune sediments overlying the caves, and other additional regional sources (Forbes & Bestland, 2007). Isotopic and elemental geochemistry of these sediments can be used for reconstruction of the environmental context for the vertebrate faunas (Darrénougué et al., 2009).

A particularly striking feature of the Naracoorte locality is the occurrence of multiple, contemporaneous fossil sites in the one relatively small geographic area. Dozens of fossil deposits within many different caves span an extended time period over at least the past 500,000 years. This enables patterns of biodiversity and environmental change to be verified, tested and correlated in time and space (Macken et al., 2013; Macken & Reed, 2014). Furthermore, there are hundreds of caves outside of the World Heritage Area within the Limestone Coast region allowing a broader regional perspective.

The vertebrate fossils found at Naracoorte are exceptionally well preserved, with the most delicate features of skulls and skeletons maintained. In some sites, fossils have been found as articulated skeletons or with elements in close association. The density of fossil material within deposits is high, with relatively small excavations yielding large numbers of bones. In some of the younger sites (<20 ka) ancient DNA has been recovered from bones (Grealy et

Figure 3 – Immense sediment cones in Sand Cave, Naracoorte (photo Steve Bourne).

al., 2016) and also macro plant fossils (Estrada et al., 2018). A range of palaeoenvironmental proxies are preserved within the sediments in direct association with the faunal remains allowing fine-grained reconstruction of past climate.

A high diversity of vertebrate species is preserved in the Naracoorte cave deposits. Over 130 species of amphibians, reptiles, birds and mammals have been identified (Reed & Bourne, 2000, 2009; Macken & Reed, 2013). As new research unfolds in the next few years this number will no doubt increase. Naracoorte has a rich record of extinct Pleistocene megafauna including nine species of sthenurine kangaroos (Prideaux, 2004) and the giant herbivores *Diprotodon optatum*, *Zygomaturus trilobus* and *Palorchestes azael*. The madtsoiid snake *Wonambi naracoortensis* was first described from specimens excavated in the Victoria Fossil Cave (Reed & Bourne, 2000). Fossils of the marsupial predator *Thylacoleo carnifex* are found in nearly all of the cave deposits and include articulated skeletons (Curry et al., 2014). Less common species are the megapode *Latagallina naracoortensis*, the giant monitor *Varanus priscus*, the koala *Phascolarctos stirtoni*, the long-beaked echidna *Megalibgwilia ramsayi* and the massive bird *Genyornis newtoni*.

From the perspective of reconstructing palaeocommunity responses to environmental change, the key faunas at Naracoorte Caves are the small mammals (Macken & Reed, 2013, 2014). Largely derived from owl pellet accumulation, the abundance, diversity and sheer volume of material for these species allows statistical assessment of palaeocommunity composition and resilience to changing conditions (Macken & Reed, 2014). The small mammal (<2kg body mass) assemblages contain around 40 species overall; but are dominated by murid rodents both in terms of diversity and relative abundance (Macken & Reed, 2013). Some of these species were driven to extinction rapidly following European settlement of Australia including the Long-eared Mouse *Pseudomys auritus*, the White-footed Rabbit-rat *Conilurus albipes* and Gould's Mouse *Pseudomys gouldii*. Marsupials account for the remaining small mammal species, with diverse assemblages of insectivorous and carnivorous dasyurids (Dasyuridae), bandicoots (Peramelidae) and possums (Phalangeridae, Burramyidae, Pseudocheiridae).

The Naracoorte Caves contain an array of materials that can be dated using numerical techniques to constrain the age of the deposits. These include speleothems, quartz sediments, bone, charcoal, macro and micro plant fossils. Recent research has resolved the chronology of several key sites in Blanche Cave, Wet Cave, Robertson Cave, Grant Hall and Cathedral Cave (Prideaux et al., 2007; Darrénougué et al., 2009; St. Pierre et al., 2009, 2012; Macken et al., 2011; Macken et al., 2013; Grealy et al., 2016). The oldest dated sediment deposits are from Cathedral Cave and fall within Marine Isotope Stage 13 (mean age 528 ±41 ka obtained via Optically Stimulated Luminescence – Prideaux et al., 2007). The youngest deposits span the late Holocene with ages <1 ka (Grealy et al., 2016).

A new era of research at Naracoorte Caves

Palaeontological research at the Naracoorte Caves has increased over the past decade, with a renewed focus on refining the chronology of key sites and placing vertebrate faunas within a palaeoenvironmental context. Important new discoveries include the presence of a palaeovegetation record preserved as pollen, phytoliths, leaf waxes and macro plant fossils (Darrénougué et al., 2009; Reed, 2012; Estrada et al., 2018). Recent excavations in several caves, and the discovery of new cave sites, has yielded additional vertebrate faunal assemblages (Reed & Bourne, 2009).

Recently, the University of Adelaide was awarded an Australian Research Council Linkage grant for four years of research into Naracoorte's fossil deposits (Reed & Arnold, 2017). This work builds on research undertaken by the author and colleagues since 2008 and capitalises on new directions developed since 2015. The project has four key aims:

1. Establish a high resolution, continuous chronostratigraphic framework for biodiversity and environmental proxy records at Naracoorte spanning the last five glacial cycles.
2. Evaluate palaeocommunity structure and dynamics of vertebrate faunas over middle–late Pleistocene timescales to elucidate megafauna extinction drivers and community responses to local, regional and global climate patterns.
3. Reconstruct long-term palaeoclimate, palaeoenvironment and palaeovegetation records from multiple, high resolution proxies preserved in the Naracoorte cave deposits.
4. Utilise project findings to promote Naracoorte's unique fossil heritage and build much-needed capacity for natural resource management, conservation, training and education.

The Naracoorte fossil record spans two major waves of extinction, namely the Pleistocene megafauna extinction around 45,000 years ago and more recently those associated with the arrival of European settlers into Australia. Elucidating the timing and causes of megafauna extinction in Australia has been a focus of research in Quaternary palaeontology for the past two decades (Roberts et al. 2001). Key shortcomings of existing datasets across Australia include the paucity of sites with high quality dates within a well-resolved stratigraphic framework and the lack of detailed taphonomic and palaeoenvironmental data associated with megafauna records. The Naracoorte fossil deposits are uniquely placed to help unravel the mysteries of megafauna extinction and the current research will yield critical data that will allow palaeontologists to test major extinction hypotheses.

Since European settlement, nearly 30 species of native mammals have become extinct in Australia. The Holocene record at Naracoorte provides critical information on faunal baselines prior to significant disruption of the distributions and structure of native mammal communities. Conservation palaeobiology is a rapidly expanding field within palaeontological research. It involves using data obtained from the fossil record to inform the conservation of modern species and ecosystems (e.g. Westaway et al., 2019). As Naracoorte's fossil record covers the last 500,000 years, the preserved faunas and environments are essentially modern and allow reconstruction of communities prior to the arrival of humans into the region. The wealth of palaeoclimate proxies in direct association with the fossil faunas allow finely resolved assessment of community level responses to climate change.

As new research generates increasing interest in the Naracoorte Caves, it will be important for management of the park to ensure there is a balance between tourism, conservation and scientific research. Naracoorte's fossil deposits are finite resources and minimal impact techniques should be applied when undertaking field sampling and excavation. Currently research includes detailed 3D scanning of the caves in order to understand spatial relationships between the caves and associated infill deposits. This minimally invasive technique provides a means to map the cave system without disturbance of fragile deposits. The conservation and realisation of the World Heritage values through appropriate research and management must remain the driving force behind activities at the Naracoorte Caves.

The integration of science into the presentation and interpretation of the park's values has always been a great strength of Naracoorte Caves. Science is dynamic, keeping pace with new evidence, questions and technologies. It brings old bones to life and unlocks the stories contained in the many layers of time preserved within the caves. One of the core aims of the current research is to use the project's scientific findings to promote and present Naracoorte's extraordinary fossil heritage to a broad audience. Since Julian Tenison-Woods first set foot into Blanche Cave over 160 years ago, some of the most passionate advocates for the site have been the palaeontologists and this tradition is still strong today.

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ABSTRACT

Seeking the Master Cave — the Junee River Karst System

ALAN JACKSON, Southern Tasmanian Caverneers

The Junee River karst system in the southern Tasmanian June–Florentine karst area is home to most of Australia's deepest caves. Hydrological theories began to sprout amongst the local caving community in the 1950s and took shape during the 60s and 70s. An injection of enthusiasm and technological improvement in the 80s and 90s resulted in great leaps forward in proving the concept. The 2000s saw a new generation of explorers plumbing the depths in search of the missing links. In 2019 the search continues; piece by piece the puzzle is coming together but we still don't really know what the picture on the box is or even how many pieces there might be. That's all part of the fun, really.

The Junee–Florentine is a large 'Gordon Group' outcrop of Ordovician limestone (approximately 15,000 ha). It comprises of two sub-areas: the Junee and the Florentine. The Florentine region (~10,000 ha) to the west is typically of low relief and comprised of multiple small independent drainage systems while the Junee region (~3000 ha of surface limestone) is a complex single drainage system with up to ~400 m depth potential and ~7,500 ha of catchment area. Water enters the system via a large number of swallets spread over the whole area but all water exits from the Junee Cave resurgence in the south-eastern corner of the karst region.

Junee Cave and the major sink Growling Swallet were discovered by explorers in the early 20th century but organised cave exploration and hydrological theories (in the form of the Tasmanian Caverneering Club) didn't appear until the mid-1940s. The JF was remote in those days and trips were infrequent. In 1957 Growling Swallet was surveyed to -174 m (Australian depth record at the time) and in the 1960s theories about possible sources for the water rising at Junee Cave were put forward and tested in the field. In the late 1960s swallets like Cauldron Pot and Khazad-Dum were located during the search for Junee Cave's source. The volume of water sinking into these caves didn't match the volume of the Junee River though so the net was cast wider. In 1972 the theory that Growling was hydrologically connected to Junee was confirmed with a positive dye trace.

With the expansion of forestry activities in the Junee, Tyenna and Florentine river valleys access became easier and multiple cave discoveries followed. Easier access and the advent of new technologies resulted in more and more discoveries. The arrival of Single Rope Technique accelerated the exploration rate significantly. A decade by decade account of major cave discoveries from the 1960s to the end of 2018 is provided.

Exploration is ongoing as there are still major gaps between sections of known master cave. The work is hard but the rewards exciting every time a new piece of the puzzle that is the Junee 'master system' is discovered. The JF should keep plenty of cavers busy for generations to come.

ABSTRACT

Push Day and the challenges of filming underground

FRASER JOHNSTON, Southern Tasmanian Caverneers

Film maker Fraser Johnston has had a fascination for Tasmania's underground since visiting Mystery Creek Cave as a child, but it was a chance meeting with Andreas Klocker in 2016 that introduced him and fellow film maker Andrew Terhell to the adrenaline-filled world of vertical caving and sump-diving in Tasmania's Junee–Florentine cave system. While a sometimes-reluctant caver, Fraser has been gripped by stories of past and present cave exploration in the JF and enjoys the unique challenges of filming underground, and has plans for a feature-length film focusing on the history and exploration of the Junee Florentine; just don't ask him when it will be finished ...

Push Day is an, as-yet, unreleased short film (22 minutes) following Stephen Fordyce and Andreas Klocker on a push dive trip into the upstream sump of Australia's deepest known cave, Niggly. This is a special pre-release screening of the film ahead of a planned 2019 festival run. Filmed over several years with the help and support of the STC, Push Day attempts to answer one of the big questions of the modern world: 'what is left to explore?'

ABSTRACT

Caves of the Western Australian mid-west: a brief history of human interaction

ANN-MARIE MEREDITH, Western Australia Speleological Group

The caves of the Western Australian mid-west have been visited by humans almost (geologically speaking) since their formation. Since the arrival of Aboriginal people in the area, humans have been interacting with these caves in a variety of ways. Shipwreck survivors, stock drovers, early settlers and even politicians have explored their gloomy depths. From the grim discovery of a dead body to a prominent Western Australian minister (later to become Premier) getting embarrassingly 'stuck', these caves have seen their fair share of man's endeavour to penetrate their underground delights.

Ann-Marie is a member of the Western Australian Speleological Group and has been caving in the Western Australian mid-west since the early 1990s. She is currently the Karst Area Coordinator for several of the areas located within its boundaries. A passionate amateur historian to boot, Ann-Marie has scoured the local daily rags of yore to dish up the (cave) dirt on several of its former subterranean guests.

Caves of the Western Australian mid-west: a brief history of human interaction

Ann-Marie Meredith

Western Australia Speleological Group

I don't know about you, but when I tell people I am a caver, I'm usually met with intrigue or horror (depending on people's level of claustrophobia). One thing I always get asked though, is 'What is it that cavers actually do?' Well … we explore, we survey and produce maps, we study bugs, bats, bones and what I like to call 'bygone barbecues' (more appropriately known as archeological hearth sites). And we simply enjoy the natural beauty of caves. We've been doing this for the past 60 odd years, however, that is a mere blip on the timeline of human interaction with the caves of the mid-west of Western Australia. In fact, unlike most caves in the world, the caves in this area are in the unique position of having had humans interacting with them almost from their inception.

Amangu people

The caves in this region started their development less than 400 thousand years ago, which places them in their geological infancy when Aboriginal people started making their way down into the area about 40 thousand years ago. Dr Carly Monks from the University of Western Australia recently excavated Aboriginal archeological sites in Yellabidde and Weelawadji Caves near Eneabba. She found evidence of human interaction from as far back as 25 thousand years ago when the coastline was approximately 40 kilometres west of its current position. This was just before the peak of the last glacial episode, when the climate was much cooler and drier. The evidence suggested sporadic use of the cave until approximately 7 thousand years ago, when the coastline reached its current position. From then on there was a considerable increase in human activity in the caves. Yellabidde Cave revealed a rich deposit of stone artefacts, ochre, charcoal, mammal bones, fish and shellfish remains, and emu eggshells. The Amangu people, like most Aboriginal tribes, did not venture far into the caves as they believed spirits inhabited them. Instead, they sheltered in cave entrances where they established short term camps — sleeping, cooking and going about their day to day business of survival and cultural activities.

Grey's expedition

We'll now fast forward to an event which saw the the beginning of a change in how humans interacted with the caves. It all started with a British exploration expedition going horribly wrong. In 1839, 27 year old army officer Lieutenant George Grey was to lead a Royal Geographical Society expedition to explore the land between Shark Bay and Perth, studying Aboriginal culture, flora and fauna and the general geography of the land in between. He and his party of 12 men hitched a ride with the American whaler, *Russel*, to Bernier Island, just north of Shark Bay. They had with them three whaleboats to convey them on their travels. A grand adventure awaited our little team as they embarked upon their long-awaited expedition. It wasn't long, however, before their dreams of adventure were dashed. Quite literally, with their whaleboats smashed beyond repair on reef and in heavy seas with the loss of most of their stores and equipment.

With no choice but to walk the 300 odd miles back to Perth over unknown land, Grey certainly had his work cut out trying to keep morale up. To make matters worse, they started their journey at the end of a long, dry summer which meant waterholes were at their lowest levels. Near the Greenough River, Grey made the difficult decision to split the party; with the stronger members forging on to seek help and the weaker contingent making their way along the coast. Grey's party skirted the limestone ridge and therefore unwittingly most of the water sources. They eventually arrived in the Swan River Colony somewhat worse for wear but alive nonetheless.

In the meantime, Mr Walker, who was in charge of the slower coastal group following the limestone ridge, had a most timely find. He wrote: 'Went into the interior about midday and found a native well six miles inland, also a large cave in the rocks'. The native well was Yewadabby Spring and the cave, also containing water, Brown Bone cave. Coincidently, Grey's party came within 2 miles of both well and cave. They saw a flock of cockatoos flying west and rightly presumed them to be flying towards water. As the men were in an extremely poor state by that stage, Grey decided not to risk deviating from their course. They struggled on for some time before eventually finding water and were very lucky indeed to have survived the ordeal. Only one of the twelve man in the original party perished en route, with the rest of the group making it safely back to Perth. And the era of European interactions with the caves had begun.

Old Stock Route

Our next wave of visitors to the caves began with the advent of what is now known as the Old Stock Route between Perth and Geraldton. When Grey returned to the colony after his ordeal, he was full of praise for what he deemed 'prime pastoral land' between the Hutt and Greenough rivers. After much to-ing and fro-ing amongst the powers that be, and multiple exploratory parties, the Champion Bay district was finally opened up for settlement in January 1851. This meant that thousands of sheep and cattle were required to stock the newly developed areas. And they had to be driven along a carefully chosen route. Assistant Surveyors Augustus and Henry Gregory went ahead of the first droving party to select the best line through the rugged landscape. One of the jewels in the Stock Route's crown was the discovery of the Stockyard Gully Cave system. Here, drovers could find fresh water and drive their livestock into the narrow gully that led to the mouth of Stockyard Tunnel. With towering limestone cliffs on either side and a forbidding, dark entrance to the cave at the far end, stock were effectively penned in on three sides. The only opening to this natural corral was where the drovers camped with their fires blazing.

Caves were often used by drovers and other travellers along the stock route as a source of clean, cool water on their long and often dusty trips. However, this source of sustenance wasn't always reliable, as one poor soul found out the hard way. In June of 1886, Mr H. Bowers ventured into Stockyard Cave to quench his thirst from the little stream which wound its way through the vast cavern. As he scrambled down into the cave, something out of the ordinary caught his eye. Peering into the gloom, he spied something glistening. Curiosity got the better of him and he picked his way over the giant boulders to investigate. Imagine his surprise at finding a silver watch and chain, with a gold ring fastened by a knot in the chain! Very odd indeed. He poked around some more and found a pair of boots, carefully placed under a rock from whence water slowly dripped. Our Mr Bowers was completely perplexed. How did these items come to be in this dark, lonely place? He moved deeper into the gloom towards what he perceived to be a log of wood. To his horror, this was no log, but the dead body of a human being!

Our Mr Bowers, not being of a particularly strong constitution, stayed not to investigate further and fled immediately the scene in a 'highly agitated state of mind'. He did have the presence of mind, however, to snatch the deceased's clutch of jewellery on his way out. Mr Bowers then rode hard to Dongara and reported the incident to the officer in charge of the police stationed there. Constable Troy immediately 'procured a conveyance' and furnished it with a jarrah coffin for the deceased. Together with Mr Bowers, the men returned to the cavern with the intent of burying the remains of the unfortunate man. The deceased was thought to be Mr James Cook who had travelled north some time ago and was returning to Guildford on horseback via the coast road. It had been reported that the man had been dead approximately two months and had neither money nor rations, leading Constable Troy to rule that he died from 'starvation and want of water'. Finding no suspicious circumstances, the two men then buried Mr Cook in a lonely grave near the cave in which he perished.

Phosphate mining

In 1908, the caves were starting to be visited for an entirely different reason altogether. At the turn of the century, a quick-acting 'artificial' fertiliser was beginning to be imported into Western Australia to help in the enhancement of growing crops. By 1907, this 'superphosphate' was gaining in popularity and the Western Australian Government engaged Hungarian-born geologist Stephen Goczel to search for a more local supply. Goczel directed his investigations towards the coastal limestone ridge between Perth and Dongara, exploring the caves in which lay significant reserves of phosphatic material built up largely from centuries of bat guano deposits. The caves of the Nambung region impressed him most, both with their phosphatic deposits and also the sheer beauty of their crystal formations. He established a camp close to the caves and continued his investigations. Goczel sent samples of phosphatic material down to the Government Analytical Laboratory in Perth which came back with promising results. Goczel's subsequent report to the Department of Agriculture also estimated there were at least 10 thousand tons which could be readily shipped from Cervantes, a short distance away.

The then Minister for Lands and Agriculture, later to be known as 'Sir' James Mitchell was an enthusiastic supporter of this project. In October 1908, he set off with his Under-Secretary and a small contingent of press to investigate Goczel's finds. Their first port of call was at the Minyulo Homestead of our Mr Bowers of Stockyard Gully fame. Goczel had supplied Mr

Bowers with a couple of pounds of the phosphate which Bowers mixed with four gallons of water and applied to 30 square feet of his rye crop. The comparison between the test patch and the remainder of the crop was significantly impressive to the minister and his little party that they left Minyulo brimming with enthusiasm. When the group arrived at the first cave, they found a substantial amount of work had been carried out in order to 'open up' the cave for the mining venture. A 30 foot shaft had been sunk into the largest chamber in preparation for guano-filled bags to be lifted out for shipping to Fremantle. The ministerial party were shown many more deposit sites in several caves the following day, which saw them scrambling through tunnels and squeezing through narrow passages to see the 'pay-dirt'. Somehow, I doubt today's politicians would be so keen to partake in such activities.

After the 'business side' of the expedition was over, the touring party were then taken to a newly discovered cave nearby. One of the accompanying reporters wrote of their little side adventure: 'To reach the chambers the party were required to clamber down a short shaft and to then crawl in serpent-fashion some 20 feet or so. An upright position without risk of collision with hanging stalactites became possible some 20 feet further on, and then chamber after chamber of gorgeous splendour was revealed. From the roof were suspended domes and myriads of long, varicoloured stalactites. The marble-like flooring was everywhere studded with huge stalagmites, which in some cases also met the suspended stalactites. In the centre of a shining ledge there had been a breaking away of the upper crust, which left an opening of oblong shape. Underneath there glittered crystals of all colours, the whole giving a replica of a well-laden jewel casket with the lid removed. So soon as he had returned to the surface Mr Mitchell gave instructions for this particular cave to be sealed up, for beholds that in days to come it must prove "One of the Greatest Tourists' Attractions in the Southern Hemisphere".' That cave, now known as Pretty Cave, was never opened up to tourism, however, and remains gated with restricted access only to experienced cavers. As an aside, our Sir James, being of somewhat 'stout' constitution, actually found himself wedged getting into the cave and had to be assisted through by members of the party. Oh, to have been a fly on that cave wall!

Goczel's team bagged and extracted 20 tons of guano from the caves and sent it down to Fremantle to be tested on Government farms and by a handful of private individuals. With ever-increasing interest in this new product, the Department of Agriculture decided it would enter the commercial market itself and sell Nambung guano to settlers 'at cost sufficient to cover the cost of obtaining and handling'. Unfortunately, the venture was doomed to failure within a year. High quality superphosphate was starting to be produced in Perth which stripped the demand for the comparatively poorer guano phosphate. In 1910 the Nambung project ceased operation and all equipment associated with it was sold off.

Fred Weston

One of the first people to more fully explore the caves of the Nambung region was a British immigrant by the name of Fred Weston. Fred had read about the 1656 shipwreck of the Dutch trading ship *Vergulde Draeck*, or *Gilt Dragon*, off the coast near Wedge Point, in a 1934 edition of the British journal *The Wild World: The Magazine for Men* — a periodical more associated with wild imaginings than actual truth. The article suggested there could be a vast fortune hidden in the land beyond where the ship was wrecked. Fred was struck with 'gold (or actually silver) fever'. He applied for a position of head stockman with the Australia New Zealand Pastoral Company and found himself in a plum position to start his investigations. Fred had fixed in his mind that the treasure was spirited away in some cave in the Nambung vicinity and took every opportunity to fully explore any hole he could find. By all accounts he was most secretive about his knowledge of the caves, however it did him little good. Fred's venture for undreamed-of riches was never realised, for the *Gilt Dragon*'s treasure never made it to shore. It went down with the ship and lay there until discovered in 1963.

Recreational caving

Locals had been visiting the caves on more of a recreational basis since the area was opened for settlement and this increased further with the advent of motorised transport. Property owners took visitors to their far-flung homesteads on journeys to the caves, which was considered high adventure indeed. In March of 1936, A local young lady who went by the delightful pen name of 'Sunny Skies' used her enthusiastic prowess with the pen to enlighten us of the experience. She entitled her little expose 'A Visit to Wonderland: A Modern "Alice" Goes Exploring', and begins with, 'Do you like cave exploring? Personally I think it too thrilling for words so I must write and tell you of our recent trip to those situated near here.' Our young lady then goes on to describe a 'treacherous track' that they 'bumped along' for ten miles before reaching the first cave on the day's agenda.

She writes: 'We left the car and walked a few yards forward. Here we descried a cavity some ten feet deep and a few yards across. Into this "hole" we stumbled, one after the other. Then, without any previous warning whatsoever we literally fell into an Aladdin's Cave. Before us yawned a vast cavern mouth — deep and gloomy at its furthest end, whilst towering rugged walls on either side rose to a vast dome above. At the entrance, the roof was shaded a delicate pink contrasting so vividly with the unrelieved blackness of the interior. To describe the myriad sensations that the rapid transit from the hot glaring world outside into that cool translucent splendour of this stupendous cavern would be quite impossible. The vastness was awe-inspiring, and as we slowly traversed the decline to the cave floor, we were silently awed by the mystic splendour of this subterranean world. We lingered as long as time permitted, walking round and round this vast silent tomb, reluctant to leave its tranquillity for the sun dazzled world above.'

Whilst for many by this stage, the caves were being visited more for the novelty value they provided than sheer survival, the caves were still being used for this purpose during the depression years of the 20s and 30s. The Aboriginal elders who assisted and consulted in Carly Monk's Aboriginal hearth excavation told how their uncles had continued the tradition of using the caves for shelter during harsh weather, camping in the cave entrances. Although living a semi-assimilated life as casual stockmen, these men had maintained a connection with the land and continued to hunt and live in the bush before they and most of their fellow tribespeople were gathered up and sent off to the Mogumber Mission.

War years

As the 1930s drew to a close, a new breed of visitor to our caves was on the horizon. With World War II taking a disastrous turn to threaten Australian shores, and especially after the sinking of HMAS *Sydney* further up the coast, a number of radar stations were hastily established to provide the area with an early warning radar network in case of invasion by the enemy. In 1942, a coast watch station was built at North Head in Jurien. The station was manned by RAAF trained technicians and guarded by the Australian Army. During patrols of the area, soldiers regularly stumbled upon caves and of course had to explore them! One particular cave, 'Thousand Man Cave' was allegedly so named after an officer investigated its vast interior and remarked that 'The Japs could hide a thousand men in here!' Personally, I think that was rather an ambitious estimate and wouldn't want to be amongst the thousand stuffed into every nook and cranny of that cave. Still the exciting lure of cave exploring enticed many of the station's personnel which can be evidenced in the recording of military service numbers on cave walls and formations in several of the caves in the area.

Protection for the caves

Although some form of management of the caves in the Western Australian mid-west had been mooted as early as 1939 by the then State Gardens Board, it wasn't until 1968 that Nambung National Park was finally vested into the National Parks Board of WA. Alf Passfield was the first ranger of the park and whilst the management of the Pinnacles was his main priority in those early days, he was keen to learn as much as he could about the caves in the area. By this stage, many of the more well known and visited caves had been heavily damaged by accident as well as by more wanton forms of vandalism, and pressure was put on park managers by head office to gate those most at risk. Drovers Cave in Jurien had been gated with a grill which allowed the cave's colony of bats to continue to exit and reenter the cave. Unfortunately, locals regularly broke into the cave by either breaking the lock, cutting bars out of the grille or simply blowing holes in the cave roof with gelignite! Passfield frustratingly found he was spending much of his time repairing the damage in order to try protect the cave so decided to completely seal the cave entrance with a more substantial gate. Despite the cavers warning Passfield that such action would decimate the cave's bat colony, Passfield went ahead and had a 75 kg steel plate door made up at the Moora Engineering Works. At the same time, all natural entrances to the cave were concreted up. Sadly, the cavers' predictions came to fruition and there no longer are bats in Drovers Cave. Even more sad is that this cave continues to be broken into and damaged on a regular basis today.

In the early days, it was common practice to inscribe one's name onto the cave wall or cave formation as our young friend 'Sunny Skies' recorded in 1936: 'Before leaving, my husband scratched the name and age of our year-old son, who will have the distinction of being the youngest baby to penetrate this cave.' That signature joined the myriad of ones dating back to the days of the old stock route and later were joined by many more. It has always been a contentious issue within the caving community when it comes to removing old signatures from cave walls and formations. Some argue it should remain as historical value, whilst others see it more as 'graffiti' in the broader sense and seek to have it removed. This also brings up the big question, of course, of when is something deemed of historical value and when does it fall into the other end of the spectrum as senseless vandalism. The actions of the individuals, both in the distant and not so distant past are the same, however, we rarely attach great value to notations of the 'Shaz and Baz 4 eva' variety. Still, in the mid 1980s, the Western Australian Speleological Group applied for a permit from the National Park rangers to remove a vast quantity of the 'graffiti' in Drovers Cave. Arguably, the most offensive to the senses was a more recent application with red house paint on the cave wall which resulted in a layer of limestone having to be removed. But still, many signatures of a more historic nature were lost in the endeavour.

Members of the Western Australian Speleological Group have worked closely with National Parks managers in the Western Australian mid-west over the past 60 years, providing support, assistance and advice on the precious subterranean environments they oversee. The future for these caves is unknown; however, with sensible management plans and greater understanding of the fragility and importance of the cave networks in this area, they will be preserved for generations to come.

ABSTRACT

Keeping White-nose syndrome out of Australia

YVONNE INGEME[1,2], PETER HOLZ[3]

White-nose syndrome (WNS) is an infectious fungal disease that has killed millions of cave dwelling insectivorous bats in North America since its appearance in 2006. It is caused by the fungus *Pseudogymnoascus destructans* that thrives below 15˚C and has been identified on bats in both Europe and China without causing population declines. The 'Qualitative Risk Assessment: WNS in Bats in Australia' has identified seven cave dwelling bats potentially at risk from contracting the disease and suggests that the most likely method of entry of *P. destructans* into Australia will be via infected surfaces such as clothing, footwear or equipment that has been used in affected caves. Implementation of strict hygiene and decontamination procedures is critical for keeping this disease from entering Australia. Any gear that has been taken into potentially infected caves and can't be treated using the appropriate decontamination procedures should not be brought into Australia. Caving clubs should establish standard procedures for responding to caving enquiries from overseas visitors highlighting the appropriate WNS hygiene protocol and potentially make gear available for use to prevent the risk of infected equipment entering Australia.

Keeping White-nose syndrome out of Australia

Yvonne Ingeme[1,2,], Peter Holz[3]

White-nose syndrome

White-nose syndrome (WNS) is an infectious fungal disease that has killed over 6.7 million cave dwelling insectivorous bats in North America since its appearance in 2006 (WNS Response Team 2018). This estimate dates back to 2011, mass deaths have continued as the disease has continued to spread across North America (WNS Response Team 2018).

WNS is caused by the fungus *Pseudogymnoascus destructans (Pd)*, previously known as *Geomyces destructans*, which thrives at temperatures below 15˚C while growth ceases above 20˚C. It prefers high humidity (Warnecke et al. (2012) in Frick 2016). It grows on and adversely impacts hibernating cave dwelling bats while they are in torpor.

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Distribution

The disease has rapidly spread throughout USA and Canada, Figure 1. It occurs in Europe (Puechmaille et al. 2011) Figure 2, and has been confirmed as occurring in north eastern China and is believed to be widespread in eastern Asia (Hoyt *et al.* 2016), refer to Figure 3.

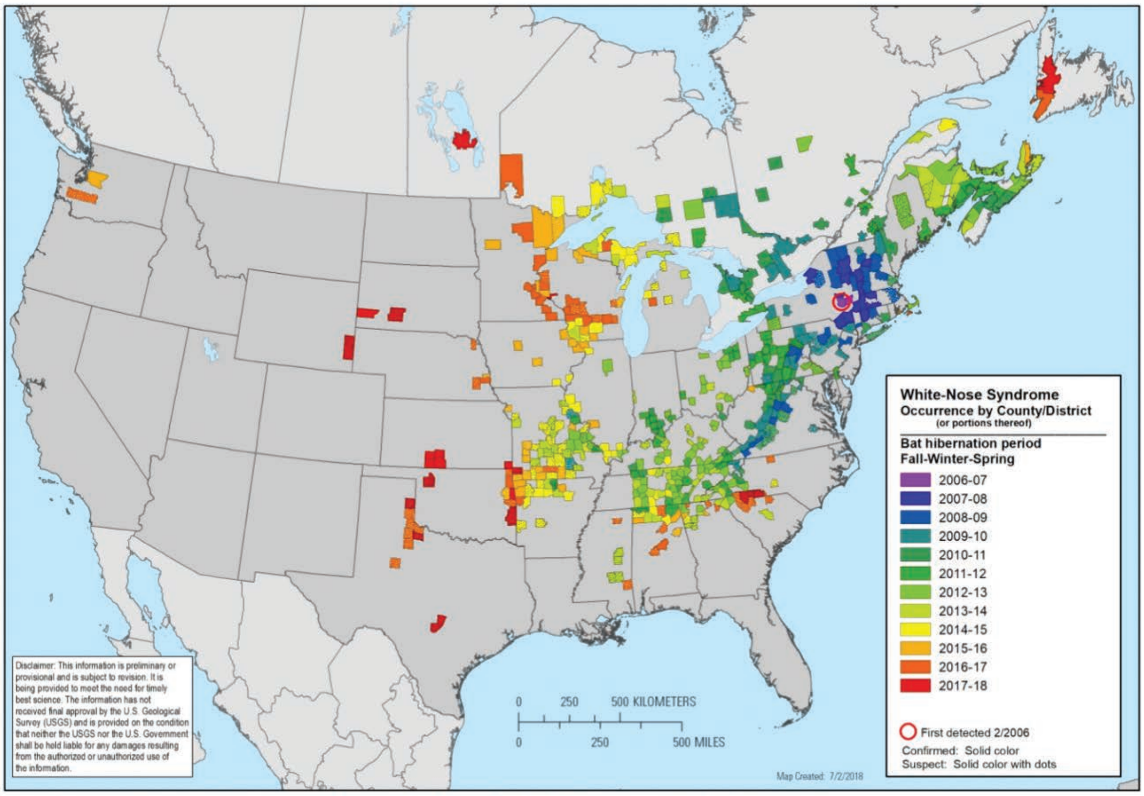


Figure 1. Distribution and annual spread of WNS in North America and Canada. Source: White-nose syndrome response team https://www.whitenosesyndrome.org/static-page/where-is-wns-now 20/12/2018

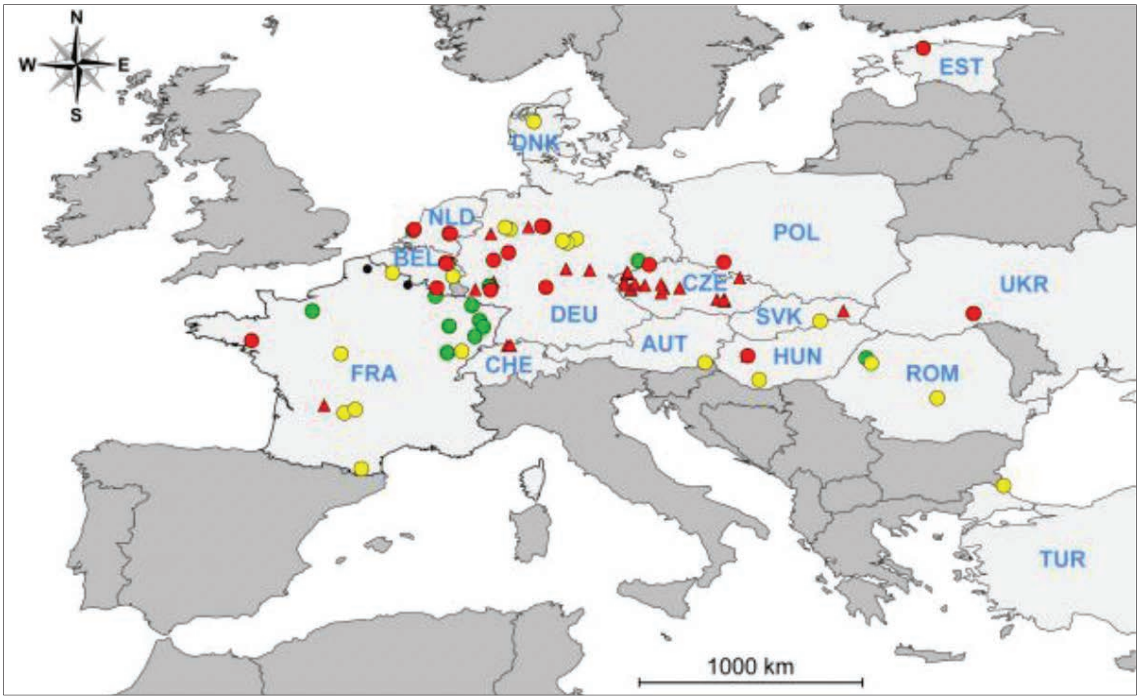


Figure 2. Distribution of confirmed and suspected records of *Pd* on hibernating bats in Europe, 2011 (Great Britain, Latvia, Russia and Slovenia have since confirmed the presence of the fungus). Confirmed records of *P. destructans* in red, photographic evidence in yellow, visual reports in green. Source: Puechmaille *et al.* 2011 & Zukal *et al.* 2016 in Holz *et al*. 2016)

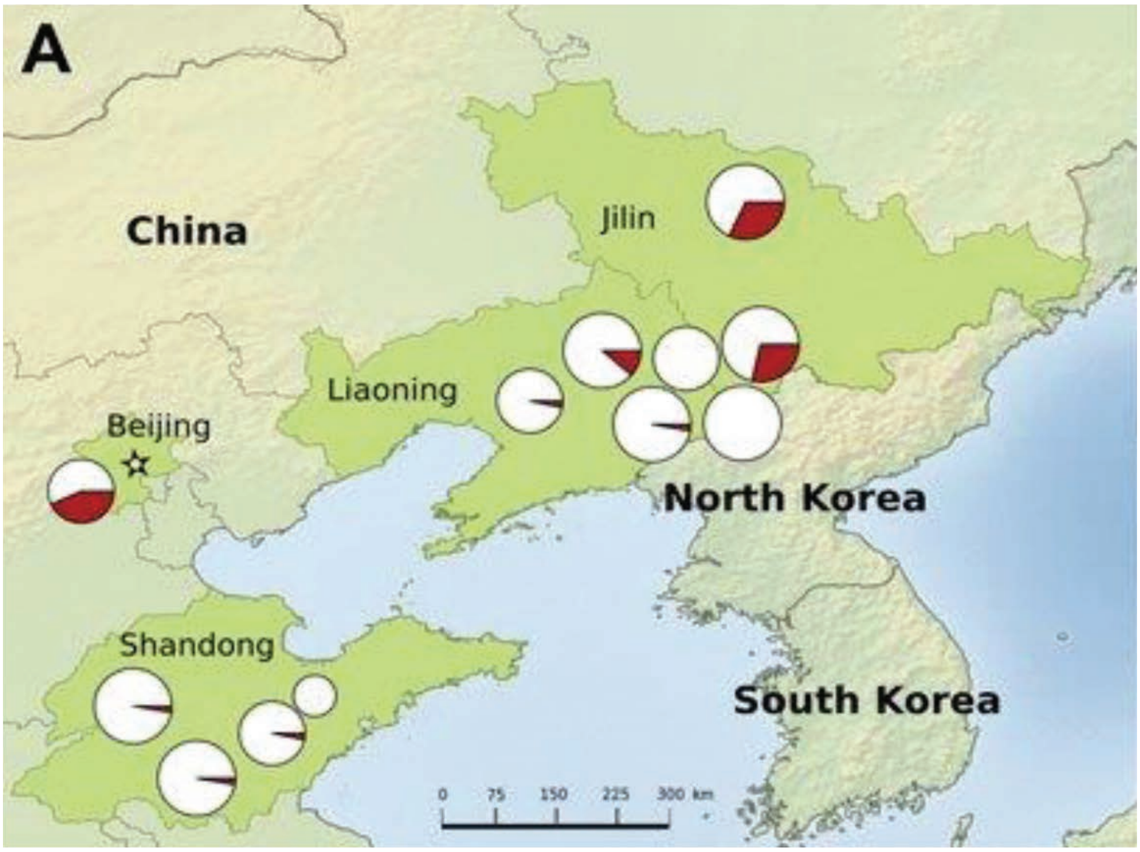


Figure 3. Distribution of *Pd* in cave environments, during the summer of 2014, in north-eastern China. Pie charts show the prevalence of *Pd* (in red) at 9 sites in northern China, and the size of the pie graphs indicates the number of samples taken at each site (range 10-35) Source: Holz *et al.* 2016.

Transmission

A photo taken by a caver in 2006 in Howes Cave, New York state, provides the first evidence of WNS in northern America (Turner and Reeder 2009 in Frick et al. 2016). Howes Cave is a popular tourist attraction with hundreds of thousands of visitors a year (Frick *et al.* 2016). The fungus is believed to have been introduced by someone with infected caving gear from Europe into North America (Puechmaille *et al*. 2011b; Leopardi *et al.* 2015 in Frick et al. 2016). Humans can spread the fungus from one hibernation cave to another by accidentally carrying the fungus on shoes, clothing, or gear (National Park Service 2019). Further transmission by humans was suspected within northern America even following extensive quarantine measures. Tourist visitation of show caves is also considered to be another means of spreading the disease widely through and outside a country and boot/shoe decontamination procedures and stations have been established at show caves, such as Mammoth Cave in Kentucky (National Park Service 2018) and throughout northern America (National Park Service 2017). Researchers are also a potential avenue to spread the disease and a comprehensive WNS decontamination protocol has been developed to minimise the risk of human-assisted transmission of WNS which applies to everyone who comes into contact with bats and/or their habitat (WNS Decontamination Team 2018).

The active on-going transmission of WNS is by bats through direct contact from infected bats to healthy bats (Lorch *et al*. 2011 in Frick *et al*. 2016) and direct contact between bats and the cave substrate. Larger movements of the disease across a country, as observed in northern America, may be through the transportation of infected hidden bats, e.g. within the awnings of camping equipment.

Pd has the ability to persist within the cave environment without bats (Puechmaille *et al*. 2011, Linder *et al*. 2011, Lorch *et al*. 2013 in Frick *et al*. 2016). The *Pd* spores are very long lived and there is a risk that the disease may be brought to Australia via a country that does not appear to have the disease physically expressed within bat populations. For example caves in New Zealand may have been contaminated by someone visiting the caves from Europe or America with contaminated gear. New Zealand bats largely roost in trees, only one species, Long-tailed bats, occasionally use caves, primarily roosting in small groups of less than a hundred (Sedgeley 2012) as such the disease may not necessarily appear evident, but potentially contaminated soil with Pd spores could then be brought to Australia and contaminate Australian caves and impact bat populations. Any cave environment with a climate that remains below 20˚C should be considered as a potential risk of supporting *Pd* and appropriate hygiene and decontamination procedures should be implemented.

Bat susceptibility

The susceptibility of a bat species to WNS is strongly influenced by the particular characteristics and behaviours of the bat species as well as the cave environment they choose to hibernate in. Bat behaviours known to increase their risk of contracting the disease, with potentially fatal consequences, include: tight clustering roosting behaviour; length of hibernation with longer hibernation periods presenting a greater risk (e.g. greater than 6 months); habitat preference e.g. cold caves with higher humidity; summer breeding swarming where large numbers of bats of different species and from different areas gather together. Where the above factors are at play, then the average weight of the bat also influences their ability to survive the disease with the lighter bats more at risk of a fatal outcome.

The cave environment strongly influences the growth rate of *Pd* with a habitat preference below 15˚C (Holz *et al*. 2016) and very high humidity (Warnecke et al. 2012).

Impact on hibernating bats

White-nose syndrome may adversely impact hibernating cave dwelling bats. Torpid bats dramatically drop their body temperature, metabolic rate and bodily functions resulting in a less active immune system (Meteyer *et al*. 2009 in Frick *et al*. 2016) thereby increasing their susceptibility to disease.

White-nose syndrome may lead to:

- Increased consumption of fat/energy reserves (infected bats used twice as much energy as healthy bats even during the early stages of WNS prior to behavioural changes (Verant, *et al*. 2014))
- Increased frequency and duration of arousals (Reeder *et al*. 2012)
- Damaged wing membrane increasing evaporation and water loss (Holz *et al*. 2016)
- Altered behaviour including spending more time grooming to remove the fungus and flying around looking for water and food when not available (Reichard and Kunz 2009 in Holz *et al*. 2016)
- Increased CO_2 levels in blood leading to respiratory acidosis and hyperkalaemia (high potassium in blood) (Verant *et al*. 2014) which can also cause heart failure
- Exhaustion of energy reserves and death (Verant *et al*. 2014)

Verant *et al*. (2014) researched the detailed physiological changes that occurred in WNS infected bats and have developed a multistage disease progression model, Figure 4, which enables a much better understanding of what is happening to the bats.

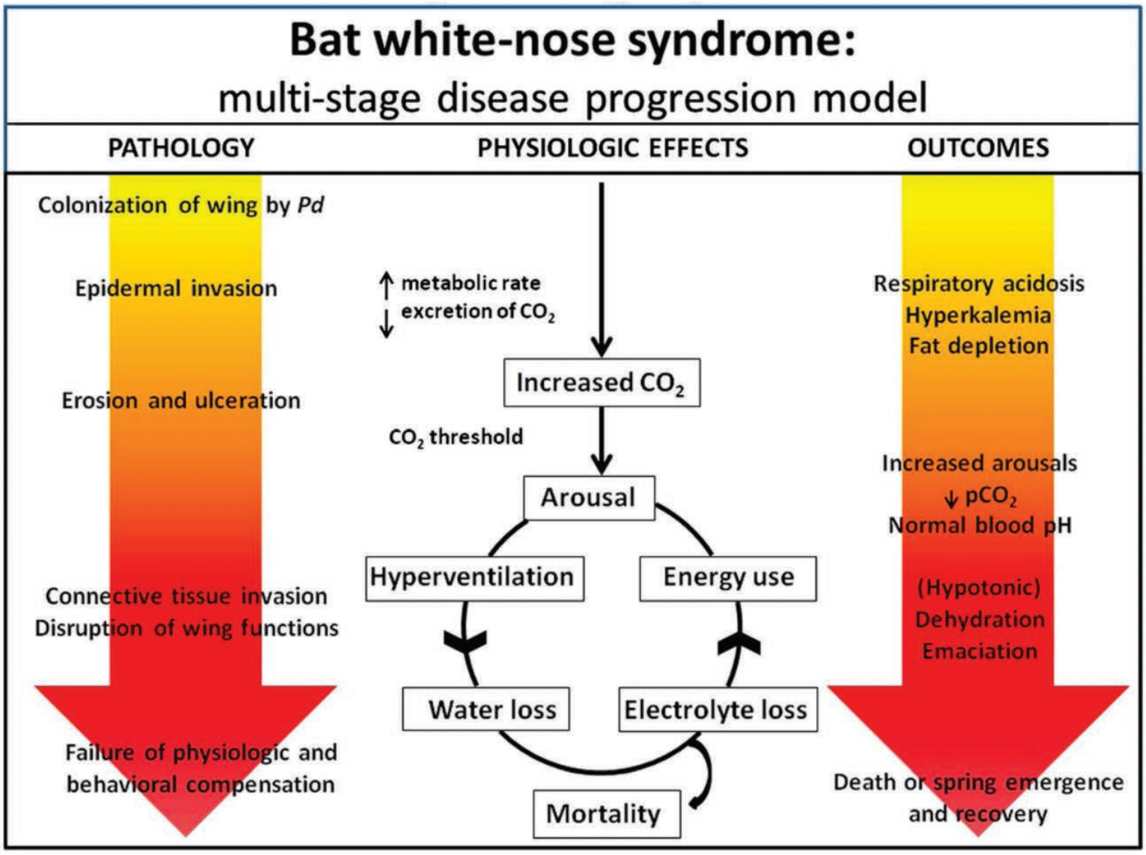


Figure 4. Disease progression model for bat white-nose syndrome (WNS). Verant *et al*. (2014) 'propose a mechanistic multi-stage disease model for WNS in a hibernating bat that encompasses current knowledge on the progression of fungal-induced wing pathology and physiologic sequelae leading to mortality from disease. Initial colonization and invasion of the wing epidermis by Pseudogymnoascus destructans (Pd) results in increased energy expenditure, chronic respiratory acidosis (elevated blood pCO_2 and bicarbonate), and hyperkalemia (elevated blood potassium). Erosion and ulceration of the epidermis stimulate increased frequencies of arousal from torpor, which remove excess CO_2 and normalize blood pH, but contribute to dehydration and depletion of fat reserves. As wing pathology becomes more extensive and severe, these effects are exacerbated by water and electrolyte loss across the epidermis (hypotonic dehydration), which stimulate more frequent arousals and create a positive feedback loop that ultimately leads to mortality when energy reserves and compensatory mechanisms become exhausted'. Source: Verant *et al*. 2014

Case study: Little Brown Bat — from common to threatened in a few years

This case study of Little Brown Bat (*Myotis lucifugus*) highlights how vulnerable a species can be to WNS. Little Brown Bat was a very common bat species numbering in the millions. It was so common no one paid any attention to it. Most of the pre-existing data available on the species was collected in an ad-hoc manner while collecting data on more threatened species of bats. Prior to WNS you would have considered the Little Brown Bat a pretty resilient species, utilising a wide variety of habitat types and overwintering in very cold humid caves rejected by most other bat species. The population has now been decimated by WNS with millions of bats dead (Figure 5) and now regarded as threatened in many places. A conservation status review of Little Brown Bat is being conducted in northern America to determine whether listing as federally endangered is warranted of this once common species (Frick *et al*. 2010 in Frick *et al*. 2016).

Unfortunately Little Brown Bats have a number of characteristics and behaviours that make them particularly susceptible to WNS with fatal consequences, these include:

- Very small bat (9g prior to torpor) (Reeder *et al*. 2012)
- Overall a very long winter torpor length (Sept to April or May depending on gender) (Langlois 2013)

Figure 5. Left: Healthy Little Brown Bat (Photo: www.batworlds.com) Centre: Little Brown Bat suffering from White-nose syndrome (Photo: Marvin Moriarty/USFWS). Right: Pile of dead Little Brown Bats killed by WNS on cave floor (Photo: A Hicks).

- Long torpor periods (average 16 days, this halves to approx 8 days with WNS) (Reeder *et al*. 2012)
- Tight clustering roosting behaviour (Wibbelt *et al*. 2010 in Holz *et al*. 2016)
- Summer breeding swarming (Humphrey and Cope 1976 in Turner *et al.* 2011
- Hibernates in very cold, humid caves (Frick *et al.* 2016, Langlois 2013)

These characteristics can be used as a benchmark for susceptibility and are a useful tool when looking at the potential vulnerability and susceptibility of other bat species to WNS.

Risk assessment

The 'Qualitative risk assessment: White-nose syndrome in bats in Australia' (Holz *et al.* 2016) has been completed. WNS is currently thought to be absent from Australia. Seven cave dwelling bat species in southern Australia are at risk from contracting the disease with potentially devastating consequences. The Southern Bent-wing Bat (*Miniopterus orianae bassanii*) was assessed as having a high risk and the Eastern Bent-wing Bat (*Miniopterus orianae oceanensis*) was assessed as having a medium risk, while the following species are regarded to be at low risk: Eastern Horseshoe Bat (*Rhinolophus megaphyllus*), Chocolate Wattled Bat (*Chalinolobus morio*), Large-eared Pied Bat (*Chalinolobus dwyeri*), Large-footed Myotis (*Myotis macropus*) and Finlayson's Cave Bat (*Vespadelus finlaysoni*) (Holz et al.2016).

The following map demonstrates the Australian latitudes which correlate with the southern US latitudes where *P. destructans* has been found and the Australian cave-dwelling bats that are found within these latitudes.

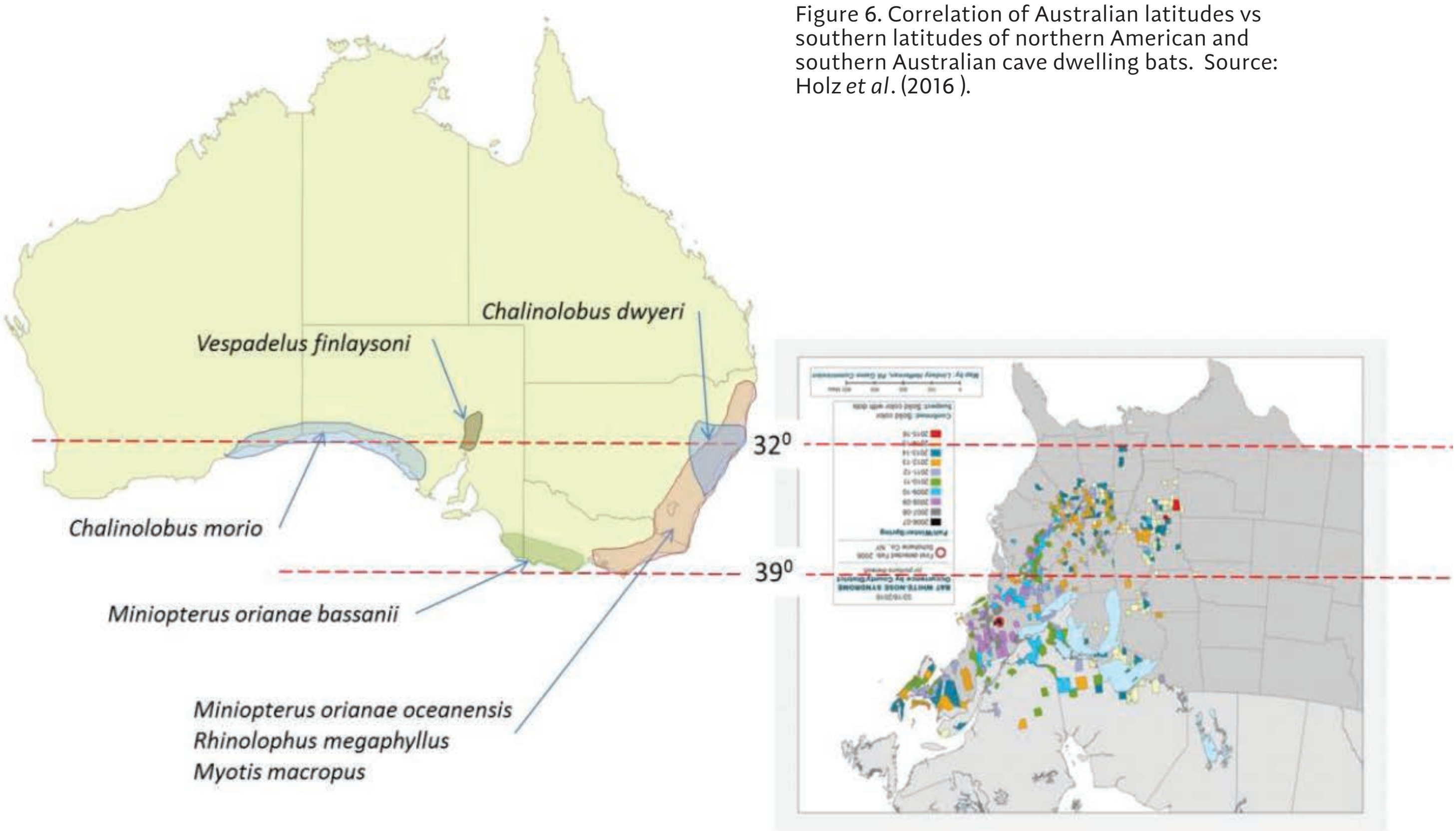
Holz *et al.* (2016) identify that both bent-wing bat 'subspecies that occur in southern Australia are likely naïve to *Pd*. and cluster in large groups, an activity associated with high mortality in the USA'. These species also occur in caves accessible to the public thereby providing a mechanism of infection. The other bats listed have stable populations and roost in smaller groups and therefore considered at lower risk (Holz *et al*. 2016).

Inadequate quarantine

The risk assessment has identified that the most likely method of entry of *Pd* into Australia will be via infected surfaces such as clothing, footwear or equipment that has been used in affected caves (eg by tourists, cavers, researchers) (Holz *et al.* 2016).

WNS is currently not a 'nationally notifiable disease' under Australian Quarantine Regulations and no specific quarantine or border security checks are in place for this disease. 'Cave visitation' is not a trigger question on the 'Australian Immigration Arrival Form'.

Figure 6. Correlation of Australian latitudes vs southern latitudes of northern American and southern Australian cave dwelling bats. Source: Holz *et al*. (2016).



No information is provided to incoming passengers about risks of contaminated gear or clothing from cave visitation.

Implementation of strict hygiene procedures is critical for keeping WNS from entering Australia. Cave gear hygiene needs to be ‘caver driven’.

The safest way to keep the disease out of Australia is to not bring potentially contaminated gear into Australia. This can be achieved by not taking caving gear from Australia overseas and visitors to Australia not bringing potentially contaminated gear into Australia.

Therefore if you are considering travelling think —
INTERNATIONAL = LEAVE GEAR AT HOME

Decontamination

The WNS Decontamination Team (2018) recommends the following procedures to decontaminate caving gear and equipment.

DECONTAMINATION PROCEDURE FOR SUBMERSIBLES:

- Thoroughly clean caving gear by removing dirt and grime.
- Submersion in hot water maintaining a temperature of greater than 55 ˚C for a minimum of 20 minutes.

DECONTAMINATION PROCEDURE FOR NON SUBMERSIBLES:

- Non-submersibles require disinfection using 6% hydrogen peroxide spray or isopropanol disinfectant wipes, see list in Table 1.
- Boots should be scrubbed to remove all mud and dirt then sterilised using a suitable and appropriate chemical from the list in Table 1 below.

Any gear that has been taken into potentially infected caves and can’t be treated using the appropriate decontamination procedures, should NOT be brought into Australia.

	Tested Applications & Products [3, 4, 5, 6, & 7]	Federal Reg No.:	Laboratory Results
Preferred Applications	Equipment Dedication	N/A	Clean according to manufacturer standards and dedicated to a site
	Submersion in Hot Water[4, 6, & 7]	N/A	Laboratory effectiveness demonstrated upon submersion in water with sustained temperature ≥ 55℃ *(131℉)* for 20 minutes.
Other Products	Ethanol (60% or greater)[4, 6, & 7]	CAS - 64-17-5	Laboratory effectiveness demonstrated upon exposure in solution for at least 1 minute.
	Isopropanol (60% or greater)[4, 6, & 7]	CAS - 67-63-0	
	Isopropyl Alcohol Wipes (70%)[4, 6, & 7]	CAS - 67-63-0	Laboratory effectiveness demonstrated immediately following contact and associated drying time.
	Hydrogen Peroxide Wipes (3%)[4, 6, & 7]	CAS - 7722-84-1	
	Rescue® (Fromerly Accel®) [4, 5, 6, & 7]	EPA - 74559-4	Laboratory effectiveness demonstrated when used in accordance with product label.
	Clorox® Bleach[3, 4, 5, 6, & 7]	EPA - 5813-100	
	Clorox® Wipes[4, 5, 6, & 7]	EPA - 5813-79	
	Clorox® Clean-Up Cleaner + Bleach[4, 5, 6, & 7]	EPA - 5813-21	
	Lysol® IC Quaternary Disinfectant Cleaner [3, 4, 5, 6, & 7]	EPA - 47371-129	

Table 1. Applications and products with demonstrated efficacy against *Pd* ([3]Shelley *et al.* 2011). Remember to consult equipment labels, registered product labels, and the appropriate Safety Data Sheet for regulations on safe and acceptable use. Source: WNS Decontamination Team (2018).

The US Environment Protection Authority has been testing various methods and disinfectants to determine effectiveness against *P. Destructans* (WNS Decontamination Team 2018), see Table 1.

How can cavers and caving clubs help?

- Consider WNS when travelling overseas and leave your gear at home to avoid contamination.
- Always use clean caving gear between caves, even in the same caving area, to avoid transferring any pathogens between caves in Australia.
- Think about purchasing caving gear that is easy to clean and decontaminate such as rubber boots rather than leather boots. Have multiple pairs of overalls to allow washing and drying between caves.
- Remember to **DECONTAMINATE!**

All Australian caving clubs should:

- Establish and implement a standard procedure for responding to caving enquiries from overseas visitors.
- Recommend to international cavers to leave their caving gear at home.
- Recommend members leave their gear at home when caving internationally.
- Provide information on WNS and decontamination procedures.

- Make gear available for use to prevent the risk of infected equipment entering Australia. (fund through grants).
- Establish and implement standard cave gear hygiene procedures to prevent the spread of any pathogens between caves.

Caving clubs can also help to fill critical knowledge gaps using minimal disturbance methods (eg climate data loggers, bat detectors, remote cameras)

- Identify bat caves and which species use them.
- Identify bat cave usage e.g. times of year etc.
- Monitor and record climatic conditions in those caves.
- Disease surveillance, recognise the signs and symptoms of WNS and report.

Wildlife Health Australia are currently trying to get *P. destructans* listed under Australian quarantine.

- The caving community could put pressure on the government demanding the disease be listed as a '**nationally notifiable disease'.**

What can ASF and ACKMA do?

- Update the Australian Speleological Federation (ASF) Minimal Impact Caving Code of Practice to include protocols and procedures around avoiding the spread of pathogens in general including WNS.
- ASF and Australasian Cave and Karst Management Association Inc. (ACKMA) can encourage all show caves to implement footware decontamination before visitors enter a cave.

Learn more about White nose syndrome by visiting https://wildlifehealthaustralia.com.au/ProgramsProjects/BatHealthFocusGroup.aspx

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ABSTRACT

Wilderness wild karst in Tasmania

CHRIS SHARPLES, Southern Tasmanian Caverneers

Many caves beneath human-modified landscapes are considered 'wild' caves because of their comparatively more difficult access and mostly un-modified cave features, which are both generally considered defining characteristics of 'wilderness'. However, such caves may be subject to hydrological (process) disturbance resulting from surface modifications, as well as high recreational pressures. This makes wild caves beneath wilderness landscapes (as widely defined) a distinctive category of caves whose lesser or negligible human disturbances of all kinds makes them more pristine examples of natural karst systems. At the same time, the lesser degree of previous karst exploration in wilderness areas make them interesting and enticing to cavers seeking new discoveries and challenging new projects in little-known regions.

Significant areas of limestone and dolomite in southwest Tasmania have substantial relief in high rainfall areas conducive to extensive cave development. Most of these areas remain little explored although some significant cave discoveries have demonstrated their caving potential. Areas such as the Weld Valley have very extensive carbonate bedrock with up to 600 metres theoretical cave depth potential but have only been explored (with some success) in a few parts. The lack of detailed geological mapping over much of the southwest — a legacy of Tasmania's environmental politics — means that the discovery of entire new karst areas remains possible and several such discoveries have occurred during the last decade. The wild nature of much of southwest Tasmania has also contributed to the survival of some unusual ecologies on karst, such as the remnant living stromatolites recently discovered on karst spring mounds in a very remote and rarely-visited south-west location. Although southwest Tasmania is a challenging environment, it is also sufficiently compact that wilderness cave exploration in the region remains within the scope of relatively light-weight expeditions.

Cave conservation issues arise regarding exploration of wilderness caves, particularly in respect of their potential to serve as pristine 'reference' examples of karst systems. However, these ethical issues have in recent times become more complex because of the likelihood that anthropogenic climate change will and indeed probably already is strongly affecting wild cave hydrology's and sedimentation processes in many regions, for example through increased flood magnitudes with increased coarse sediment transport into and through caves. This raises the still largely un-examined issue of what 'wilderness' even means in an age of global anthropogenic climate change, and how we should treat it.

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Wild caves in wilderness — anything special?

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The concept of wilderness (in reference to surface landscapes) is a widely challenged but arguably still meaningful concept. 'Wilderness' has been broadly defined as land entirely or dominantly un-modified by human technology. Wilderness is widely valued for a range of intrinsic benefits, ranging from ecosystem protection and resilience, recreation and health (including mental health) benefits, scenic values, experiential and inspiration values, and other non-depleting ('utility') benefits.

This concept of wilderness landscapes having value intrinsically or 'for what they are' underpinned a great deal of mid-late twentieth century environmental activism in Australia, notably the Lake Pedder and Franklin River conservation campaigns. However, in more recent decades the issue of wilderness has been challenged from several perspectives. The most discussed of these is that the indigenous pre-European human occupation of most places including Australia means there are few places globally that can truly be called wilderness; in response some have narrowed the definition of wilderness to refer to land unmodified by *recent* technology. The less discussed but most pervasive issue is that of climate change; it is rapidly becoming the case that no place on the Earth's surface will be unchanged by new weather patterns resulting from global climate change, which in turn affects vegetation, fire regimes, water, land-forming processes and fauna; this raises the question of whether wilderness is still a meaningful concept in the Anthropocene. If wilderness can no longer serve as 'benchmark' pristine environments against which to measure human change elsewhere, do they still have ecological value as environments with only indirect rather than direct human modifications? Questions such as these have barely been asked, let alone resolved.

A recent review of the wilderness concept by Hawes *et al.* (2018) argues that despite such objections, the *experience* of being in wilderness remains clearly distinctive and for some inspirational. Hence they argue that the concept of wilderness is still meaningful in some sense, even if some tweaking of definitions may be required.

This perspective suggests that whilst the ecological value of wild caves as pristine exemplars of their type has been thrown into some (unresolved) doubt by global climate change, the human experiential value of wild caves in wilderness clearly includes qualities less likely to be found in wild caves beneath modified landscapes. The greater access difficulties involved in wilderness mean that wilderness wild caves are less explored, less mapped, and thus more prone to speculation and imagination — in a word, more of a magnet for the adventurer.

Wilderness karst in Tasmania

Irrespective of issues surrounding the concept of wilderness, the extent of wilderness in Tasmania can be quantified and mapped using a methodology based on biophysical naturalness and distance from artificial disturbances which yields mapping that typically corresponds well with subjective perceptions of wilderness extent (see Hawes *et al.* (2018) for details of methodologies). Figure 1 depicts the extent of wilderness in western Tasmania as defined by this methodology.

Geological mapping across the western Tasmanian wilderness exists at good (1:25,000) scales in limited areas such as the Weld River valley but is mostly available only at very coarse scales because the Tasmanian Geological Survey has done little mapping in the region since large portions were declared national parks in the 1970s and 1980s. Figure 1 depicts the extent of known karstic bedrock in western Tasmania (excluding the Tarkine region) based on the existing geological mapping, however it is important (and interesting) to note that this mapping is known to be inaccurate or to omit karstic bedrock in some areas. For example, along the Jane and Denison rivers in SW Tasmania the writer has seen substantial areas of limestone and dolomite outcrops — some with caves — which are not depicted on the current best-scale geological maps.

Figure 1: Extent of wilderness landscapes (LHS) and known karstic bedrock (RHS) in western Tasmania (excluding the Tarkine region in the north-west). The wilderness quality map was prepared by the Tasmanian Parks and Wildlife Service (2005) using a revised version of the National Wilderness Inventory method. The distribution of karst area is based on Tasmanian Geological Survey maps at a variety of scales, as reproduced by Kiernan (1995).

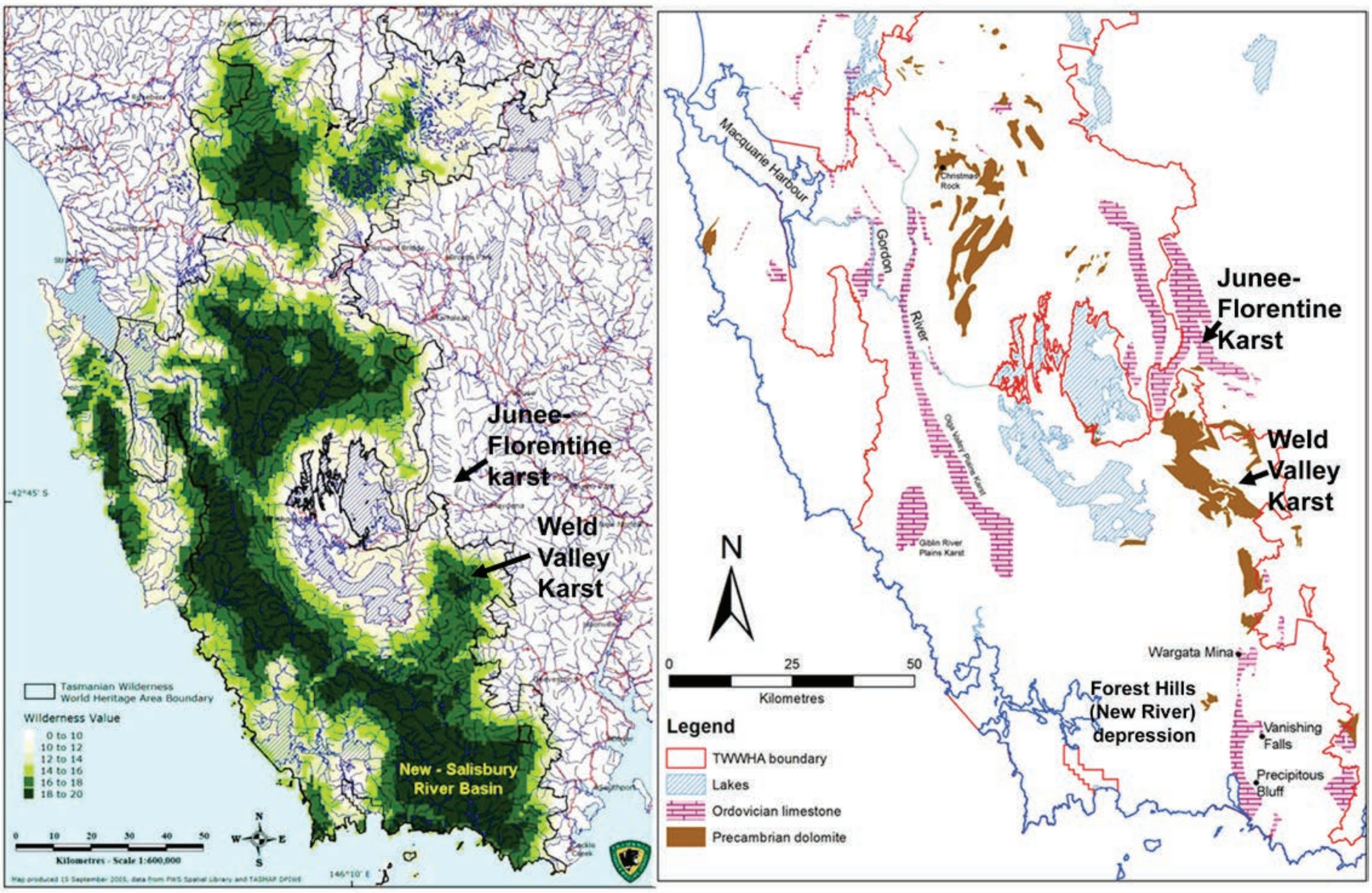


Figure 2: Christmas Rock, Lightning Plains, western Tasmania wilderness. Photo by Chris Sharples (1983).

The known karstic bedrock in western Tasmania is dominated by Ordovician-age limestones (equivalent to those forming the Junee–Florentine karst) and Precambrian-age dolomites (Mg-limestone) equivalent to the cavernous Hastings Karst. Whereas dolomite shows little cavernous development in many parts of the world, this is not the case in Tasmania where dolomite shows very extensive cavernous development in areas such as Mt Anne and the Hastings karst. Acidic soil and stream waters in western Tasmania may partly account for this unusual development.

Large areas of the known limestone and dolomite bedrock in western Tasmania forms flat poorly-drained, low-relief valley bottoms with little potential for cavernous development, such as in the Olga Valley and Vale of Rasselas. However, the western Tasmanian wilderness area also includes areas with some of the highest relief of carbonate bedrock in Tasmania, with up to 600 metres relief at the Weld Valley–Mt Anne, and around 400 m relief at areas such as Mt Picton and Mt Ronald Cross. Combined with high rainfalls in western Tasmania (up to 3000 mm per year in parts) there is considerable potential for cavernous karst development in the region. Whereas the potential for glacial sediments and cold climate slope deposits to choke and prevent cave development is present in some potentially karstic areas, this is also true of some of Tasmania's best-explored karst regions such as the Junee–Florentine and Exit Cave regions, where it constrains but has certainly not prevented extensive cave development.

Some early cave discoveries in western Tasmania's wilderness occurred during general exploration and survey trips. One of the earliest of these was an exploratory trip undertaken through western Tasmania during 1842 by Governor John Franklin and his wife Jane Franklin (not without grumbling from bureaucrats back in Hobart, since John was in fact the serving governor at the time and exploration was not seen to be amongst his vice regal duties). A large dolomite hill or hum called Christmas Rock was discovered at Lightning Plains by the track-cutters who prepared the way (and bestowed both place names). This notable feature has several arches, a stream cave and large sheltered overhangs under which the Governor's

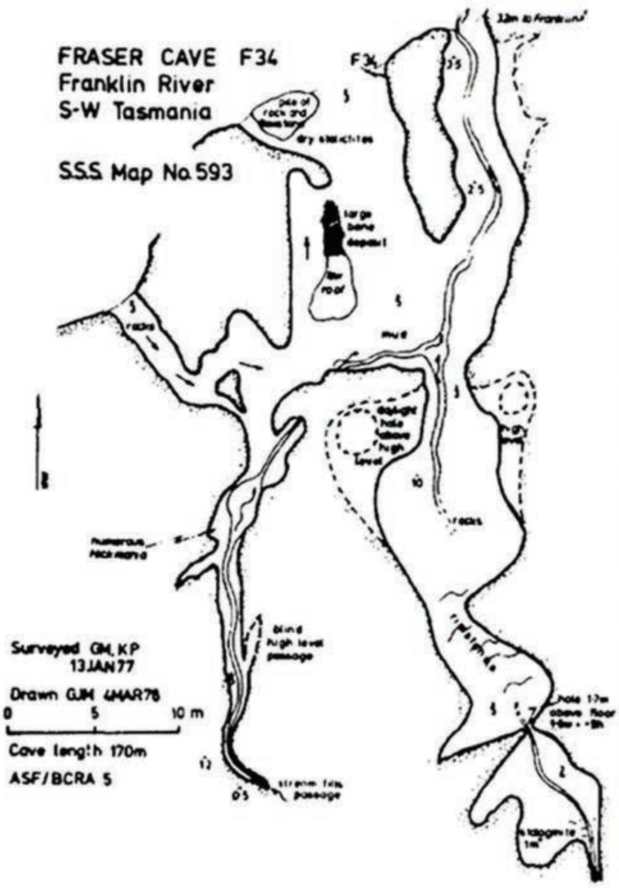


Figure 3: Kevin Kiernan and Rhys Jones excavating in Kutikina Cave (aka 'Fraser Cave') during March 1981. Photo by Greg Middleton. The discovery of Aboriginal occupation evidence in this cave was pivotal in deciding the High Court case which led to the stopping of the Lower Gordon Dam project and the protection of the Franklin River.

party camped. Despite its place in Tasmania's history, this wilderness karst feature remains little known and rarely visited to the present (but see Sharples 1999).

Probably the most intensive phases of cave exploration in the western Tasmania wilderness have been driven by conservation concerns, initially in response to a proposal for limestone quarrying in the cavernous Precipitous Bluff limestones during 1973, and then a few years later in response to plans for hydro-electric dams impounding cavernous limestone along the Gordon and Franklin rivers. In both cases the rationale was that the discovery and documentation of caves and their natural (and potentially cultural) contents could build a case for conservation of the wilderness they were situated in. Although the rationale for a quarry at Precipitous Bluff turned out to be rather shaky and unlikely to have proceeded, in the case of the Franklin River this rationale turned out to be the pivot on which the entire campaign to stop the damming of the Franklin River turned: after the incoming Hawke Labor Government declared the proposed dam illegal in 1983, the Tasmanian government High Court challenge to this legislation was only defeated by the presence of Aboriginal cultural heritage discovered in a cave on the banks of the Franklin River during 1981 by Kevin Kiernan, Bob Brown and Bob Burton (see Figure 3).

Pure adventure and the desire to explore has also motivated cave exploration in the Tasmanian wilderness, but to date has been limited to only a few obvious exploration targets relatively close to access, such as the very deep cave potentials of the Mt Anne north ridge (Weld Valley) and Mt Ronald Cross (both within a few kilometres of roads). Exploration of more remote karst areas has been very limited although one example was successful cave exploration at the very remote Vanishing Falls that was facilitated by helicopter access (Eberhard *et al.* 1991).

Forest Hills — a classic wilderness karst mystery resolved

The exploration of karst in the very remote Forest Hills karst depression (New River basin) in southwest Tasmania provides a good example of both the enticements and the pitfalls of cave exploration in wilderness. The New River catchment, between Federation Peak and Tasmania's south coast, is the largest river basin anywhere in Tasmania that has essentially no visible human disturbances such as forest clearance, tracks, roads or infrastructure, the only exception being a rough walking track and campsites near the tidal lagoon at the far downstream end of the river (Sharples 2003; see Fig. 4). The basin is one of the two largest areas of remote core wilderness in Tasmania, as measured by the National Wilderness Inventory method (see Figure 1). Right at that remote core lies a large enclosed landscape depression over 1 km wide and 60 m deep into which several large streams flow to disappear in at the deepest point. The existence of this feature had been known since the 1970s when the first 1:100,000-scale contour maps of the area were produced from air photos. However the New River basin has to this day remained rarely visited because it is one part of the Tasmanian wilderness that actually corresponds to the hype: it is in fact a very rugged (steeply incised) region cut by deep scrubby ravines and fully covered in thick-understorey rainforest (Figure 4), quite unlike the more accessible button grass moorlands that characterise much of the western Tasmanian wilderness. It really is very difficult country to access on foot!

Like many other young wilderness adventurers during the 1970s and 1980s, I had pored over maps of the south-west wilderness looking for exploration targets, and the Forest Hills depression virtually jumped off the map as a fascinating feature crying out to be explored. An enclosed depression that size with several large streams disappearing in its middle surely had to be hiding some big caves. Rumour held that only a very few people had attempted trips down the New River itself, and only one of these — a fabled trip on tractor inner tubes by Atilla Vrana and Jeanette Cox during the 1970s — was supposed to have visited the depression itself, some distance south of the river. The rumours mentioned a cave but no details seemed to be available. Drawn by the wildness of the river itself as much as by the depression, myself and Grant Dixon undertook an arduous 12-day bushwalk during 1986, in which we descended the river on a lilo and a micro-duckie. The going on the river was so

Figure 4: View south over the New River Basin and Forest Hills Depression (Photo by Chris Sharples).

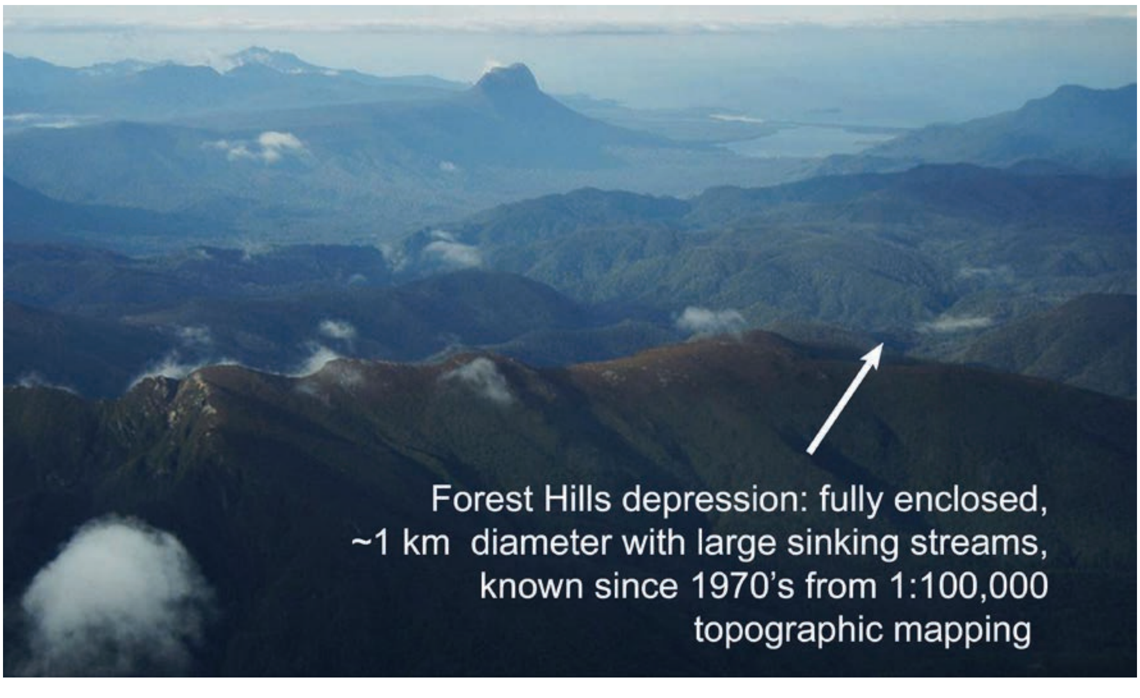


Figure 5: The only available campsite in the upper New River Gorge, *en route* to the Forest Hills karst depression in 2012. Photo by Chris Sharples.

difficult we spent four days just negotiating the main 8 km section of the gorge, and in the end did not make it to the depression itself. Nonetheless on finally reaching the mouth of the river at Prion Beach we felt like we had achieved a major bushwalking epic and were content. (I later published some purple prose about this trip in *Wild* magazine without identifying the river: see Sharples 1987.)

Years passed and while many people talked and wondered about the obvious mapped depression, I heard of few trips down the river and none into the depression. Life went on, the enthusiasms of youth faded, and I eventually shelved the idea of visiting the depression. Then in 2012 Rolan Eberhard conceived the idea of visiting the depression as part of a survey of karst in the Tasmanian Wilderness World Heritage Area (TWWHA) that he was undertaking for his employer, the Department of Primary Industries, Parks, Water and Environment (DPIPWE). The eventual exploration team comprised Rolan, Stefan Eberhard, myself and Grant Dixon, and this time we had helicopter transport to an open ridgetop north of the New River gorge. Even so, it still took us two days of hard scrub-bashing to cross the New River gorge and reach the depression. The terrain was so steep that our halfway camp was on shingles in the bed of the New River itself (see Figure 5), there being literally no riverside spots flat enough to pitch a tent on. (Fortunately it did not rain!)

We finally reached the low stream-sink point in the Forest Hills depression late on our second arduous day of scrub-bashing. There we found — as anticipated — a large 'train tunnel' cave taking all the depression drainage (see Figure 6). Disappointingly however, the big horizontal passage ended at a stream sump less than 80 metres inside the cave entrance. Indeed the high overhanging doline walls above the cave entrance were a more spectacular

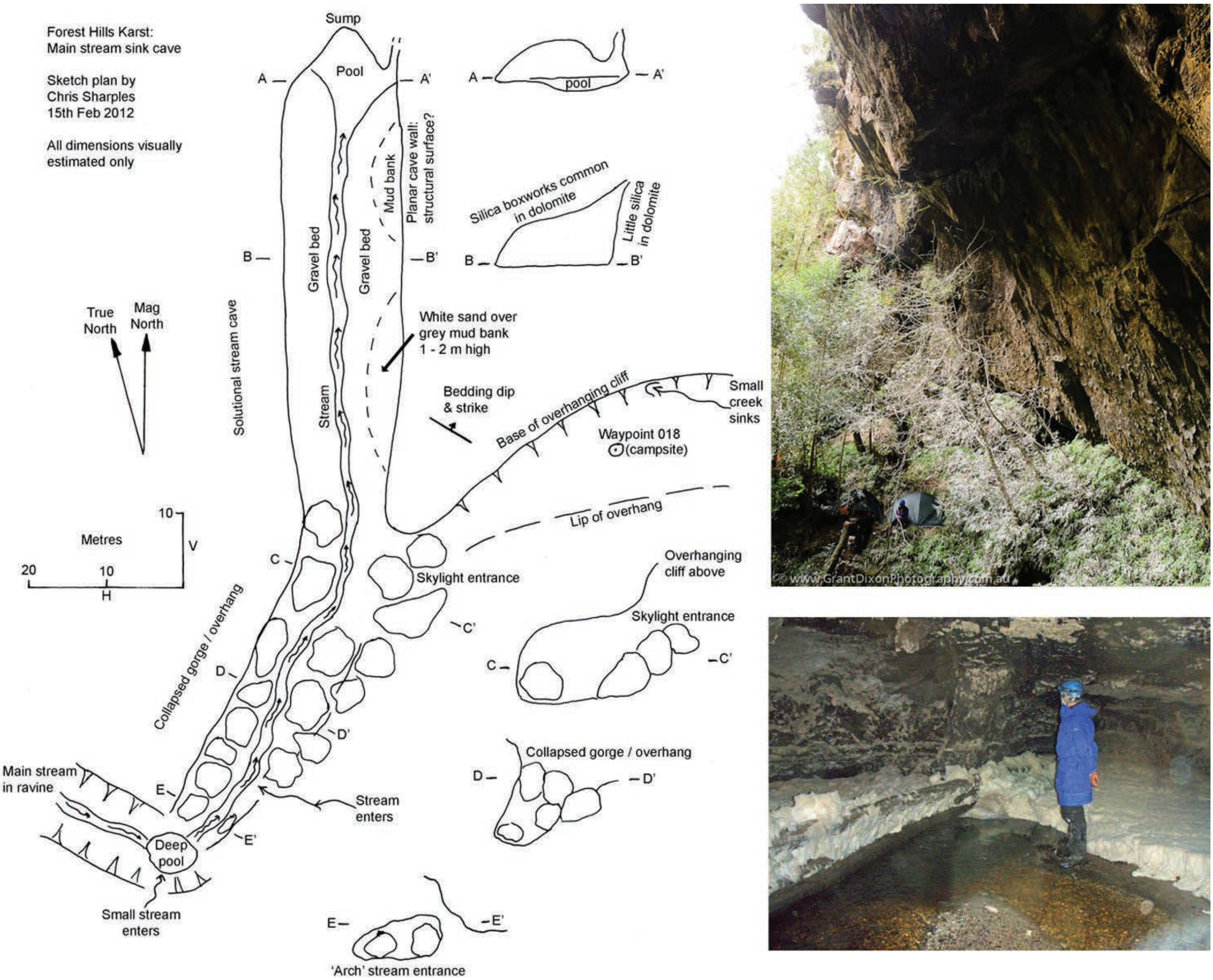


Figure 6: Plan of the streamsink cave at the bottom of the Forest Hills karst depression. Inset photos: Top — overhanging dolomite cliff adjacent streamsink cave (photo by Grant Dixon); visible white foam on vegetation indicates this area becomes a lake when inflows exceed the karst conduits' capacity. Bottom: the cave stream sump inside the streamsink cave (photo by Chris Sharples).

feature (Figure 6), and foam patches covering vegetation around and above the cave indicate that the karst water conduit is of limited size since the doline clearly turns into a deep lake when the stream discharges exceed the stream-sinks capacity. The geological mapping I undertook as part of my role on this trip indicates that despite the large size of the enclosed depression, the extent of the karstic dolomite bedrock is limited to a somewhat smaller fault block. Whilst we did not explore every corner of the depression, our results indicate that the caverneering potential of the Forest Hills Depression must, after all, be quite limited.

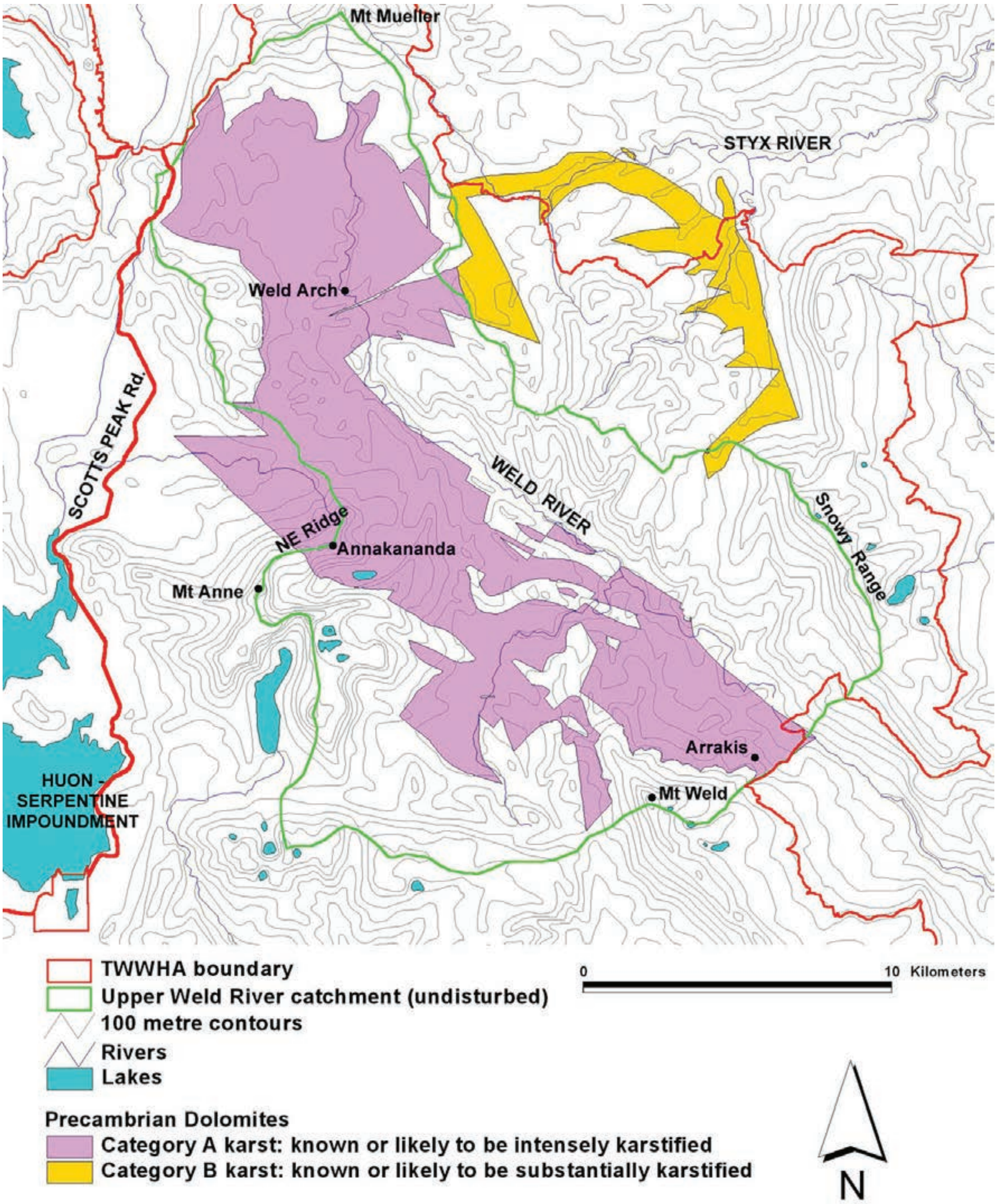
Disappointing? Yes, but also the (likely) truth, and satisfying to have determined the matter at long last. But there was one more intriguing discovery: there was essentially no naturally flat ground to camp on in the bottom of the depression, yet we found several small flat ledges obviously dug out of the soil slope and just big enough to accommodate our tents. These told us that we were not the first to visit the Forest Hills cave after all, yet we had heard or found no clear record of previous visits. It seems that not all wilderness explorers feel the need to publish their findings. This is not a bad thing.

The Weld Valley – high wilderness wild cave potential?

So where are the big promising wilderness wild cave potentials in Tasmania? If anybody were asking me, I'd say it's the Mt Anne–Weld River Valley karst. Regional-scale geological mapping was undertaken in this area prior to its inclusion in the TWWHA, so the extent of relatively pure Precambrian dolomite is known with some confidence, despite the undisturbed and mostly untracked nature of this mostly-forested wilderness area (see Figure 1).

The Weld Valley dolomites (Figure 7) cover a nearly-continuous surface area of 140 km^2, comparable to the Junee–Florentine karst, and cover a vertical range of 600 m which is

Figure 7: Geological map illustrating the extent of potentially cavernous Precambrian dolomite in the Weld River Valley, with some key known caves indicated.



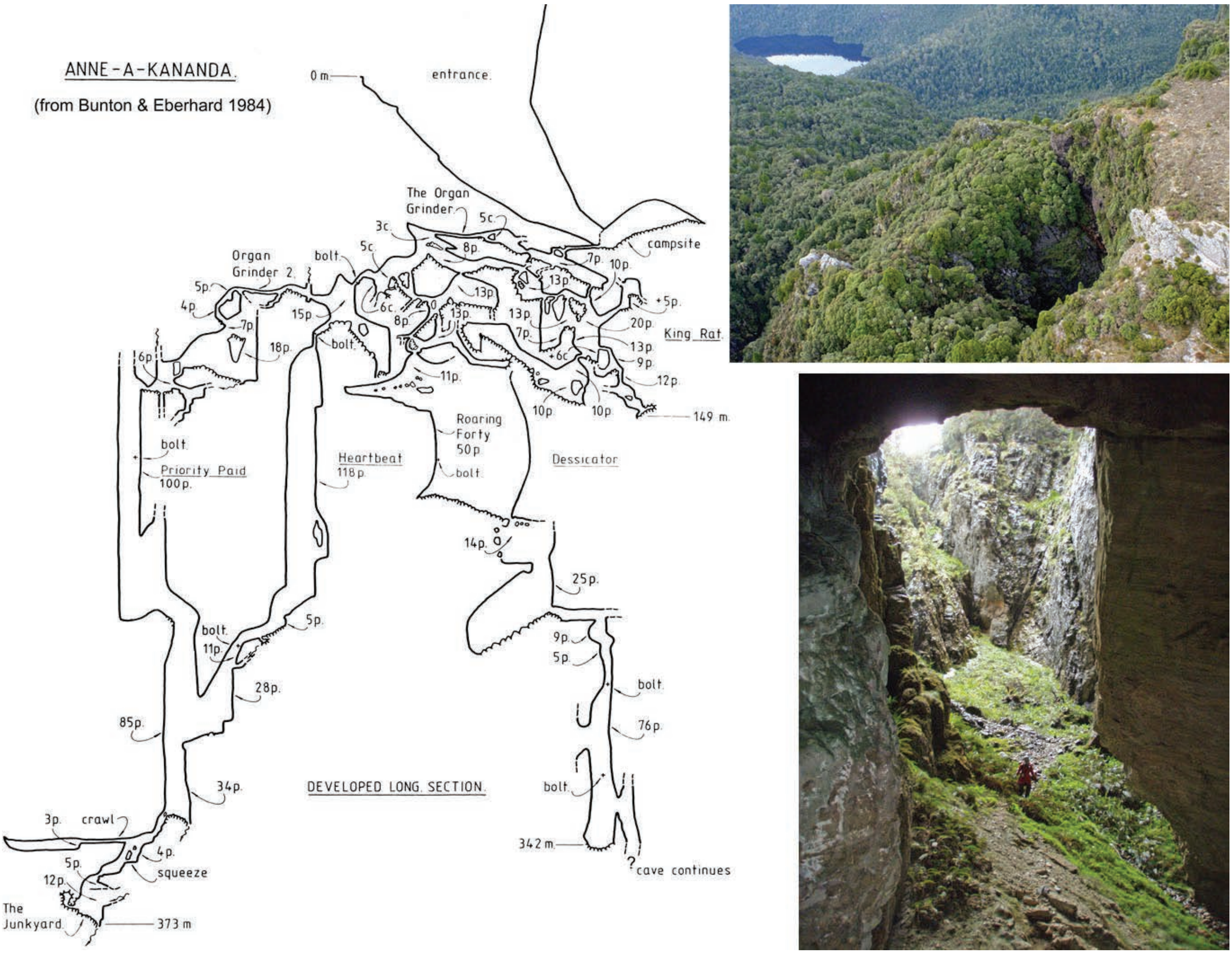


Figure 8: Anne-A-Kananda Cave, a very deep cave in the Weld Valley dolomites (at Mt Anne North-east ridge), which at one time was Tasmania's deepest known cave. Inset photos of Anne-A-Kananda entrance: upper photo by Rolan Eberhard, lower photo by Chris Sharples.

greater than the Junee–Florentine. Nearly all the dolomite occupies moderately to steeply sloping ground, with only minor low-relief valley-bottom areas, yielding the hydraulic gradients necessary for percolating groundwaters to form caves. As elsewhere in western Tasmania, glacial and slope sediments may have inhibited cave development in parts of the valley, but the existence of large known caves demonstrates that this is not a deal-breaker.

Caves of substantial scale have been explored in three relatively-accessible areas within the Weld dolomites, namely at Mt Anne North-east Ridge (accessible from Scott's Peak Road), Arrakis (accessible from nearby forestry roads via the Mt Weld track) and at the Weld River Arch where the entire river flows underground for a short distance (easily visited on rafting trips down the river). Amongst these, the north-east ridge is of note for the cave Anne-A-Kananda, which once held the record as Tasmania's deepest cave (Figure 8). Kiernan (1990) has speculated on a possible hydrological connection between Anne-A-Kananda and known springs at the lower margin of the dolomite, which if confirmed (and humanly explorable) would yield Tasmania's deepest cave at about 600 m depth. Away from the three known cavernous areas, numerous large enclosed depressions are evident on 1:25,000 contour maps and suggest widespread cavernous or at least karstic development.

There has been only very limited and sporadic exploration for caves in the Weld Valley dolomites away from the three best-explored areas at Northeast Ridge, Arrakis and Weld Arch. Uninspiring results of a handful of such trips recorded in the Southern Tasmanian Caverneers newsletter *Speleo Spiel* give a distinct impression that the area has little to offer cavers. However, it is worth reminding ourselves that exploration away from the three main areas amounts to literally a handful of exploratory attempts. It is worth asking ourselves how much karst would be known in the Junee–Florentine area is that was all the exploration that had occurred there. We would probably think that Growling Swallett and one or two other entrances was the extent of cavernous development there. Of course we now know that there is much more cave development than that, but remember how much exploration it has taken to demonstrate it!

Should we even explore wilderness wild caves?

It is sometimes suggested that knowing too much about nature can destroy its wonder, that by reducing nature to 'data' we destroy its value as a source of inspiration. This attitude was encapsulated by the poet John Keats in his line that Isaac Newton had 'destroyed the poetry of the rainbow by reducing it to a prism' and that science would 'unweave a rainbow'.

An implication of this notion is that the more we learn about nature, the less we value it; hence we should let it remain mysterious, so that we might continue to value it and be inspired by it. If we accept this, we should leave wild caves alone lest we find out so much about them that they are no longer of interest and no longer inspire us sufficiently to value their wildness.

However, I think Keats view — still widely held today — is only really held by those poets and mystics who want to believe certain nonsensical propositions about the world; they despise science because it tells them that their favourite fantasies are not true. But those poets and mystics — like Keats — almost certainly never had a scientific epiphany, they never experienced the exhilaration of finally — through observation, data and testing — understanding how some natural phenomenon really works. They only condemned science because they never understood that reality is more inspiring than fantasies and mysticism.

So, I do not see exploration of wilderness karst as being in any way undesirable; on the contrary better knowledge of wild karst yields better appreciation of its value and more capacity to protect it. However, the best protection of wilderness karst lies in its wildness; if access is difficult, damaging levels of trogging are unlikely. To protect wild wilderness caves, protect wilderness.

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ABSTRACT

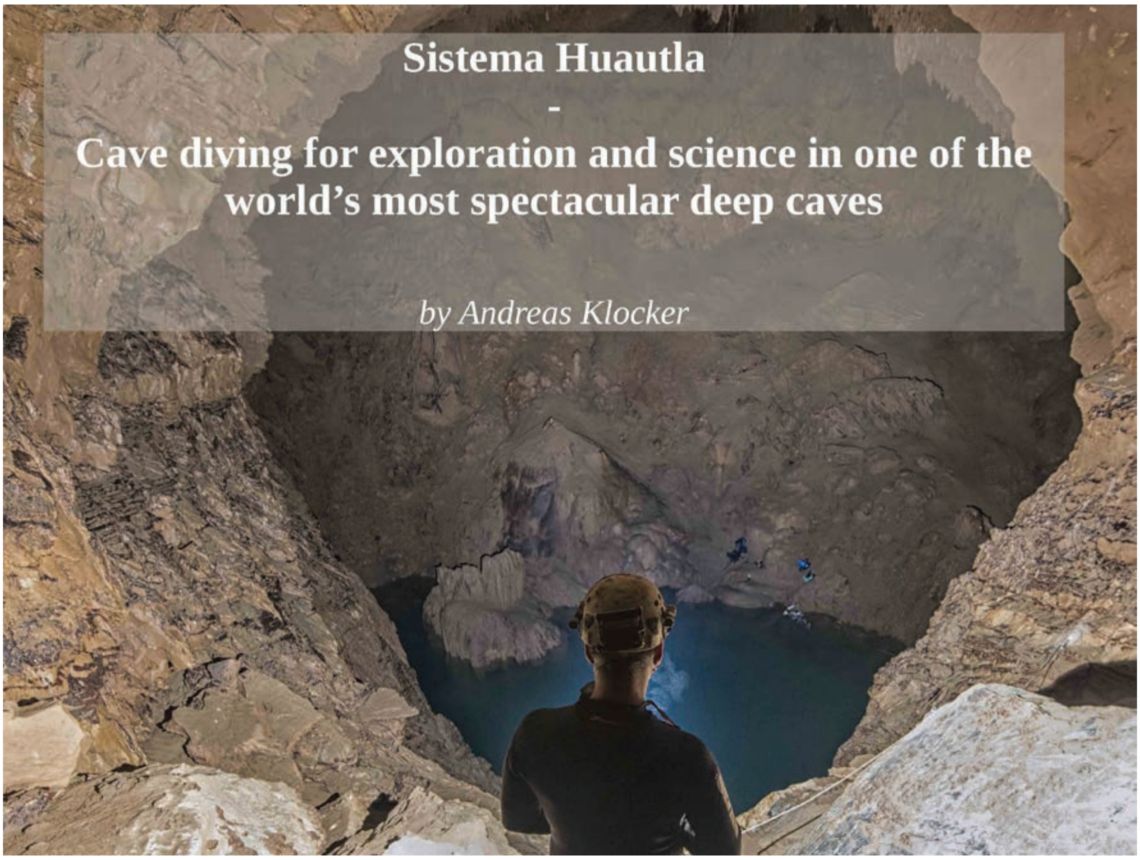
Huautla — cave diving for exploration and science in one of the world's most spectacular deep caves

ANDREAS KLOCKER PhD, Southern Tasmanian Caverneers

Since 2016 I have been leading cave diving expeditions to Sistema Huautla, one of the world's deepest cave systems located in the southern Mexican state of Oaxaca. The goal of these expeditions is to connect Sistema Huautla with its resurgence in the 10-kilometre distant Santo Domingo Canyon. The successful connection of Sistema Huautla with its resurgence would result in the world's deepest and most spectacular cave traverse.

In this talk, I will focus in particular on the two-month long expedition in 2018 which was one of the most ambitious and challenging cave diving projects ever attempted. We pushed two months to surpass the previous limit of exploration reached in 1984, some five kilometres into the mountain, beyond six sumps, to continue the exploration of Sump 7 with the hope it will lead us to the underground river connecting Sistema Huautla with its resurgence.

It was during one of these long exploration trips to the end of the cave when unexpected rainfall started filling up the cave we were exploring, trapping myself and five others for three days. All we had was one space blanket, four granola bars, and the wetsuits we were wearing.

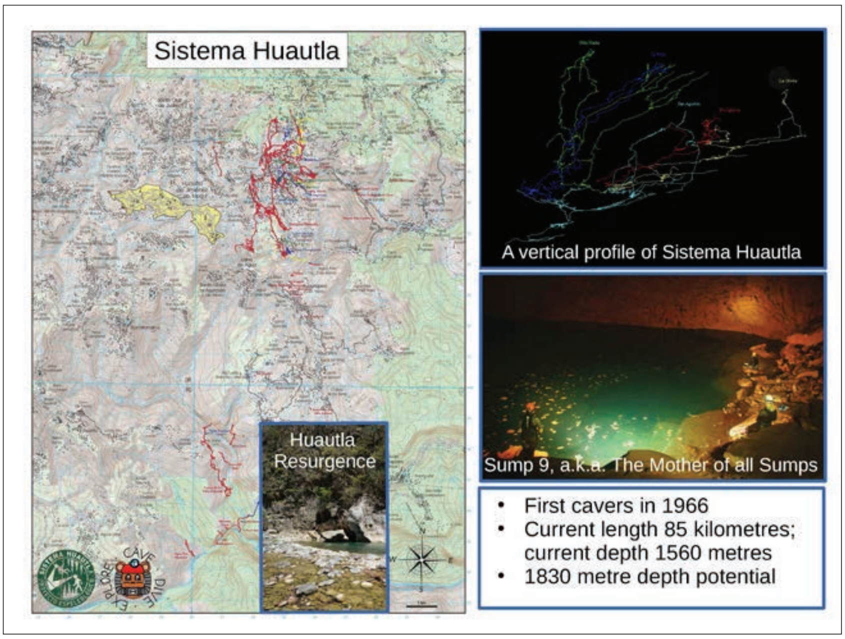


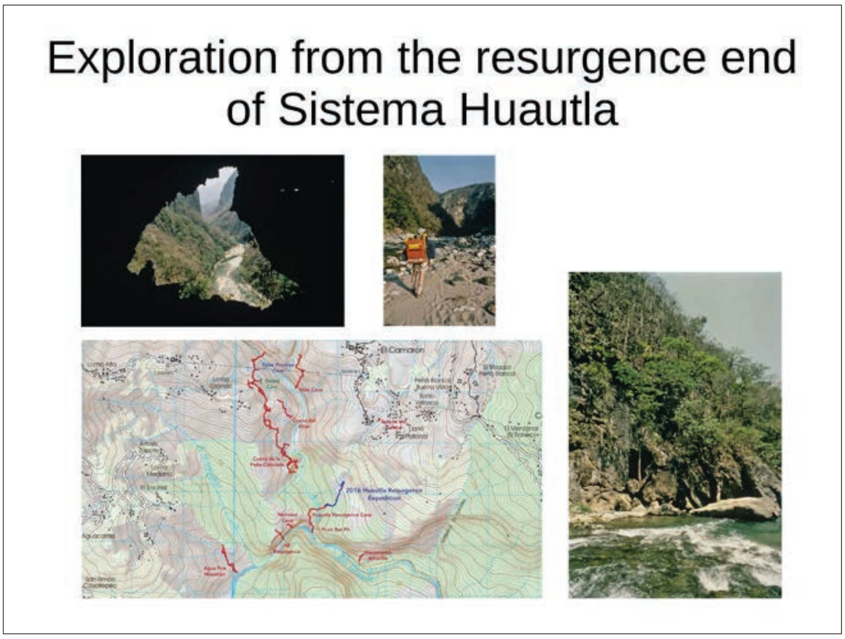
Outline

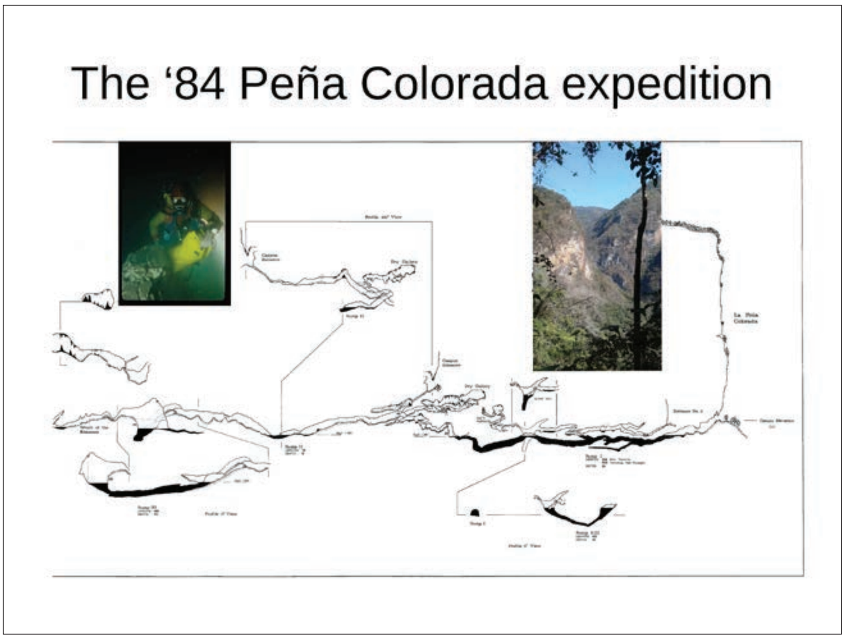
- A bit of history – a summary of the major expeditions in the past, pushing towards the connection of Sistema Huautla with its resurgence.
- The beginning of an obsession – a summary of our 2016 and 2017 expeditions to the Huautla Resurgence.
- The big one – exploration of the Cueva de la Peña Colorada - diving one of the most remote sumps on Earth.

A bit of background and history on cave exploration in Sistema Huautla

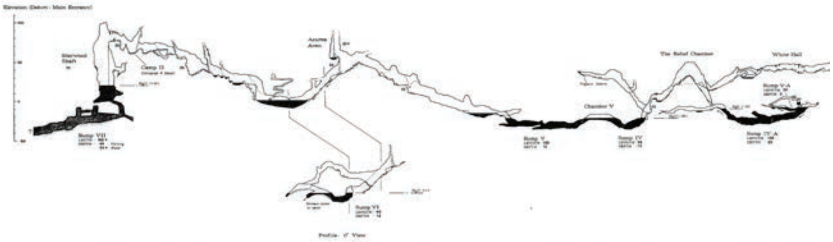
Huautla de Jimenez, Oaxaca, Mexico

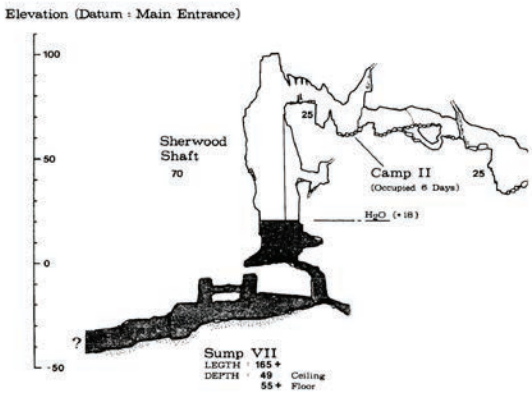

Sistema Huautla
A vertical profile of Sistema Huautla
Huautla Resurgence
Sump 9, a.k.a. The Mother of all Sumps
• First cavers in 1966
• Current length 85 kilometres; current depth 1560 metres
• 1830 metre depth potential


Exploration from the resurgence end of Sistema Huautla


The '84 Peña Colorada expedition

The '84 Peña Colorada expedition

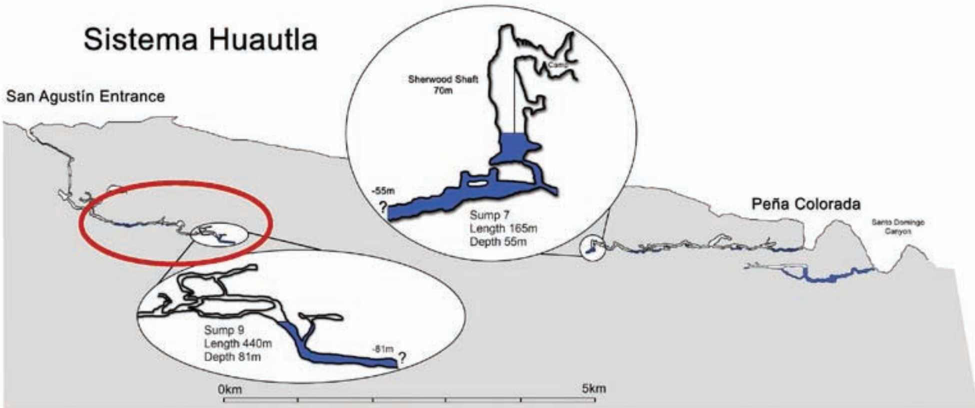




A total of 7.8 kilometres of virgin territory leading into the plateau were surveyed on this expedition with 1.4 kilometres of this distance totally underwater, comprising 7 sumps, the longest of which was 524m in length. The expedition established the first subterranean camp set beyond an underwater tunnel. The logistics of apparatus transport (a pyramid supply system) and problems with nitrogen narcosis in the final underwater corridor led to a decision to retreat.

The development of the CIS-Lunar rebreather

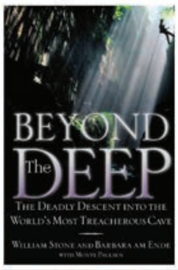
The '94 San Agustín expedition

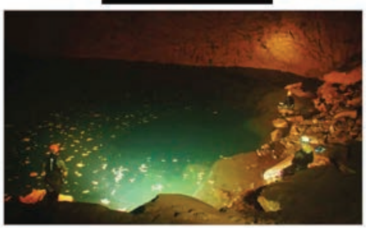


For 17 years, since its discovery in 1977, the flooded tunnel marking the deepest point in Sistema Huautla, Oaxaca, México - a remote place known as the San Agustín Sump - remained unexplored. Cave diving efforts using traditional Scuba in 1979 and 1981 failed to pass the underwater tunnel due to the logistics of transporting sufficient cave diving equipment down 92 vertical pitches and tension traverses. The sump lies at a depth of 1325 meters and requires the use of multiple, staged underground camps in order to reach it. The focus of the 1994 expedition was to use modern closed cycle life support systems (rebreathers) to allow for protracted underwater exploration at the San Agustín Sump and, hopefully, to reach air filled galleries beyond the sump that led into the heart of the Huautla Plateau.

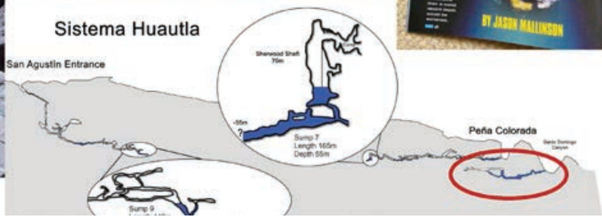
- The team used the newly developed rebreathers to crack Sump 1, which proved to be 430 meters long to a small airbell, followed by another sump of 170 metres length.
- The expedition was to be, this success was marred by the death of cave diver Ian Rolland during the exploration.

- After a 6 day body recovery exercise the exploration resumed and some weeks later Dr. Bill Stone and Barbara am Ende dived through both the sumps, finding a total of 3.3 kilometers of new passage
- They were halted at another sump which they called - sump 9, aka "The Mother of all Sumps"!

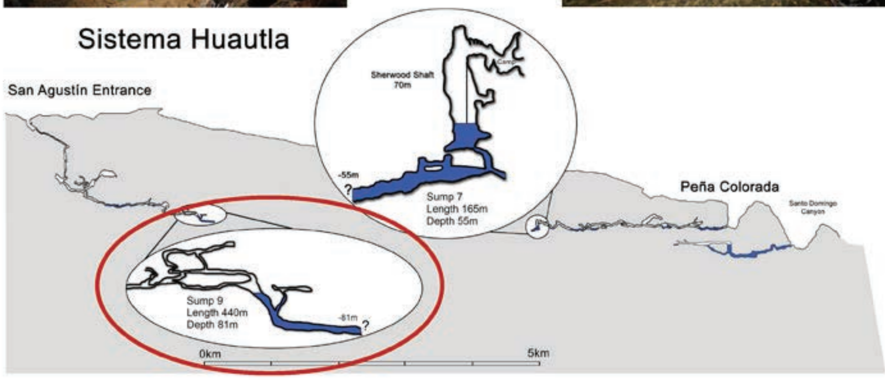




The '95 & '01 Huautla Resurgence expeditions



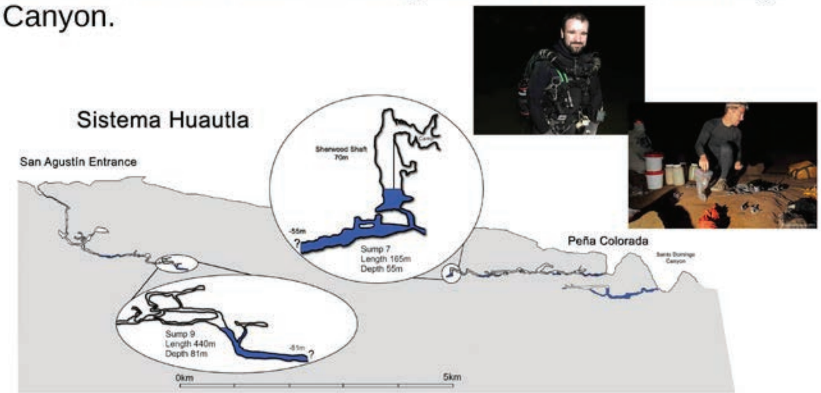
The '13 San Agustín expedition



- Over 6 weeks, 40 cavers supported 2 push divers, Jason Mallinson and Chris Jewell, so they could push Sump 9.
- On the final dive, Jason Mallinson pushed the sump to a distance of 440m and a depth of 81m. The passage continued big, with Jason estimating it to quickly reach a depth of over 100m.
- This expedition renewed interest in the exploration in Sistema Huautla.

Beyond the Sump Expeditions

- The goal: A sustained effort of an international team of cavers and cave divers to push towards the connection of Sistema Huautla with its resurgence in the Santo Domingo Canyon.



Beyond the Sump Expeditions Huautla Resurgence 2016/17

Our support team:


Bill Stone (USA)


Alejandra "Alex" Mendoza (MEX)


Alma Rodríguez (MEX)


Ernie Garza (USA)


Fernando Hernandez (MEX)

The rest of the 2016/2017 team:


Andreas Klocker (AUS/AUT)


Zeb Lilly (USA)


Chris Jewell (UK)


Connor Roe (UK)


Gilly Elor (USA/ISR)


Max Fisher (UK)


Dave Bardi & Sandy Varin (AUS)


Matt Vinzant (USA)

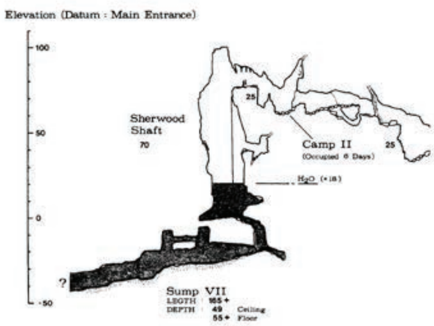
Beyond the Sump Expeditions Huautla Resurgence 2016/17







Return to the Peña Colorada - 34 years later...



- The goal: Continue the exploration of Sump 7, and push towards Sistema Huautla.
- 

  M. L. Barker, 1408 Chap... man Bldg.

  MEN WANTED for hazardous journey, small wages, bitter cold, long months of complete darkness, constant danger, safe return doubtful, honor and recognition in case of success.
  Ernest Shackleton 4 Burlington st.

  MEN—Neat-appearing young men of pleasing personality,

- We will make use of the latest in dive gear technology, including mixed gases, dual rebreathers, Lithium-powered scooters, and habitats.

Return to the Peña Colorada - the team

- Adam Haydock (USA)
- Adam Walker (CAN)
- Alejandra Mendoza (MEX)
- Andreas Klocker (AUS/AUT)
- Andrew Atkinson (GBR)
- Charlie Roberson (USA)
- Chris Jewell (GBR)
- Connor Roe (GBR)
- Dane Motty (USA)
- Dave Watts (GBR)
- Fernando Hernandez (MEX)
- Gareth Davies (GBR)
- Gilly Elor (ISR/USA)
- Jim Warny (IRL)
- Josh Bratchley (GBR)
- Katie Graham (CAN)
- Kyle Moshell (USA)
- Matt Jenkinson (GBR)
- Matt Vinzant (USA)
- Maxwell Fisher (GBR)
- Michael Waterworth (GBR)
- Mirek Kopertowski (POL)
- Teddy Garlock (USA)
- Tomasz Kochanowicz (POL/CAN)
- Zeb Lilly (USA)

Cutting-edge rebreather technology...

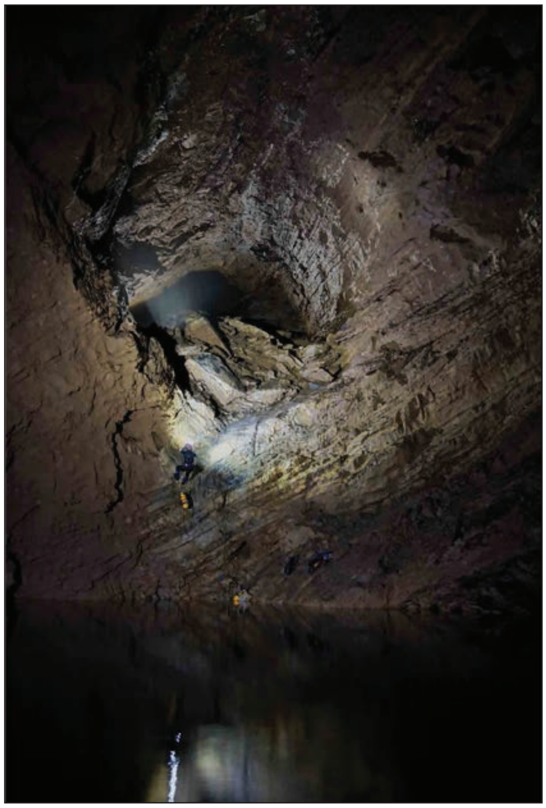
...carbon fibre tanks filled with Trimix...

...long-range scooters and dry tubes.

Return to the Peña Colorada

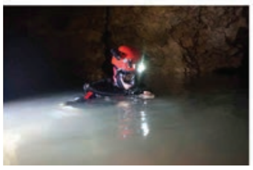
A lot of time is spent sorting/maintaining/fixing gear…

Return to the Peña Colorada

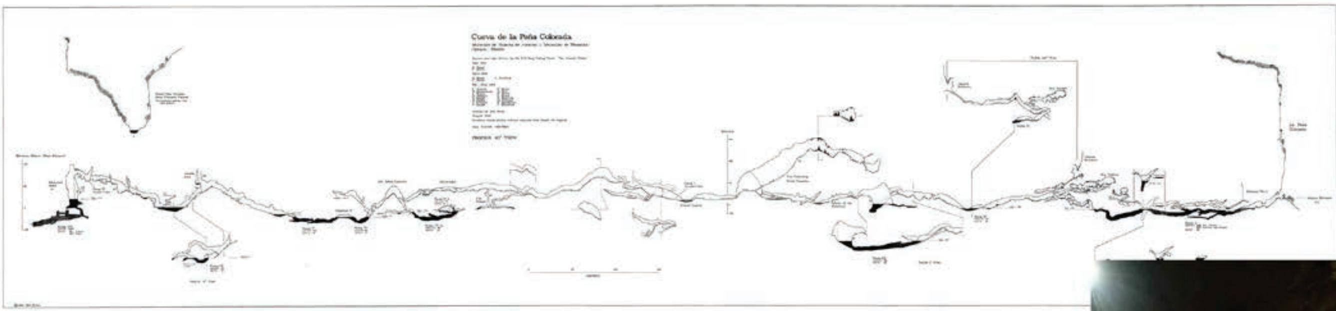



1984
2018





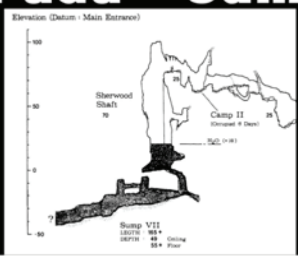
The beginning of a long trip...



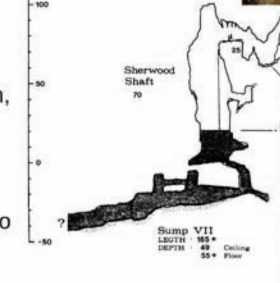
Cueva de Peña Colorado
Mpios. Huautla de Jiménez and Mazatlan
Oaxaca
AMCS Activities Newsletter no. 14, follows p. 54, 1984

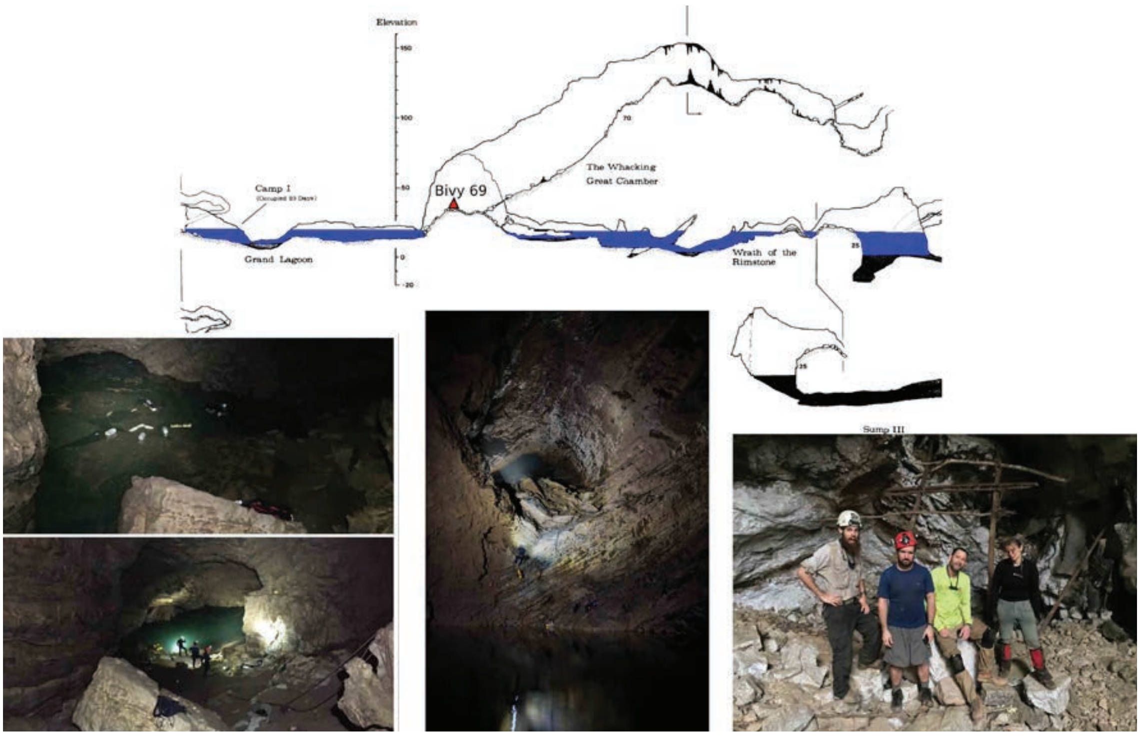


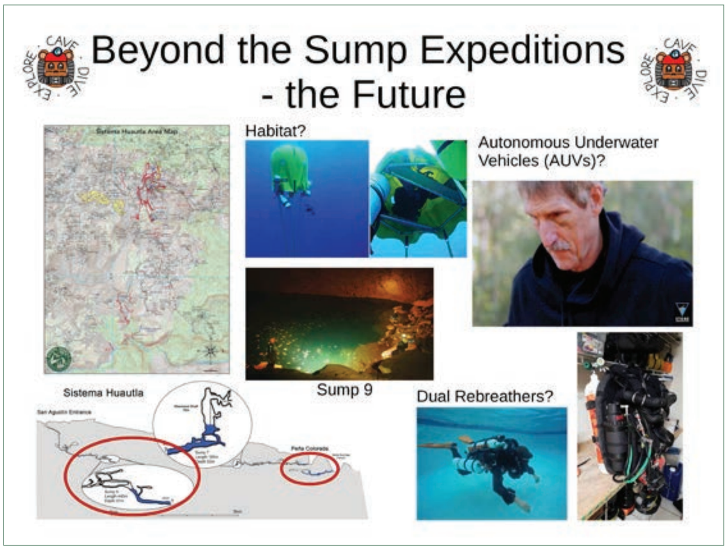
Cueva de la Peña Colorada - Sump VII



- After 3 weeks we started diving Sump 7.
- Sadly, only a few tens of metres beyond the previous end of exploration, a rock pile stopped progress
- As opposed to the '84 expedition, no flow was observed.
- After 4 dives, without finding a way on, we started to retreat.
- We dumped a dye into Sump 7 to see if there is any connection to the resurgences in the Santo Domingo canyon.





Elevation
150
100
50
0
-20
Camp I
Bivy 69
The Whacking
Great Chamber
Grand Lagoon
Wrath of the
Rimstone
Sump III


Beyond the Sump Expeditions
- the Future
CAVE · DIVE · EXPLORE
Habitat?
Autonomous Underwater
Vehicles (AUVs)?
Sistema Huautla
Sump 9
Dual Rebreathers?


CAVE • DIVE • EXPLORE
Exploration
BEYOND THE SUMPS OF
Sistema
Huautla
MEXICO
https://www.beyondthesump.org
https://www.facebook.com/cavedive

ABSTRACT

Slaying the Beast — mapping Kubla Khan

ALAN JACKSON, Southern Tasmanian Caverneers

Kubla Khan in Tasmania's Mole Creek karst area is considered Australia's most spectacular cave by many in the caving community. Massive chambers, acres of flowstone and an abundance of exquisite speleothems draw visitors from around the world. Despite its grandeur, and no doubt in part because of it, a thorough survey and detailed map didn't exist until 2017.

Maps produced during the principle exploration period (circa 1967–1973) were relatively low on detail and didn't include all known passages. The sheer size of the cave made the amount of time (and paper!) required to produce a map at anything better than ~1:1000 a mammoth task. In the 1980s, as management of the cave became a key concern by the then National Parks and Wildlife Service, it became obvious a good map of the cave was required.

The Southern Caving Society were commissioned by NPWS to complete such a survey but despite accurate surveying of >80% of the cave's known passages, the project stalled at the usual hurdle — collection of detailed in cave sketches and final map drafting. The idea would sit dormant for over twenty years until a box containing the 1980s data was discovered and the seed was sown.

Liberal applications of water and fertiliser by key personnel during 2013 saw that seed germinate and the first underground survey trip took place in January 2014. Three and a half years (and over 700 person-hours) later a 'final' map was produced which (hopefully!) included all known passages at the scale of 1:250.

This presentation will provide a synopsis of the methods employed to collect and collate in-cave data and create a final digitally drafted map and identify the keys ingredient to success.

Slaying the Beast — mapping Kubla Khan

Alan Jackson

Kubla Khan in Tasmania's Mole Creek karst area is considered Australia's most spectacular cave by many in the caving community. Massive chambers, acres of flowstone and an abundance of exquisite speleothems draw visitors from around the world. Despite its grandeur, and no doubt in part because of it, a thorough survey and detailed map didn't exist until 2017.

Maps produced during the principle exploration period (circa 1967–1973) were relatively low on detail and didn't include all known passages. Some were even hilariously inaccurate. The sheer size of the cave made the amount of time (and paper!) required to produce a map at anything better than ~1:1000 a mammoth task. In the 1980s, as management of the cave became a key concern by the Parks and Wildlife Service, it became obvious a good map of the cave was required. The Southern Caving Society were commissioned by PWS to complete said survey but despite accurate surveying of >80% of the cave's known passages by Jeff Butt and co, the project stalled at the usual hurdle — collection of detailed in cave sketches and final map drafting. The idea would sit dormant for over twenty years until a box containing the 1980s data was discovered and the seed was sown. Liberal applications of water and fertiliser by key personnel during 2013 saw that seed germinate and the first underground survey trip took place in January 2014. Three and a half years (and over 700 person hours) later a 'final' map was produced which (hopefully!) included all known passages at the scale of 1:250.

Step 1 was sorting the paperwork. Rolan Eberhard (DPIPWE) and the Mole Creek Parks and Wildlife Service made all this happen (it's no coincidence that Parks' abbreviations (PWS) is also an abbreviation of 'Paper Work Service').

With a gold-pass permit and cave key issued the collection of underground data commenced. An initial sweep of the standard tourist trip route was undertaken with a DistoX and PDA. This allowed us to quickly obtain the backbone of the cave and confirm the new data matched the historic SCS dataset (which we believed to be very accurate, since that was Jeff Butt's forte). Every survey station on this backbone had a labelled pink tape attached for the life of the project.

Highly sensitive sections of the cave (e.g. Dulcimer) were only allowed to be visited once so synchronous shot data and sketch collection was conducted. Data was plotted by hand (pencil and paper) and sketching done to scale.

Lower sensitivity areas had shot data collected first (leaving labelled stations), the data was reduced electronically and its accuracy checked, then in-cave sketching was completed on a subsequent trip using a printed line plot (pencil and paper again). Personally I am not a fan of PDA sketching, particularly for projects requiring high detail collection. Significant detail (large speleothems, rocks, other features) were located with DistoX devices and plotted to scale on numerous occasions — otherwise it was very easy to get 'lost in space' even with a printed line plot.

In large passages multiple data lines were collected to allow more accurate positioning of floor detail during the sketch phase (a single centre line plot down the middle of 60 m wide passage simply doesn't cut it).

A large number of strategically placed survey stations were photographed (close up and at a distance) to allow for easy relocation in the future for rectifying errors, tying in future discoveries etc. once the pink tapes were removed at the end of the project.

Some small and or complicated passages (e.g. Helictite Dungeons) were surveyed and sketched simultaneously to rough scale and re-sketched out of the cave following data entry and line plot printing.

Once all shot data and sketches were collected the sketch sheets were digitally scanned and stitched together in Adobe Illustrator (AI), a scalable vector graphics (SVG) drawing software. Some of the 'sketch to scale in the cave' sheets were 'morphed' in Compass 'Sketch Editor' software prior to stitching (note that this only works on fairly accurate sketches as poorly 'to scale' sketches result in too much distortion for the detail to be useful). The sketches were then digitised in AI.

The AI file was broken into multiple layers (e.g. passage outline, floor substrate, water arrows, slope indicator, pretties, rocks, edges and ledges etc.) and many layers were further broken into sublayers (e.g. the 'pretties' layer was divided into straws, stalagmites, stalactites, helictites, shawls, flowstone etc.). While this was tedious to implement it paid enormous dividends later on when producing different maps at different scales as you can selectively remove or add particular features throughout the entire map with the check of a box. The digital drafting (with SVG software) and layering system utilised allows for simple production of other maps at any scale and various lower scale maps have been produced (e.g. maps for the Cave Access Policy Zoning Statements for Kubla Khan and zoning maps for the cave's Rescue Plan)

Plan view (with cross sections) and a long section view at 1:250 scale were produced. Due to the size of the overall map in plan view at 1:250 it was broken into overlapping A1-sized artboards. The orientation of the majority of the cave passages allowed a single long section view along the 255–75 degree plane to fit on a continuous length, A1 height sheet. A1 was selected for hard copies as printers up to that size are common and it is more manageable than A0. It was anticipated that the majority of map viewing would occur electronically on a computer screen, however a single page electronic version has not yet been produced (file size and artboard size a bit too large for the software and my laptop to handle just yet ...). There's always more to do, particularly with David Wools-Cobb constantly rearranging the bootwash stations and stringlines in the cave, making the map out of date!

Genghis Khan, which is effectively a cut off section of Kubla Khan, was also surveyed during the project and aligns with the plan view map sheets of Kubla.

Vital statistics

Cave — Total m: 'cave length' m : depth

Genghis — 1016 : 700 : 79

Kubla — 13,250 : 4,950 : 114.5

102 cross sections

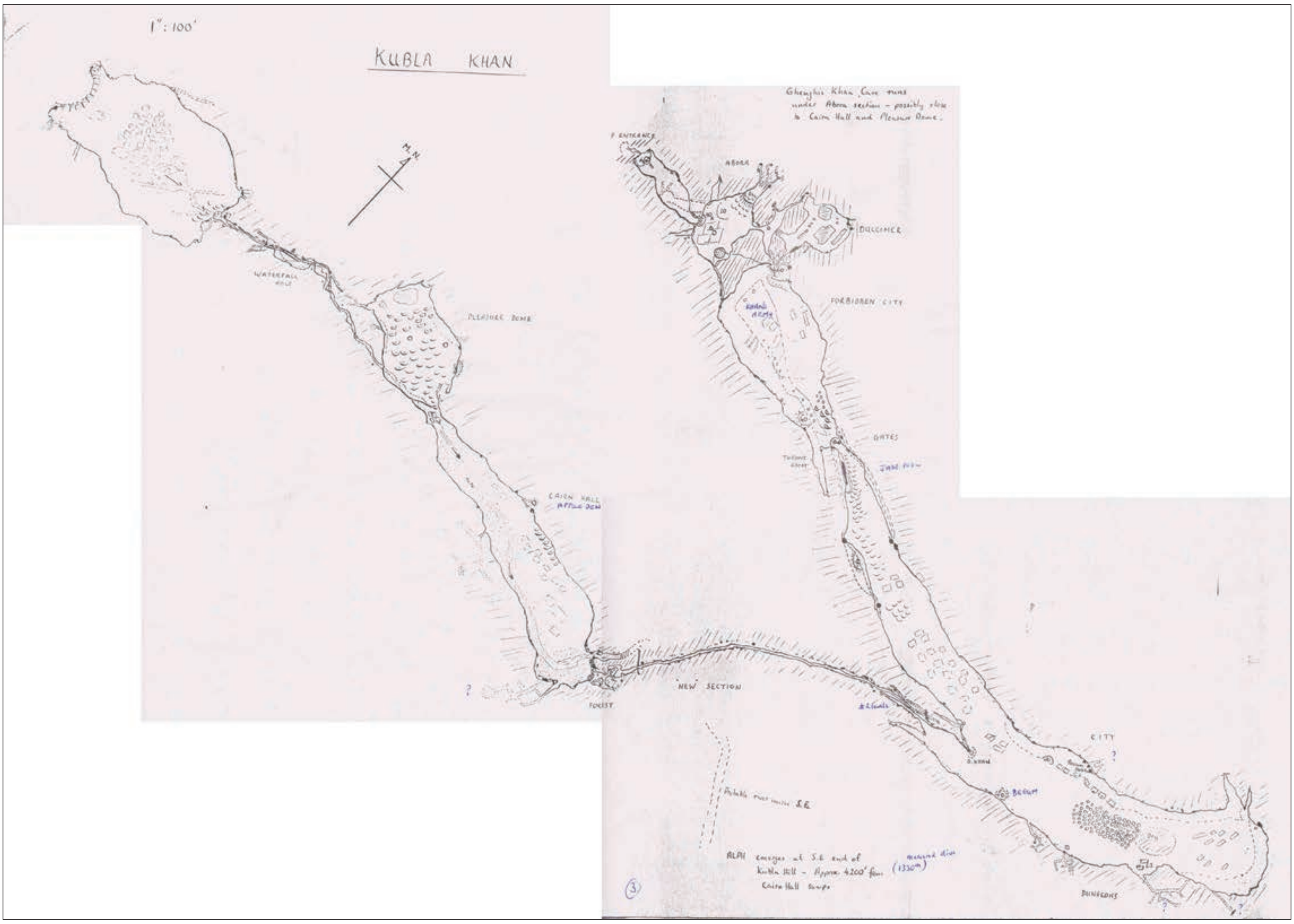
414 person hours underground (AJ — 130)

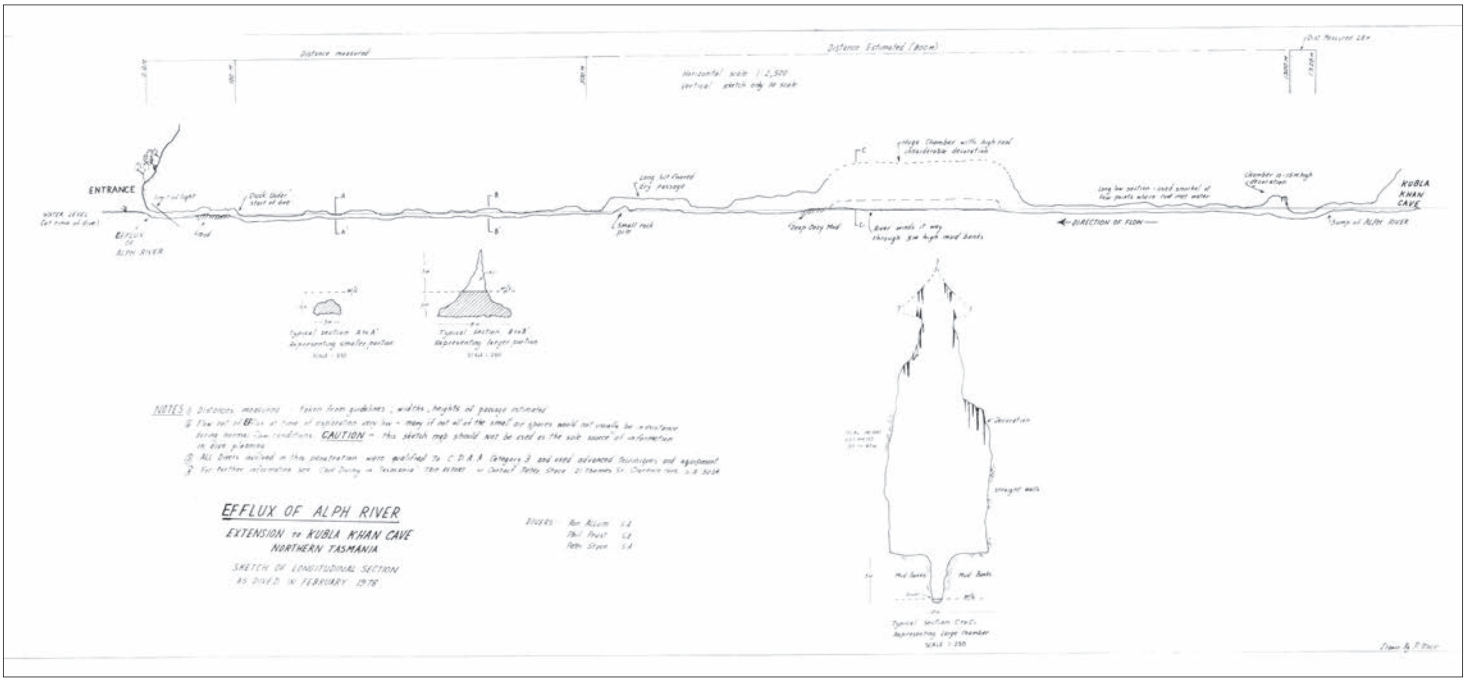
293 person hours 'desktop' (data and digital drafting) — (AJ 286 ...)
(Does not include time spent on travel and reporting, PWS time or 1983 TCC Sunless Sea mapping)

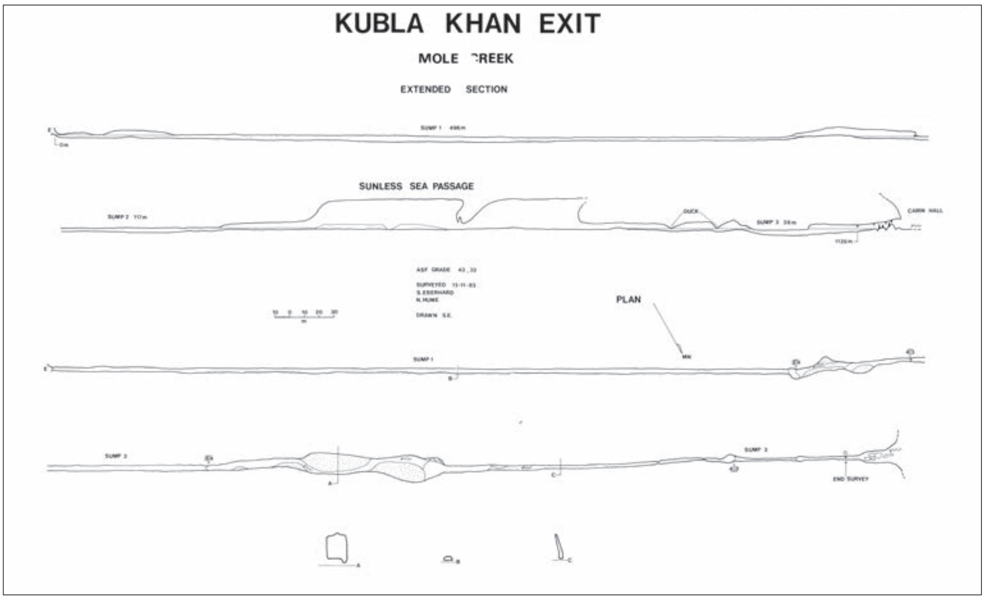
Acknowledgements

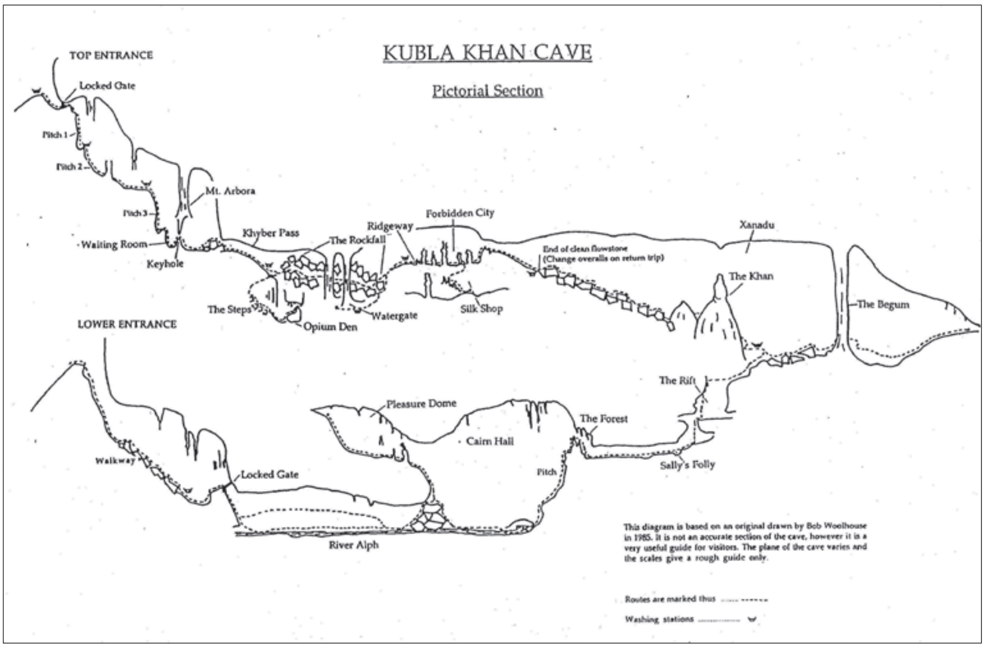
Rolan Eberhard (50+ hours)
Janice March (50+ hours)
Sarah Gilbert (~30 hours)
Various others (too many others to mention individually)

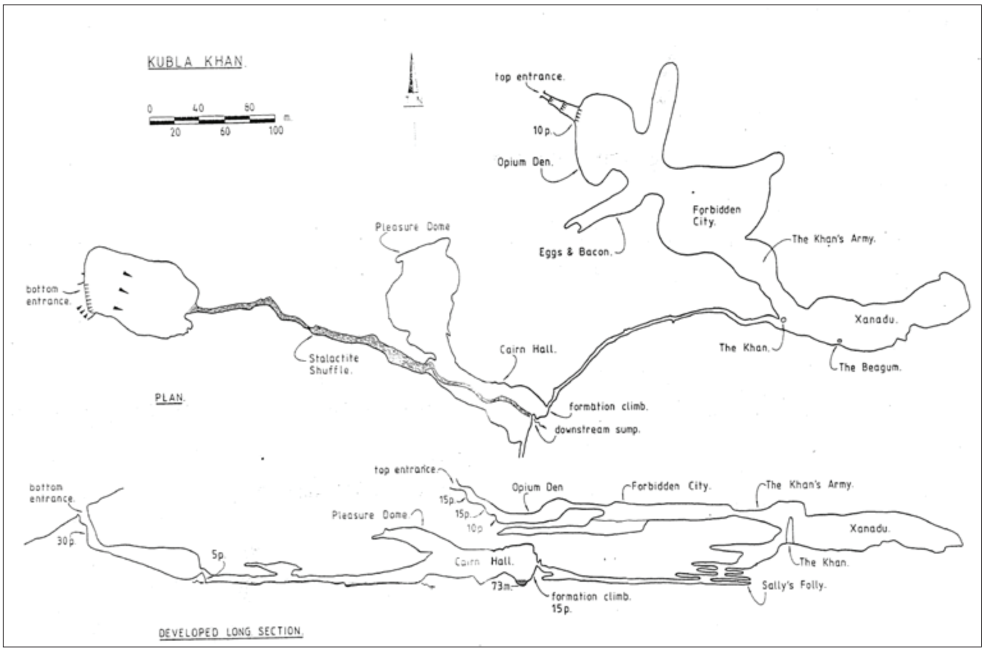
It was a massive project but luckily I'm a particularly anally retentive individual who was just the right balance of 'too dumb and egotistical to say no but sufficiently proud to make sure failure was not an option'. I kind of enjoyed it in a way, but don't tell anyone I said that.

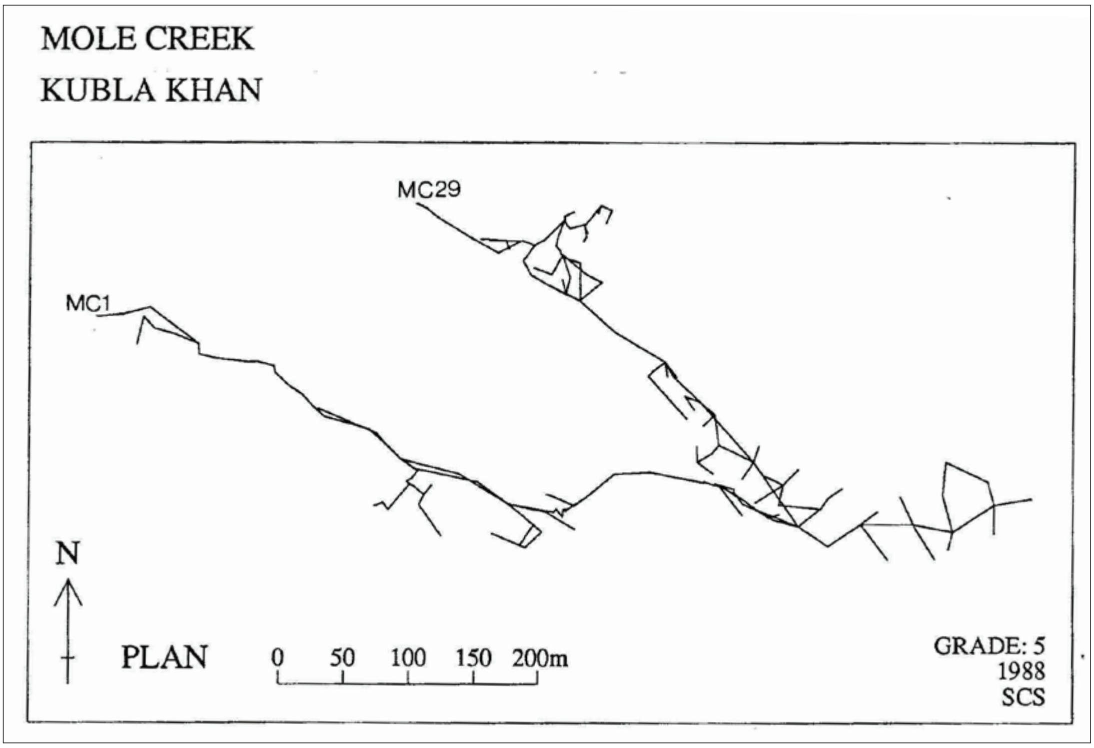

1": 100'
KUBLA KHAN
ENTRANCE
ABORA
DULCIMER
FORBIDDEN CITY
GATES
WATERFALL
PLEASURE DOME
CAIRN HALL
FOREST
NEW SECTION
CITY
DUNGEONS


ENTRANCE
KUBLA KHAN CAVE
DIRECTION OF FLOW
EFFLUX OF ALPH RIVER
EXTENSION to KUBLA KHAN CAVE
NORTHERN TASMANIA
SKETCH OF LONGITUDINAL SECTION
AS DIVED IN FEBRUARY 1978


KUBLA KHAN EXIT
MOLE CREEK
EXTENDED SECTION
SUNLESS SEA PASSAGE
PLAN
END SURVEY


KUBLA KHAN CAVE
Pictorial Section
TOP ENTRANCE
Locked Gate
Pitch 1
Pitch 2
Mt. Arbora
Pitch 3
Khyber Pass
Waiting Room
Keyhole
Ridgeway
Forbidden City
The Rockfall
Xanadu
End of clean flowstone
(Change overalls on return trip)
The Khan
The Begum
The Steps
Watergate
Silk Shop
Opium Den
LOWER ENTRANCE
The Rift
Pleasure Dome
The Forest
Cairn Hall
Walkway
Locked Gate
Pitch
Sally's Folly
River Alph
This diagram is based on an original drawn by Bob Woolhouse in 1985. It is not an accurate section of the cave, however it is a very useful guide for visitors. The plane of the cave varies and the scales give a rough guide only.
Routes are marked thus
Washing stations


KUBLA KHAN
0 40 80 m.
20 60 100
top entrance.
10p.
Opium Den.
Forbidden City.
Pleasure Dome
Eggs & Bacon.
The Khan's Army.
bottom entrance.
Xanadu.
Stalactite Shuffle.
Cairn Hall.
The Khan.
The Beagum.
PLAN.
formation climb.
downstream sump.
top entrance
Opium Den
Forbidden City.
The Khan's Army.
bottom entrance.
15p.
Pleasure Dome
15p.
10p.
Xanadu.
30p.
5p.
Cairn Hall.
The Khan.
73m.
formation climb.
15p.
Sally's Folly.
DEVELOPED LONG SECTION.



TASMANIA

APPROVAL AND AUTHORITY TO UNDERTAKE CAVE SURVEYING ASSOCIATED WITH THE KUBLA KHAN CAVE MAPPING PROJECT ON RESERVED LAND (MOLE CREEK KARST NATIONAL PARK)

Granted to:

Alan Jackson, the Survey Leader / Coordinator.

All appointed participants of this activity from Australian Speleological Federation (ASF) affiliated caving clubs.

Approval is hereby given to organise and conduct cave surveying within Kubla Khan Cave, Mole Creek Karst National Park for cave management purposes subject to the conditions listed below.

Authority issued in accordance with Regulation 26 & 28 of the National Parks and Reserved Land Regulations 2009 to organise and conduct a group activity on reserved land within a limited access area, subject to the conditions listed below, that would otherwise be prohibited under Regulations 16 and 17 of the *National Parks and Reserved Land Regulation 2009.*

Authority or approval valid: *From: Wednesday the 1st January 2014 To: Monday the 30th June 2014*

Please note that for the purposes of this authority the following definitions apply:

Survey Trip: is defined as a trip with the primary purpose of undertaking the Kubla Khan Cave mapping project

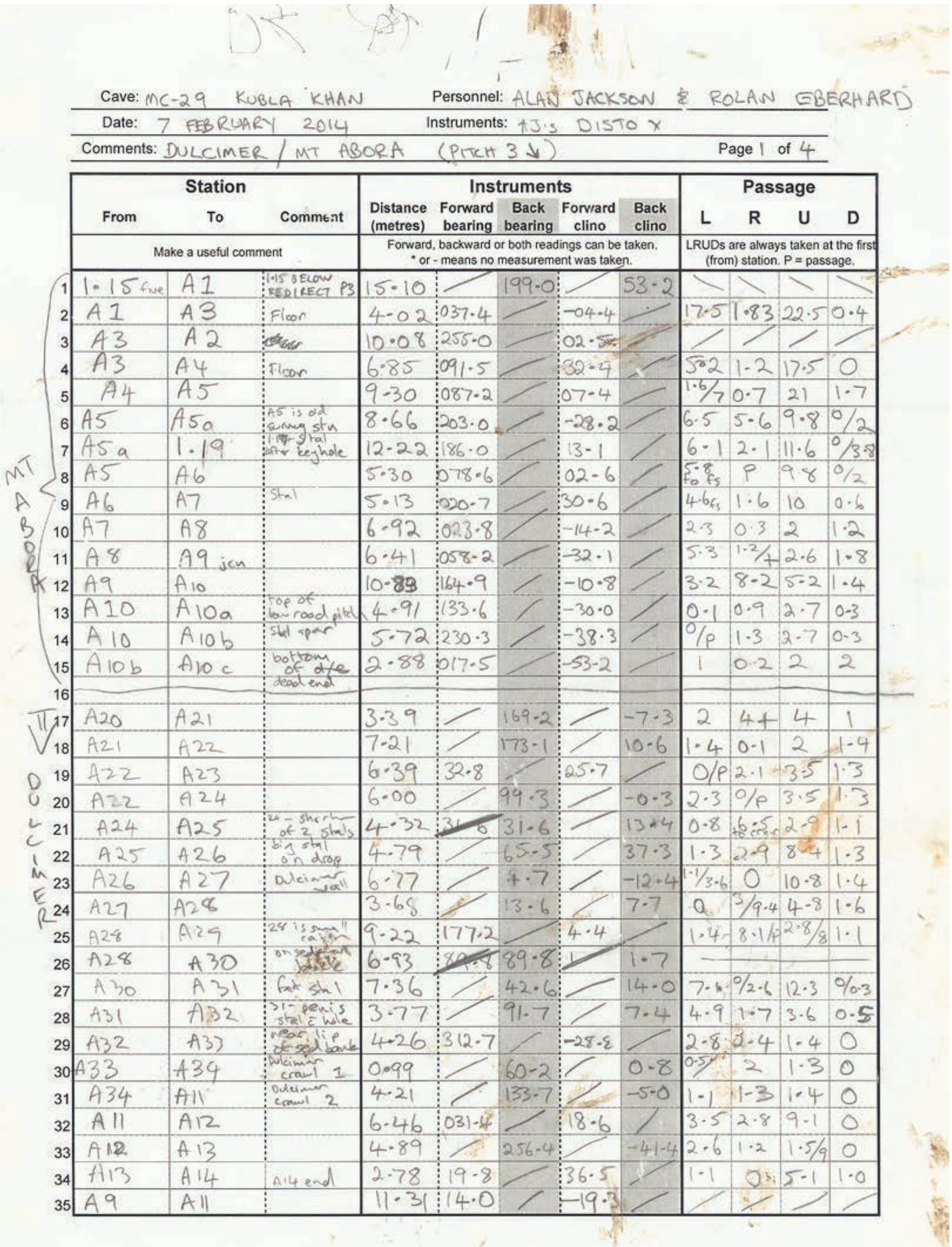
Survey Leader/Coordinator: the caver who has agreed to be responsible for coordinating the mapping project, in accordance with the documented proposal and these permit conditions.

Survey Personnel: means all individuals who are appointed as survey assistants by the survey leader/coordinator and will include only persons actively engaged in practical tasks related to surveying.

Kubla Khan: is defined as the system of passages directly connected to cave entrances numbered MC1 and MC29 and the resurgence of the River Alph (Kubla Khan Efflux). It is taken to include Genghis Khan (MC38).

Land Manager: Means the Parks and Wildlife Service ("PWS").

Land: Means the Mole Creek Karst National Park (MCKNP).



Cave: MC-29 KUBLA KHAN | Personnel: ALAN JACKSON & ROLAN EBERHARD
Date: 7 FEBRUARY 2014 | Instruments: AJ's DISTO X
Comments: DULCIMER / MT ABORA (PITCH 3 ↓) | Page 1 of 4

	Station			Instruments					Passage			
	From	To	Comment	Distance (metres)	Forward bearing	Back bearing	Forward clino	Back clino	L	R	U	D
	Make a useful comment			Forward, backward or both readings can be taken. * or - means no measurement was taken.					LRUDs are always taken at the first (from) station. P = passage.			
1	1.15 fwe	A1	1.15 BELOW REDIRECT P3	15.10	/	199.0	/	53.2	\	\	\	\
2	A1	A3	Floor	4.02	037.4	/	-04.4	/	17.5	1.83	22.5	0.4
3	A3	A2	[illegible]	10.08	255.0	/	02.5	/	/	/	/	/
4	A3	A4	Floor	6.85	091.5	/	32.4	/	5.2	1.2	17.5	0
5	A4	A5		9.30	087.2	/	07.4	/	1.6/7	0.7	21	1.7
6	A5	A5a	A5 is old survey stn	8.66	203.0	/	-28.2	/	6.5	5.6	9.8	0/2
7	A5a	1.19	1.19 stal after keyhole	12.22	186.0	/	13.1	/	6.1	2.1	11.6	0/3.8
8	A5	A6		5.30	078.6	/	02.6	/	5.8 to fs	P	9.8	0/2
9	A6	A7	Stal	5.13	020.7	/	30.6	/	4.6fs	1.6	10	0.6
10	A7	A8		6.92	023.8	/	-14.2	/	2.3	0.3	2	1.2
11	A8	A9 jcn		6.41	058.2	/	-32.1	/	5.3	1.2/+	2.6	1.8
12	A9	A10		10.89	164.9	/	-10.8	/	3.2	8.2	5.2	1.4
13	A10	A10a	top of low road pitch	4.91	133.6	/	-30.0	/	0.1	0.9	2.7	0.3
14	A10	A10b	stal spar	5.72	230.3	/	-38.3	/	0/p	1.3	2.7	0.3
15	A10b	A10c	bottom of dfe dead end	2.88	017.5	/	-53.2	/	1	0.2	2	2
16												
17	A20	A21		3.39	/	169.2	/	-7.3	2	4+	4	1
18	A21	A22		7.21	/	173.1	/	10.6	1.4	0.1	2	1.4
19	A22	A23		6.39	32.8	/	25.7	/	0/P	2.1	3.5	1.3
20	A22	A24		6.00	/	94.3	/	-0.3	2.3	0/p	3.5	1.3
21	A24	A25	24 – shorter of 2 stals	4.32	~~31.6~~	31.6	/	13.4	0.8	6.5 to crack	2.9	1.1
22	A25	A26	big stal on drop	4.79	/	65.5	/	37.3	1.3	2.9	8.4	1.3
23	A26	A27	Dulcimer wall	6.77	/	4.7	/	-12.4	1.1/3.6	0	10.8	1.4
24	A27	A28		3.68	/	13.6	/	7.7	0	3/9.4	4.8	1.6
25	A28	A29	28 is small cavern	9.22	177.2	/	4.4	/	1.4	8.1/P	2.8/8	1.1
26	A28	A30	on sediment [illegible]	6.93	~~89.8~~	89.8	~~1~~	1.7				
27	A30	A31	fat stal	7.36	/	42.6	/	14.0	7.1	0/2.6	12.3	0/0.3
28	A31	A32	31 – penis stal & hole	3.77	/	91.7	/	7.4	4.9	1.7	3.6	0.5
29	A32	A33	near lip of sed bank	4.26	312.7	/	-28.8	/	2.8	2.4	1.4	0
30	A33	A34	Dulcimer crawl 1	0.99	/	60.2	/	0.8	0.5/	2	1.3	0
31	A34	A11	Dulcimer crawl 2	4.21	/	133.7	/	-5.0	1.1	1.3	1.4	0
32	A11	A12		6.46	031.4	/	18.6	/	3.5	2.8	9.1	0
33	A12	A13		4.89	/	256.4	/	-41.4	2.6	1.2	1.5/9	0
34	A13	A14	A14 end	2.78	19.8	/	36.5	/	1.1	0.3	5.1	1.0
35	A9	A11		11.31	14.0	/	-19.3	/	/	/	/	/

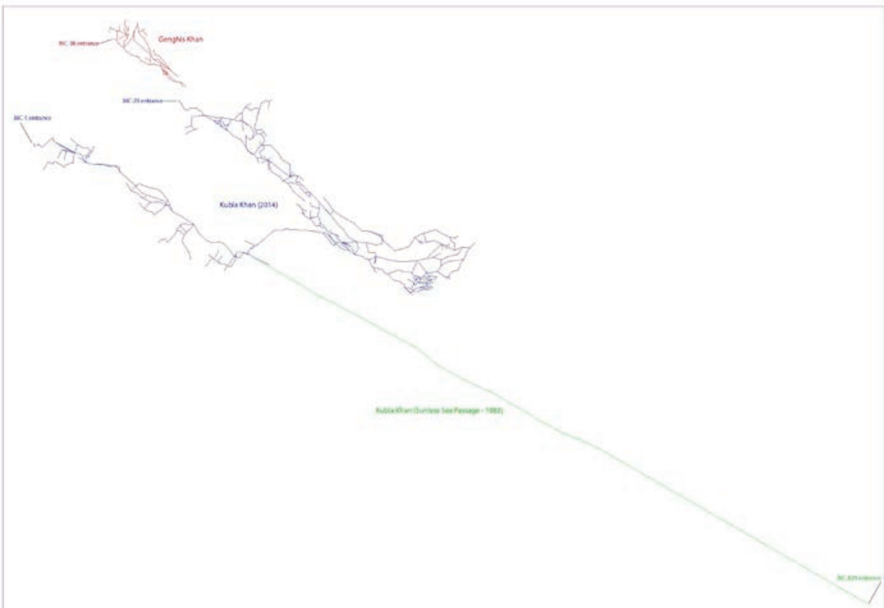
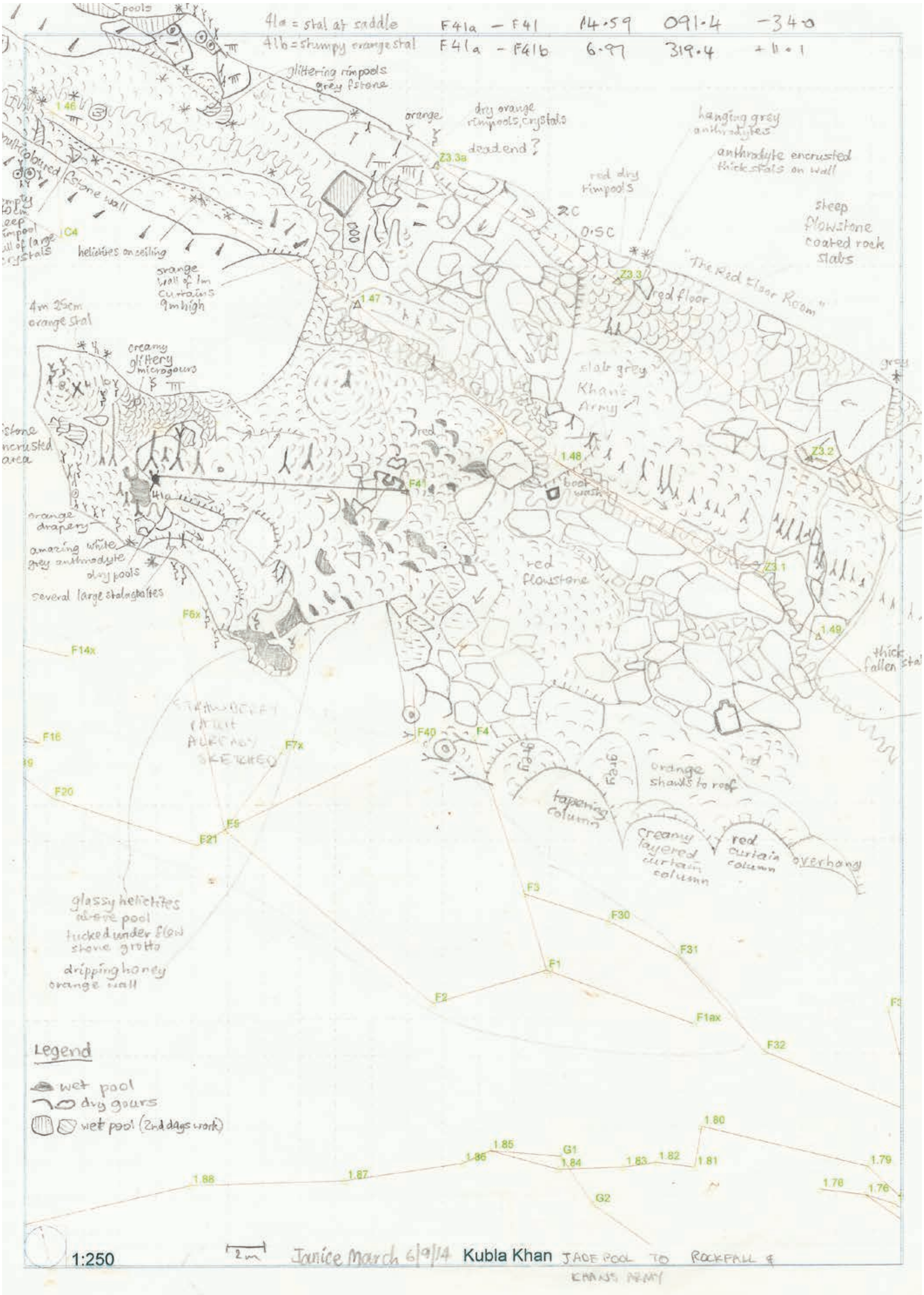
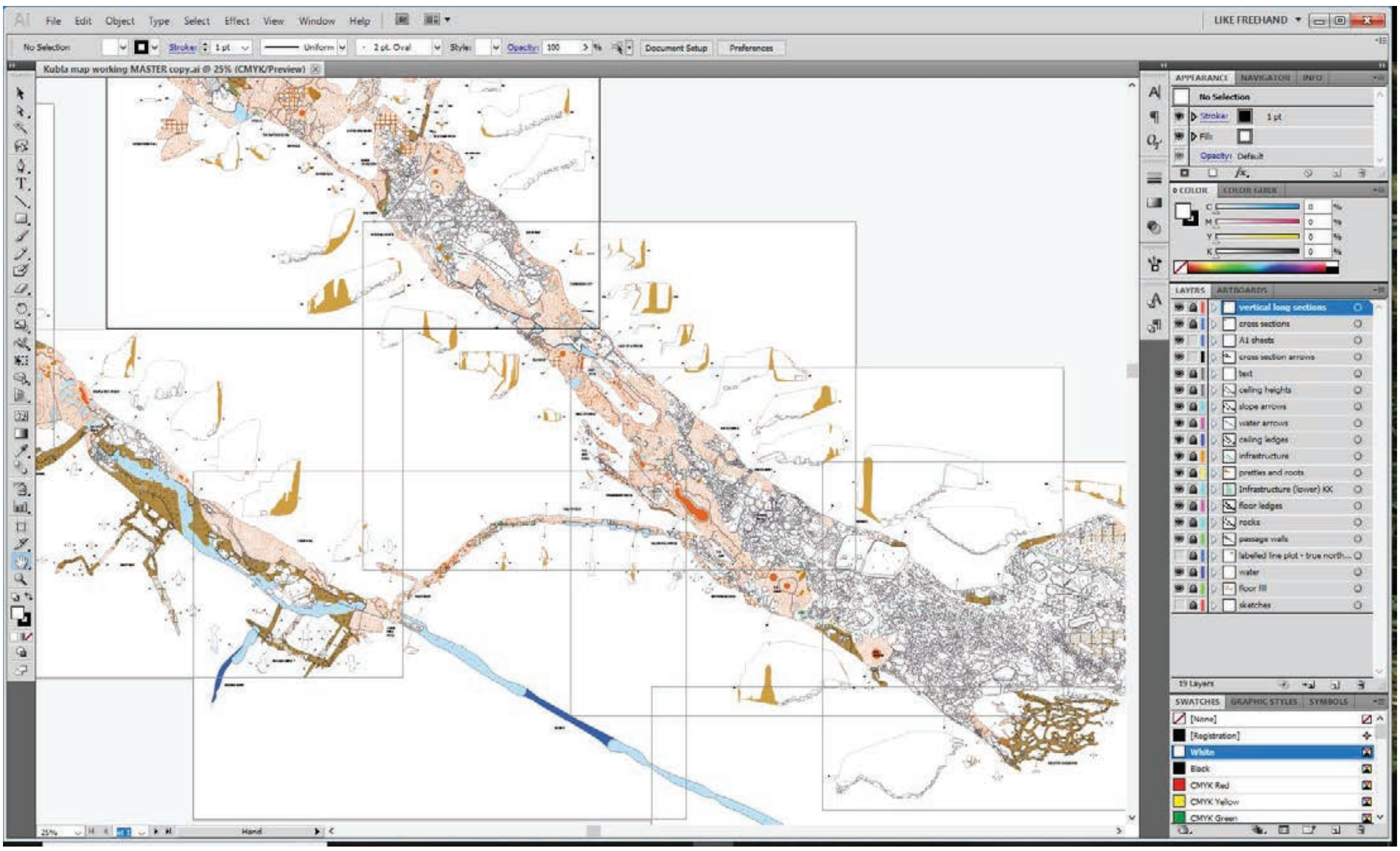
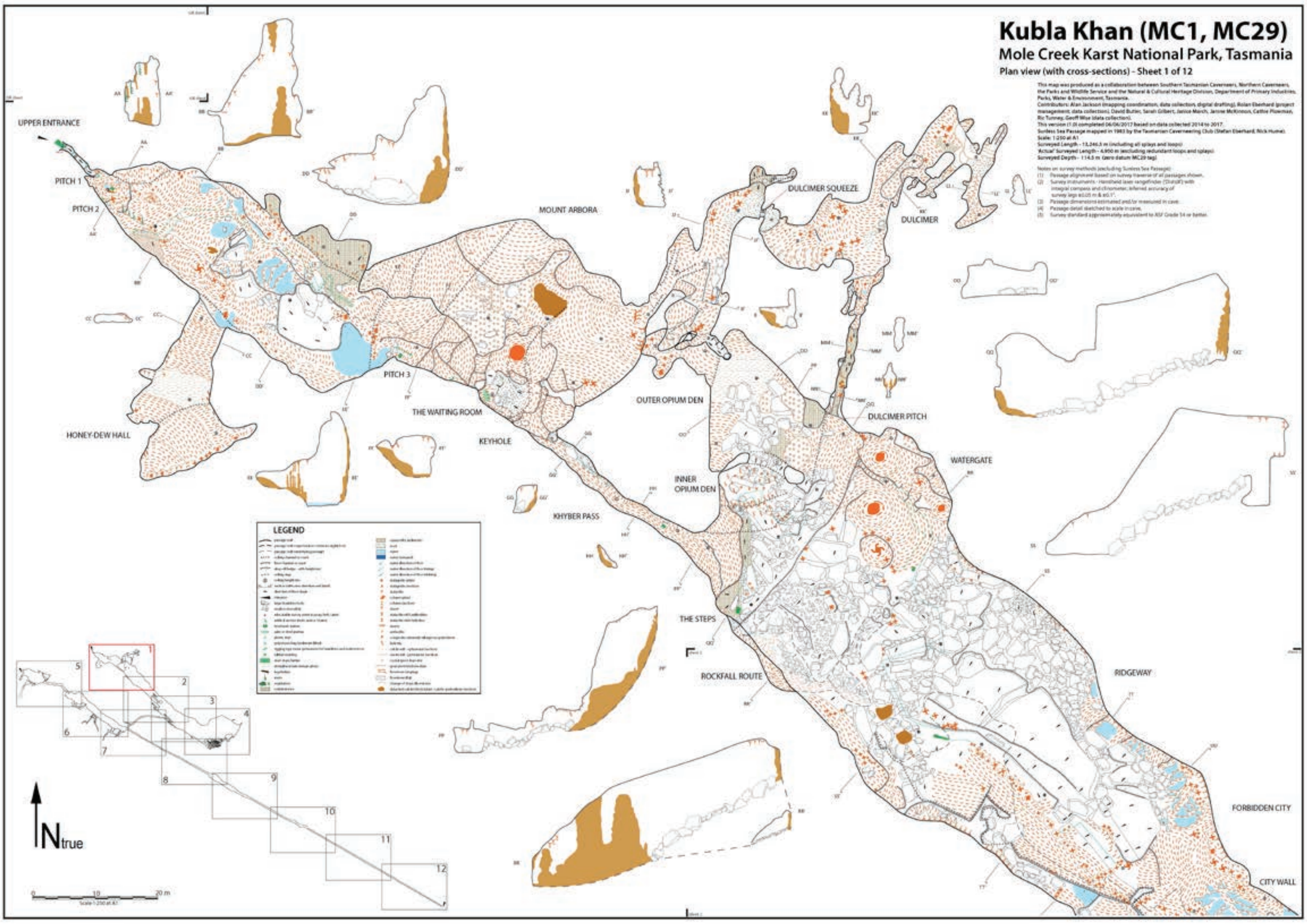


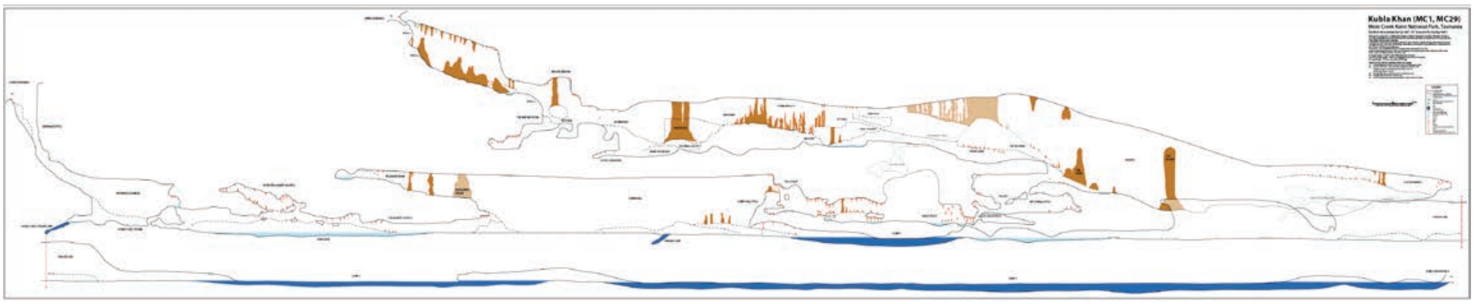
Figure 1. Line plot of Kubla Khan and Genghis Khan survey data - plan view - 2014 project data (blue & red) and 1983 TCC data (green)

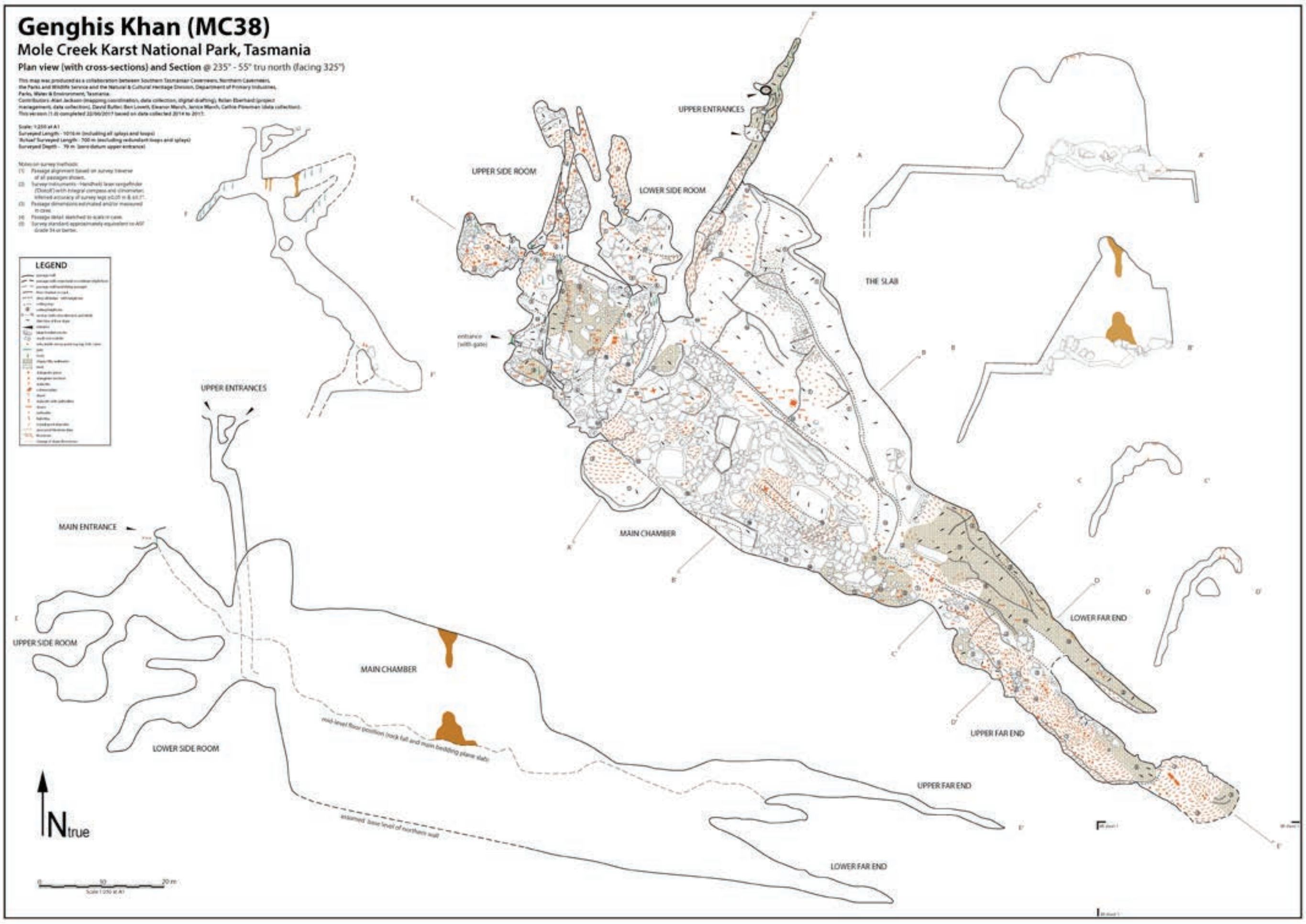

41a = stal at saddle
41b = stumpy orange stal
F41a – F41 14.59 091.4 -34.0
F41a – F41b 6.97 319.4 +11.1
glittering rimpools grey fstone
orange
dry orange rimpools, crystals
dead end ?
hanging grey anthodytes
anthrodyte encrusted thick stals on wall
red dry rimpools
steep flowstone coated rock slabs
"The Red Floor Room"
red floor
helictites on ceiling
orange wall of 1m curtains 9m high
4m 25cm orange stal
creamy glittery microgours
slab grey Khans Army
red
boot wash
orange drapery
amazing white grey anthodyte
dry pools
several large stalagmites
red flowstone
thick fallen stal
orange shawls to roof
tapering column
creamy layered curtain column
red curtain column
overhang
glassy helictites above pool tucked under flow stone grotto
dripping honey orange wall
Legend
wet pool
dry gours
wet pool (2nd days work)
1:250
2m
Janice March 6/9/14
Kubla Khan
JADE POOL TO ROCKFALL & KHANS ARMY

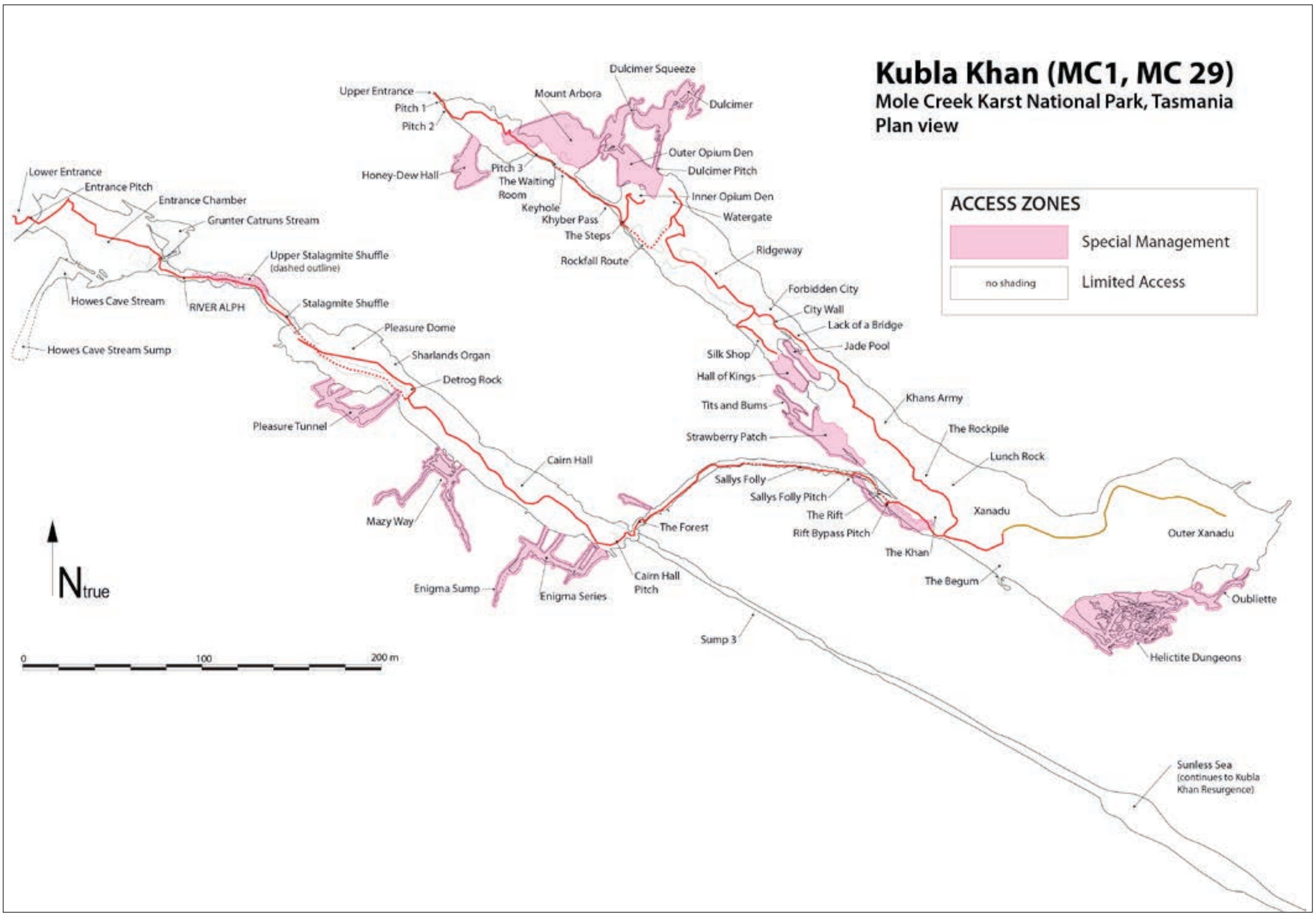

coarse rounded gravels up to 150 mm
MAGNETIC
1:250
Kubla Khan - Helictite Dungeons
SKETCHED 9/9/2014

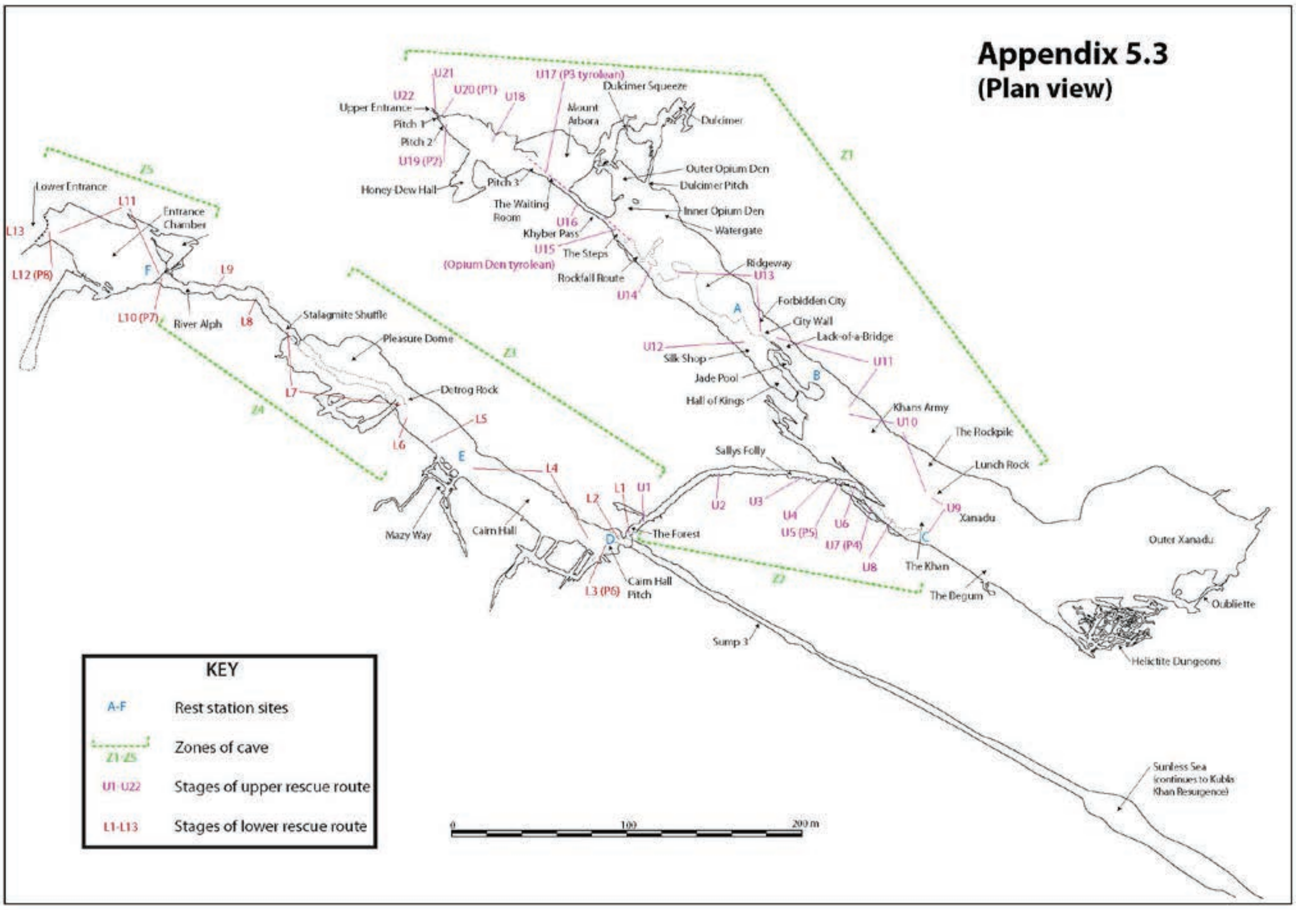

Kubla map working MASTER copy.ai @ 25% (CMYK/Preview)
vertical long sections
cross sections
A1 sheets
cross section arrows
text
ceiling heights
slope arrows
water arrows
ceiling ledges
infrastructure
pretties and roots
Infrastructure (lower) KK
floor ledges
rocks
passage walls
labeled line plot - true north
water
floor fill
sketches
19 Layers


Kubla Khan (MC1, MC29)
Mole Creek Karst National Park, Tasmania
Plan view (with cross-sections) - Sheet 1 of 12
UPPER ENTRANCE
PITCH 1
PITCH 2
HONEY-DEW HALL
PITCH 3
THE WAITING ROOM
KEYHOLE
MOUNT ARBORA
OUTER OPIUM DEN
INNER OPIUM DEN
KHYBER PASS
THE STEPS
ROCKFALL ROUTE
DULCIMER SQUEEZE
DULCIMER
DULCIMER PITCH
WATERGATE
RIDGEWAY
FORBIDDEN CITY
CITY WALL
LEGEND
Ntrue

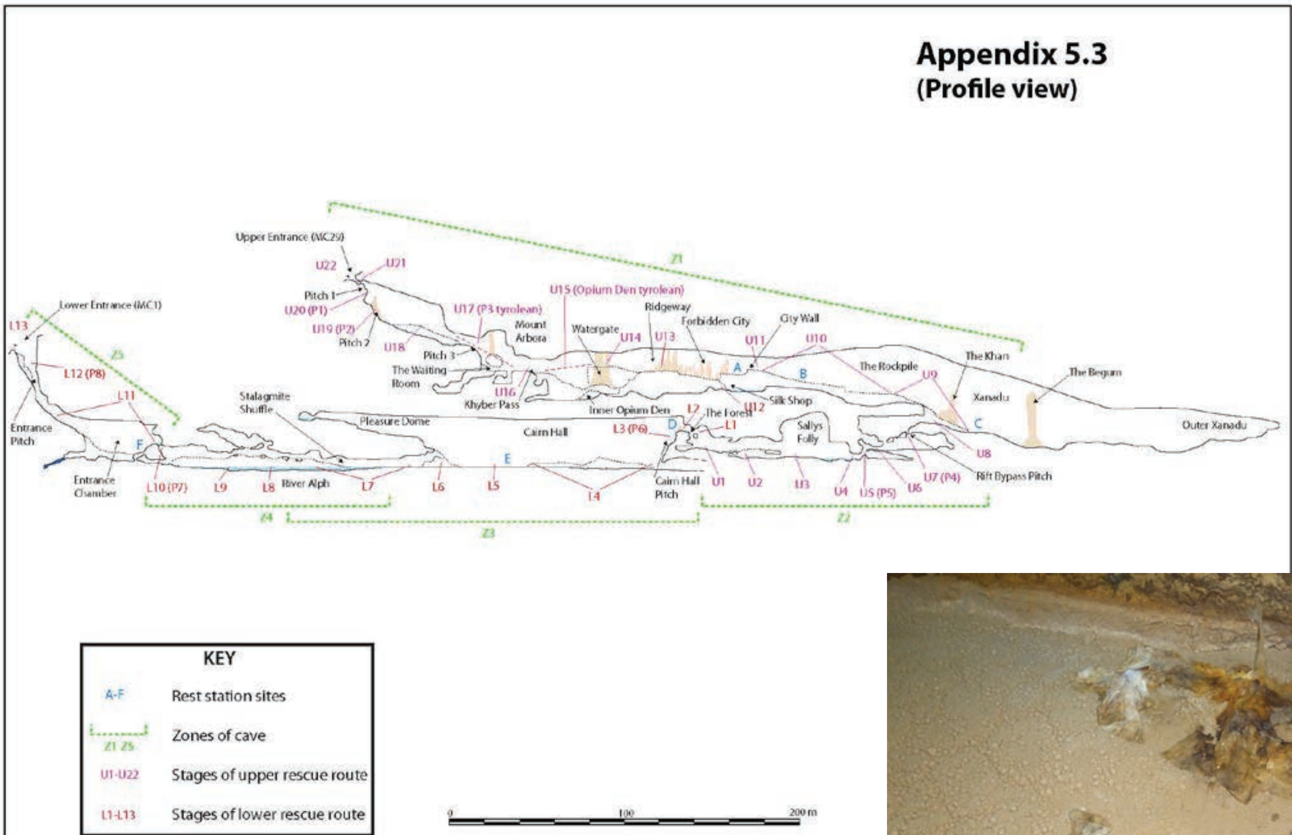

Kubla Khan (MC1, MC29)
Mole Creek Karst National Park, Tasmania


Genghis Khan (MC38)
Mole Creek Karst National Park, Tasmania
Plan view (with cross-sections) and Section @ 235° - 55° tru north (facing 325°)
LEGEND
UPPER ENTRANCES
UPPER SIDE ROOM
LOWER SIDE ROOM
entrance (with gate)
THE SLAB
MAIN CHAMBER
LOWER FAR END
UPPER FAR END
MAIN ENTRANCE
Ntrue


Kubla Khan (MC1, MC 29)
Mole Creek Karst National Park, Tasmania
Plan view
ACCESS ZONES
Special Management
no shading
Limited Access
Dulcimer Squeeze
Upper Entrance
Mount Arbora
Dulcimer
Pitch 1
Pitch 2
Outer Opium Den
Dulcimer Pitch
Honey-Dew Hall
Pitch 3
The Waiting Room
Keyhole
Khyber Pass
The Steps
Inner Opium Den
Watergate
Rockfall Route
Ridgeway
Lower Entrance
Entrance Pitch
Entrance Chamber
Grunter Catruns Stream
Upper Stalagmite Shuffle
(dashed outline)
Howes Cave Stream
RIVER ALPH
Stalagmite Shuffle
Pleasure Dome
Howes Cave Stream Sump
Sharlands Organ
Detrog Rock
Pleasure Tunnel
Forbidden City
City Wall
Lack of a Bridge
Jade Pool
Silk Shop
Hall of Kings
Tits and Bums
Khans Army
Strawberry Patch
The Rockpile
Lunch Rock
Cairn Hall
Sallys Folly
Sallys Folly Pitch
Xanadu
The Rift
Rift Bypass Pitch
Outer Xanadu
Mazy Way
The Forest
The Khan
The Begum
Oubliette
Enigma Sump
Enigma Series
Cairn Hall Pitch
Helictite Dungeons
Sump 3
Ntrue
0
100
200 m
Sunless Sea
(continues to Kubla Khan Resurgence)



Appendix 5.3
(Plan view)
Upper Entrance
Pitch 1
Pitch 2
Pitch 3
Honey Dew Hall
Dulcimer Squeeze
Mount Arbora
Dulcimer
Outer Opium Den
Dulcimer Pitch
Inner Opium Den
Watergate
The Waiting Room
Khyber Pass
The Steps
(Opium Den tyrolean)
Rockfall Route
Ridgeway
Forbidden City
City Wall
Lack-of-a-Bridge
Silk Shop
Jade Pool
Hall of Kings
Khans Army
The Rockpile
Lunch Rock
Sallys Folly
Xanadu
Outer Xanadu
The Khan
The Begum
Oubliette
Helictite Dungeons
Sunless Sea (continues to Kubla Khan Resurgence)
Sump 3
The Forest
Cairn Hall
Cairn Hall Pitch
Mazy Way
Detrog Rock
Pleasure Dome
Stalagmite Shuffle
River Alph
Lower Entrance
Entrance Chamber
KEY
A-F Rest station sites
Z1-Z5 Zones of cave
U1-U22 Stages of upper rescue route
L1-L13 Stages of lower rescue route
0
100
200 m



Appendix 5.3
(Profile view)
Upper Entrance (MC29)
Lower Entrance (MC1)
Pitch 1
Pitch 2
Pitch 3
U17 (P3 tyrolean)
U15 (Opium Den tyrolean)
Mount Arbora
Watergate
Ridgeway
Forbidden City
City Wall
The Waiting Room
Khyber Pass
Inner Opium Den
The Forest
Silk Shop
Sallys Folly
The Rockpile
The Khan
The Begum
Xanadu
Outer Xanadu
Rift Bypass Pitch
Stalagmite Shuffle
Pleasure Dome
Cairn Hall
Cairn Hall Pitch
Entrance Pitch
Entrance Chamber
River Alph
KEY
A-F Rest station sites
Z1-Z5 Zones of cave
U1-U22 Stages of upper rescue route
L1-L13 Stages of lower rescue route
0
100
200 m

ABSTRACT

The Australian Speleological Federation Strategic Plan — 2019 to 2024

STEVE MILNER PhD (Facilitator), ASF Executive

It has been some time since the ASF has actively shaped its strategy; however, what has been done by the ASF over the last 60 years has served the Federation well.

The ASF was inaugurated in 1956 with a purpose to 'to act as an agency for the collection, preservation and publication of scientific, historical and other information relating to Speleology'. The ASF grew to accommodate the majority of caving clubs in Australia, brought together with biennial conferences and a national magazine.

Today, the ASF is the national body that represents the interests of 24 caving clubs, with over 950 members throughout Australia, and represents Australia on the International Union of Speleology.

ASF Inc. is declared as an Environmental Organisation, registered by the Department of the Environment and Energy in Canberra, with the primary objective of protecting the cave and karst environment of Australia.

In the 1990s some strategic planning work was done by the ASF to evaluate the changing environment and its relevance to the organisation, but the external environment is constantly changing, including but limited to:

- membership demographics (aging);
- burgeoning interests of scientists (wider disciplines);
- sustainable development (impact on karst environment);
- challenges in access (land management);
- respect of indigenous peoples (protection of cultural values), and
- technological changes (social media and communications).

The ASF Executive has implemented a strategic review which will culminate in the issue of a strategic plan. By the time of the conference, the draft plan will have been put to member clubs for comment. This facilitated workshop is an opportunity for individuals and club representatives to learn more and to discuss it further.

What is a Strategic Plan? A strategic plan outlines where an organization wants to be, typically over a fixed period, and defines how it is going to get there. The foundation of an organisation's strategic plan is its vision and its values, and the plan should always tie back to these.

A good strategic plan (either through a document or a collaborative strategic planning process) will spell out the goals everyone in the organization is seeking to achieve. From there, it will identify the action steps necessary to achieve each goal.

The final draft Strategic Plan will be put to the Council General Meeting for ratification.

Australian Speleological Federation

Proposed Strategic Plan

2019 - 2024

What is a strategic plan?

- It is a document that outlines where an organization wants to be over a fixed period, and defines how one is going to get there.
- The strategic plan will spell out the goals everyone in the organization is seeking to achieve;
- It will identify the action steps necessary to achieve each goal; and
- It will be used to communicate and align activities with the vision.

- It is not a management plan *per se* ... these will be developed following the Strategic Plan

Methodology

STEP	ACTION	RESPONSIBILITY	TIMING
1	Undertake workshops to develop a strategic plan	ASF Executive	Workshop 1
2	Look inwards (including a SWOT analysis), identify what the organisation is, and what it is not	ASF Executive	Workshop 1
3	Look outwards (including a PESTELD Analysis), identify current issues, systemic issues, and key drivers	ASF Executive	Workshop 1
4	Develop an inspirational vision	ASF Executive	Workshop 1
5	Identify far-reaching goals that effectively serve the caving community and related stakeholders	ASF Executive	Workshop 1
6	Incorporate the vision and goals into the draft strategic plan	ASF Executive	Workshop 1
7	Develop specific objectives and priorities	ASF Executive	Workshop 2
8	Engage members and other stakeholders	Members	31st ASF Conf.
9	Take on board findings, refine the plan and objectives	ASF Executive	TBA
10	ASF Council ratifies the Strategic Plan	ASF Council	TBA

Why now?

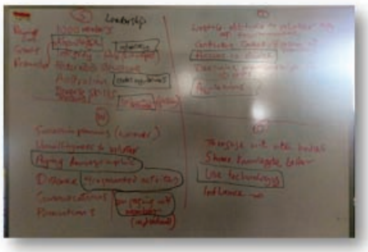
- To be relevant, active strategic development is required
- Today, in 2018, the ASF is the national body that represents:
  - 24 caving clubs
  - over 800 individuals
  - Australia on the International Union of Speleology.
- The ASF Executive has prepared the strategic plan document for:
  - ratification of the Strategic Vision and Values;
  - ratification of the Guiding Principles; and
  - ratification of the Actions.

Assumptions

1. The ASF's customers are people, not just organisations.
2. There is a perceived lack of value in being a member of the ASF.
3. The third assumption is that in order to become a relevant and sustainable organisation, the ASF should be managed as a professional way, and source reliable funds in order to implement its activities.
4. The reliance on volunteers in an aging demographic presents significant risks to the Federation.

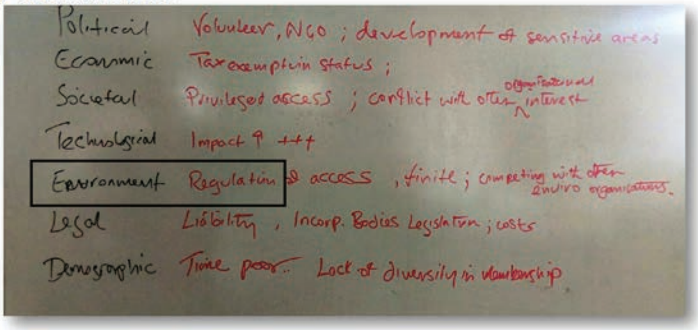
SWOT Analysis

Strengths	Threats
• Leadership • Knowledge • Advocacy • Codes and Guidelines • Dedication and Purpose	• Access to Karst • Regulations
Weaknesses	**Opportunities**
• Aging Demographic • Fragmented Activities • Engaging with Members • Reduced Exploration	• Use Technology



PESTELED Analysis

The purpose of the PESTLED analysis is to identify current issues, systemic issues, and key external drivers.



Top Issues / Challenges / Opportunities

- Barriers to membership limit diversity
- Complex communication channels
- Access to knowledge and information
- Integration of speleological-related research
- Capitalisation of guidelines, training and education
- Requirement for proactive advocacy
- Raise organisational visibility
- Diversify income to fund activities
- Improve organisational efficiencies

Vision and Values

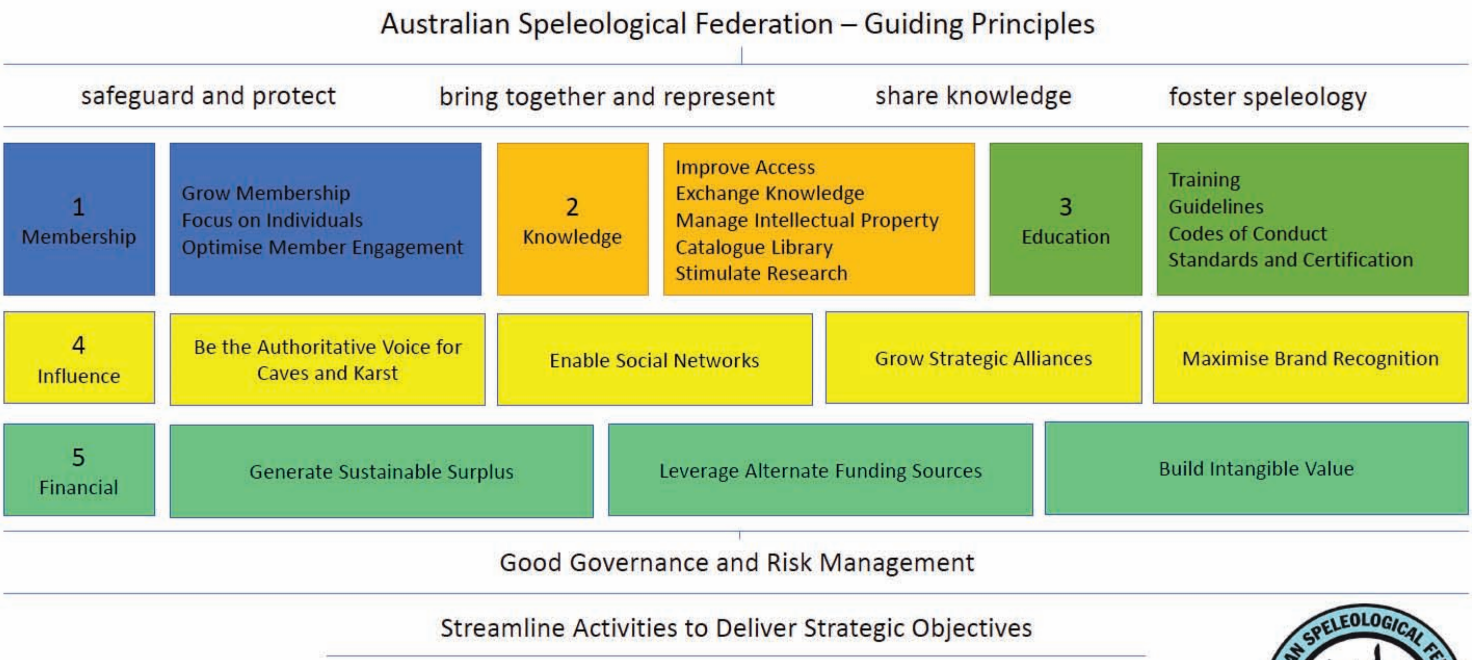
To be the lead national body for karst conservation and speleology in Australia; and to represent the interests of Australian cavers and speleologists at all levels in the community.

The Australian Speleological Federation organisational values are that:
- We are dedicated to safeguard and protect the cave and karst environment;
- We strive to bring together and represent those interested in caves and karst in Australia;
- We share knowledge; and
- We foster speleology in all of its aspects.

Strategic Objectives

There are five keys areas which require attention:
1. Membership
2. Knowledge
3. Education
4. Influence
5. Financial

These should be underpinned by good governance, risk management, and effective delivery of activities.



Vision: *To be the lead national body for karst conservation and speleology in Australia; and to represent the interests of Australian cavers and speleologists at all levels in the community.*

Membership – Entry Requirements

ISSUE: **Barriers to membership limit diversity**

ACTION (1): Convey to the Council the need to alter membership requirements to accommodate greater diversity in membership.

Membership – Engagement and Comms

ISSUE: **Complex communication channels.**

ACTION (2): Diversify and coordinate communication channels to suit a wide range of styles; and engage a volunteer communications specialist from the wider membership.

PRIORITY

Knowledge – Sharing Info & IP Mgmt

ISSUE: **Access to knowledge and information.**

ACTION (3): Communicate what information is available to members and how to access this; promote two-way exchanges of information.

ACTION (4): Ensure ready access to potentially sensitive cave and karst information for *bone fide* persons.

ACTION (5): Resolve perceived intellectual property and copyright issues and develop strategies to better share information digitally.

PRIORITY

ISSUE: **Access to knowledge and information.**

ACTION (6): Issue an intellectual property management policy.

ACTION (7): Complete the cataloguing of the ASF library and make the library fully accessible to members.

Knowledge – Promoting Research

ISSUE: **Integration of speleological-related research.**

ACTION (8): Develop and approve a strategic integration plan to strengthen ASF's role in furthering karst knowledge.

PRIORITY

Education

ISSUE: **Capitalisation of guidelines, training and education.**

ACTION (9): Consult with members and develop and issue a training and education policy.

ACTION (10): Develop and approve a standards development business plan.

Influence – Advocacy

ISSUE: **Requirement for proactive advocacy.**

ACTION (11): Develop a 5-year proactive advocacy plan to reduce threats to the Australian cave and karst environment by 2019 AGM.

PRIORITY

ACTION (12): Appoint an interim volunteer spokesperson who is capable of lobbying, effective immediately.

ACTION (13): Build a strategic network of related organisations.

ISSUE: **Requirement for proactive advocacy.**

ACTION (14): Promote ASF expertise in cave and karst conservation to Govt. departments and lobby for participation as a key stakeholder on management committees.

ACTION (15): Raise the profile of ASF as key stakeholder and represent both members and the cave and karst environment.

Influence – Visibility

ISSUE: **Raise organisational visibility.**

ACTION (16): Review the effectiveness of the brand, then develop and approve an ASF Marketing and Stakeholder Management Plan to maximise brand recognition.

Financial – Funding

ISSUE: **Diversify income to fund activities.**

ACTION (17): Develop and approve an ASF Business Plan, including how the plan will be implemented.

PRIORITY

Organisational Efficiencies

ISSUE: Improve organisational efficiencies.

ACTION (18): Review and complete an organisational review by the 2020 AGM.

ACTION (19): Undertake baseline member satisfaction survey.

Priorities

The top priorities, which are the key drivers for the success of this strategic plan include the following:

- Improve communication with members (Action #2)
- Provide digital access to knowledge (Action #5)
- Develop a speleological research integration plan (Action #8)
- Develop a 5-year advocacy plan (Action #11)
- Approve the ASF Business Plan (Action #17)

Timelines

Feedback

- Who will coordinate / implement / drive the delivery of actions?
- What role does ASF have in promoting and evaluating caving competency?
- Communications are ok.
- It needs more meat [on the bones of the Strategic Plan].
- It's about time we had a plan.

Success Factors (Challenges)

- Commit to the Strategic Plan
- Sense of urgency
- Find resources (people effort)
- Professional input
- Delegate authority to ASF Exec to act (e.g. approve plans)
- More frequent ASF Executive Meetings
- Coordination and integration of activities
- Commitment to a budget (to bring people together, professional fees)

Where to from here?

- Ratification of:
  - Strategic Vision and Values; Guiding Principles; and Actions.
- Address success factors (challenges)
- Start work on the priorities immediately
  - Communications (Action #2) ... quick wins possible
  - ASF Business Plan (Action #17), which brings the following together
    - Advocacy Plan (Action #11)
    - Research Integration Plan (Action #8)
  - IP Management (Action #5) ... long term

ABSTRACT

Rescue training on the North Island

BRIAN EVANS, Illawarra Speleological Society

What has the rest of Australia been doing to prepare for potential cave rescues over the last few years? This session will provide updates on what has been happening in New South Wales, Western Australia, South Australia and Queensland.

Rescue training on the North Island

BRIAN EVANS, Illawarra Speleological Society

Who?

It was a web survey, open to any, and sent initially to those contacts I knew were involved in cave rescue. It grew to 17 responses, including all states except Victoria, and including a response each from NZ and the USA. Some regions spoke with many voices, for some, one voice spoke for many people — e.g. one response representing about 50 people in the NSW Cave Rescue Squad.

If you belong to an organisation for cave rescue, what is it? 12 responses

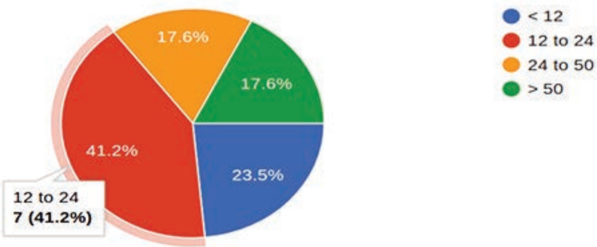
No
I wouldn't call this a cave rescue organisation
WA SES
Scouts Queensland
MCCC, but should say recently retired nth Tas caveSAR co-ordinator
WA SES
Search and Rescue officer, Southern Tasmanian Caverneers
no
NSW CRS
I am a national instructor for the NCRC (National Cave Rescue Commission) and a regional instructor for the SW region of NCRC. It should be noted that the NCRC is not a membership organizati. It is a commission of the NSS (National Speleological Society). I am a member of New Mexico Search and Rescue (serve as incident commander during a mission).
NZSS CaveSAR
CDAA, CEGSA, ACRC SA Rep, IUCRR Australan Rep

Club diversity

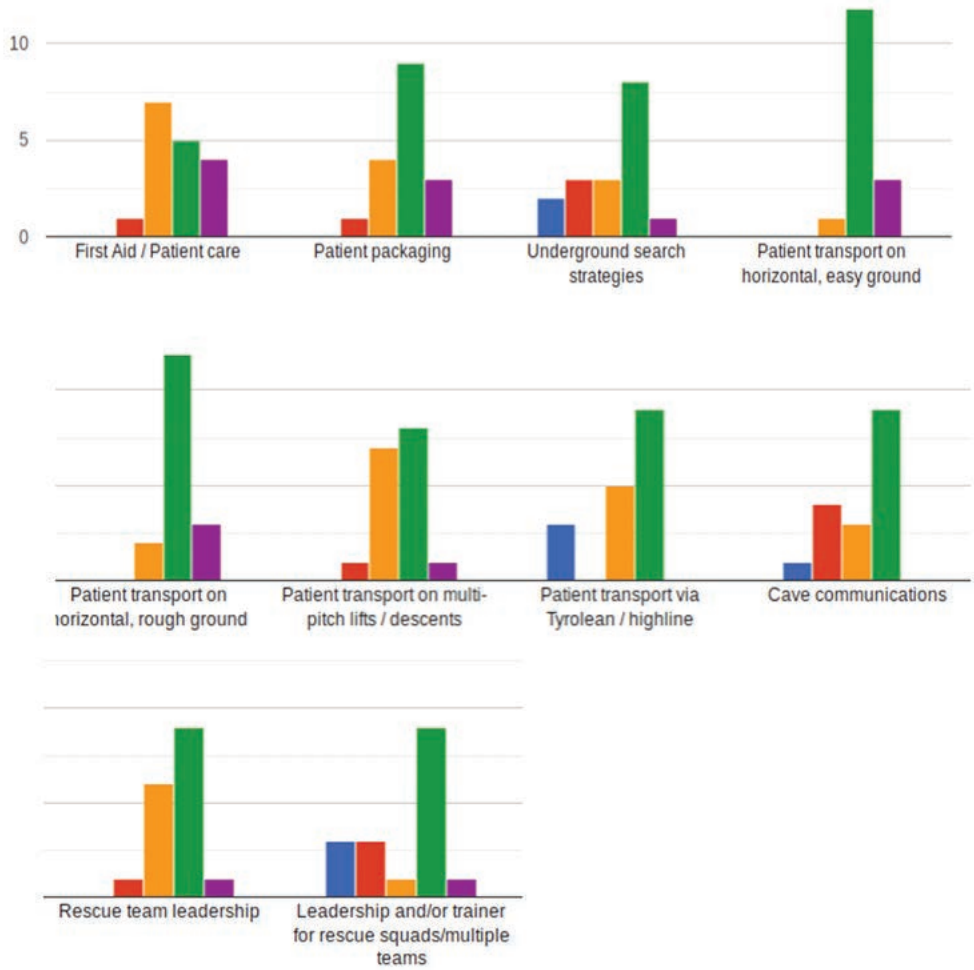
- Some outside Australia
- Some non-ASF
- Victoria, ACT and NT not represented
- Note some places spoke with many voices, some with one!

If you belong to a caving club, what is it?
Southern Tasmanian Caverneers (STC)
Flinders Uni Speleo Society Inc
Northern Caverneers
WASG
Chillagoe Caving Club, Scouts Queensland
Mole Creek Caving Club
WASG
Southern Tasmanian Caverneers
Chillagoe
Southern Tasmanian Caverneers
Flinders University Speleological Society Incorporated
Southern Tasmania Caverneers
ASF
National Speleological Society (US) and Cave Research Foundation
Nelson Speleological Group
CEGSA, FUSSI

Approximately how many hours do you spend in cave rescue or training each year? 17 responses



Categorise your skills and competence in cave rescue 17 responses

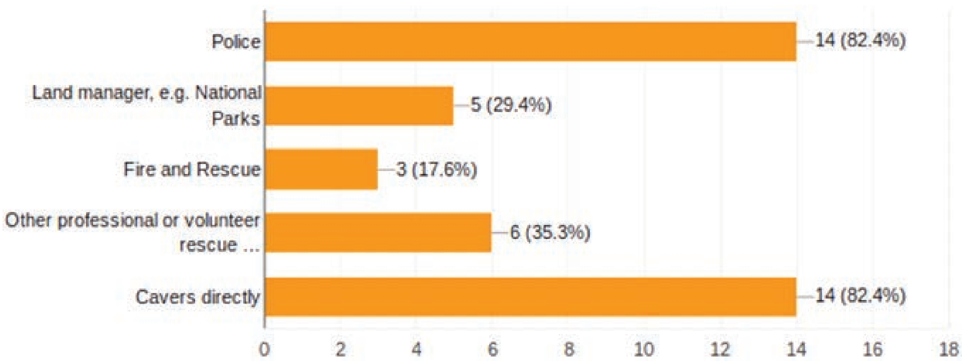


How do you make the organisation ultimately responsible for cave rescue in your area aware of your team's skills and expertise?

Im in it
Regular exercises for which we try and get police to join
Take the local cop caving and we have Winfried as well
We invite them to our exercises and talk to them regularly. Many of our club members are close personal friends with key members of the TasPol SAR team.
Never
Regular communication, inviting them to exercises, use their facilities for rope testing etc.
joint exercises
The require annual update of team information.
We have a good relationship with the Police. They provide the IC and help cavers with the Incident management
Regular meetings
Long time association with TasPol Search & Rescue squad. Regular cave rescue practices with TasPol S&R. Participation in real rescues with TasPol S&R.S
Working on it. Currently no cross communications with police. good relations with State Emergency Services
Our coordaintor send TasPol an emailed newletter about our activities 6 monthly
N/a
Have started open communications with local disaster management committee

When called, what organisation calls you (or would call you)?

Respondents could and did make more than one response to this question.

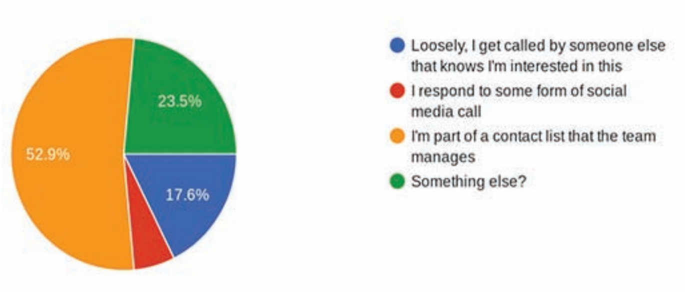


How does your team organise itself?

- STC has an S&R officer, who is first called if the person calling the emergency (the contact for the group) has their contact details. If not, whoever is contacted within the club by the person making the call (for example, wife at home who is worried hubby hasn't contacted her yet and it is after he said he'd be home, and she only knows one person in the club to call) immediatley contacts the S&R officer. If they are not available, either a second (or third) experienced caver in STC is contacted, or alternatively, the STC member taking the call undertakes the start of the rescue, if they feel competent to do so. An initial response group is assembled and starts to organise a visit to the cave. If TasPol have not been called at the same time then the first STC experienced caver responder informs Taspol of the situation. They may, or may not, be asked to attend at this point. The STC caver now coordinating the response starts to contact cavers for the rescue, if needed. They liase with TasPol.

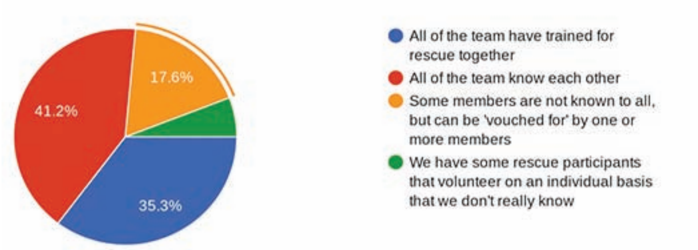
- Not formalised. Working on these things. We are not on any official call out lists. You need a choice with states: not applicable or unknown.
- Northern Tas ACRC is a group of caving clubs each with a SAR contact person
- Thru Dept Fire & Emergency Services
- Loose group, only just starting to formalise
- 1. Until recently we had an inclusive north Tas twice yearly meet of Tas's three northern clubs, frequently attended by reps of STC as well. Now MCCC will be working with SES instead. 2. (Questions above and below) Most of the time until now cavers were not contacted when a cave rescue was underway (SES, Police and/or Fire do it). Now I hope that MCCC and SES will be working together in nth Tas. We have not been called out to a rescue since 2002. At the time we still had annual multi-agency Search and Rescue Liaison Committee meetings and annual combined services landSAR weekends. I have records of all known rescues and callouts in Tasmania since 1997. 3. The questions below refer to "team" so I have chosen to answer for MCCC.
- Callout via pager/mobile phone via operational protocol
- Team leader, advanced operators, others
- Mainly a loose group in the club; everyone knowns everyone;
- Loose group of experienced cavers who know the caves and have some rescue training
- STC has a 'Search and Rescue Officer' position filled at our AGM. It is currently Andreas Klocker. I was the club's SAR Officer for ~10+ years before handing the baton to Andreas. Between the two of us we drive SAR training for the club, attend liaison meetings with TasPol, liaise with NSW CRS and ACRC.
- As an incorporated body we have a committee and a president and so on, but the structure is fairly loose. On trips there is a trip leader and the more experienced cavers lead groups through the cave.
- Caving club, no specific predetermined roles as no garuantee these people will be available at time of call. Most experienced cavers take on leadership roles. For deployment, group facebook message, SMS and phone calls from Club contact. Police lead overall incident as per the Tasmanian Emergency Management Plan, however due to good relationships and trust STC leads sections of cave under police command.
- Formal
- Formal structure with fluidity. Most SAR team members are non-cavers, so we arrange a callout through the SW region of NCRC and caver callout.
- National CaveSAR Group is affiliated with Landsar NZ. Regions are represented by the Caving groups
- CDAA and CEGSA call me as the SAR officer. Police call me due to established relationships

Callout — how do you know you are needed?



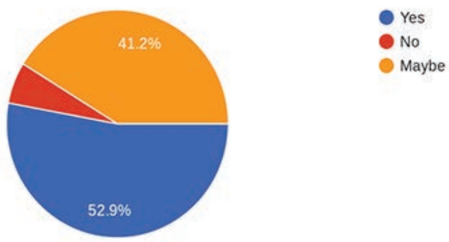
Experience of members

17 responses



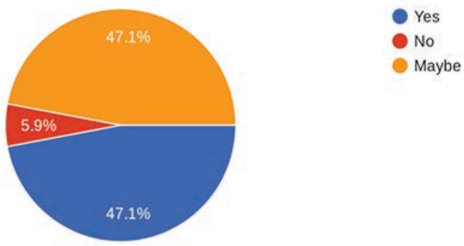
Do you have a prime contact if another state/region requires support from your team?

17 responses



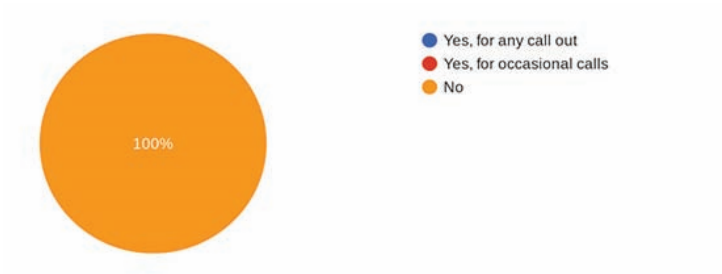
Do you have a backup contact if your prime contact is away?

17 responses



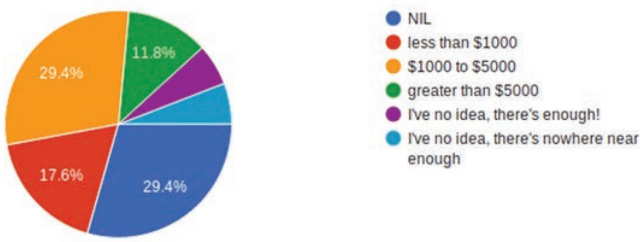
Funding:
Do you receive any personal payment for your involvement in cave rescue?

17 responses



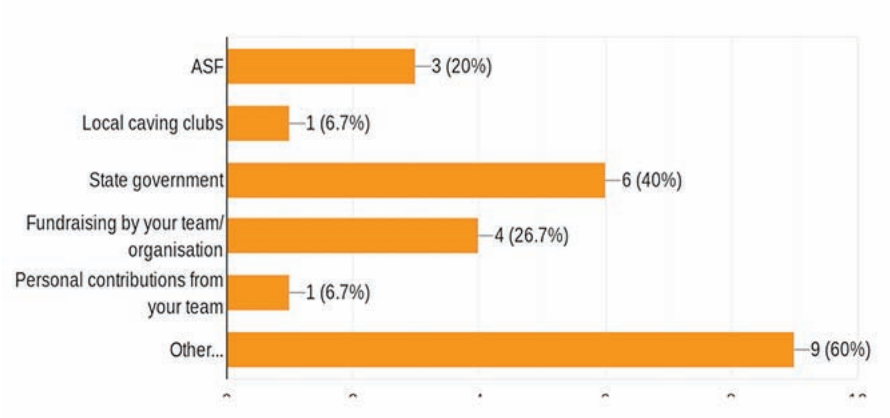
Approximately how much money does your team receive for all purposes, per year?

17 responses

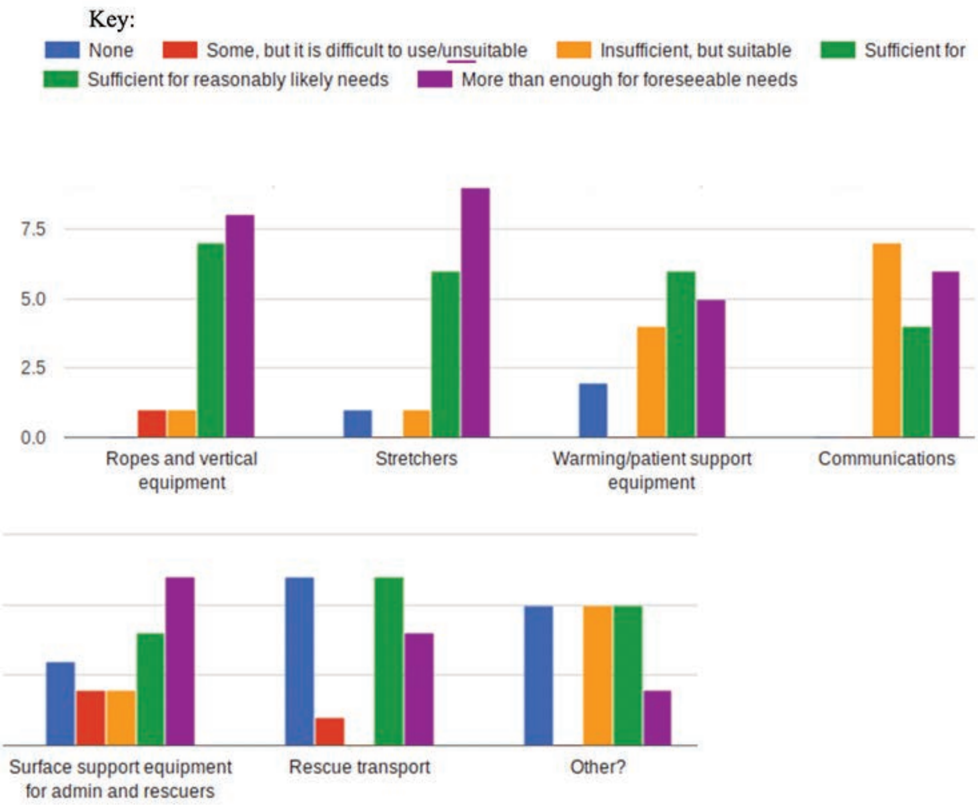


What sources does this money come from?

17 responses

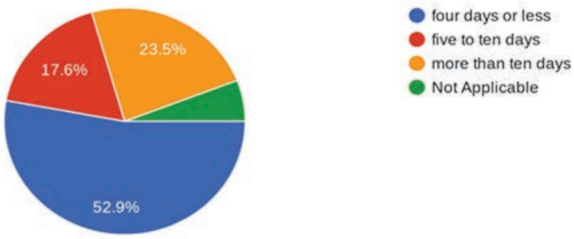


Rescue equipment

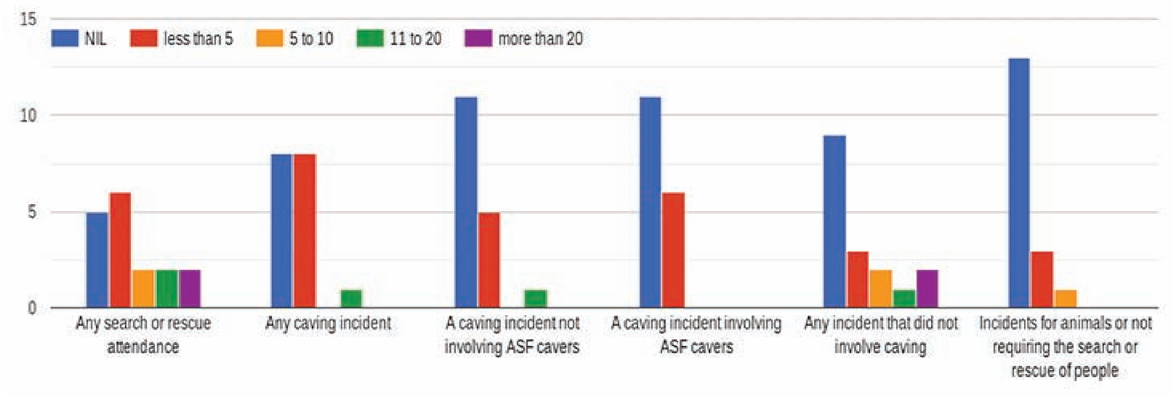


How much training is offered to/run by your team each year?

17 responses

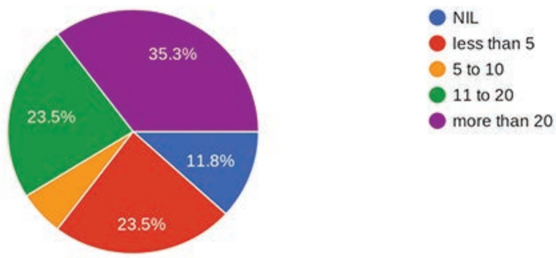


During the past five years, how many authentic rescues have you been involved in? 17 responses



What is the largest number of team members mobilised for any authentic incident during the past five years?

17 responses



ABSTRACT

Rescue training in Tasmania

JANICE MARCH, Northern Caverneers

An update on what Tasmanians been doing to prepare for potential cave rescues over the last few years.

Tasmanian cave rescue practices overview 2010-18

Cave rescue in Australia has undergone a rapid evolution over the past decade with the push by the ASF's Australian Cave Rescue Commission to improve cavers' ability to rescue their own.

I wanted to give this talk to show the variety of things we have practised and to mention the equipment we have acquired and the people involved in the past 8 years of the ACRC northern Tasmania branch. We have participated in all the southern Tasmanian exercises which Andreas has coordinated, so I am going to summarise all of Tasmania's cave rescue training since 2010.

Back in 2010, there was a big ACRC event with then commissioner Joe Sydney. It was at Honeycomb Cave at Mole Creek with 18 cavers from all 4 Tasmanian clubs. I wasn't there but they tried out the brand new Michie phones and a second-hand Paraguard stretcher that was donated to our gear store. Deb Hunter volunteered to coordinate the 3 Northern Tasmanian clubs to do 6 monthly rescue practices at Mole Creek.

In Nov 2011, keen new ACRC commissioners Ross Anderson and Ian Collette came over with a group from WA and conducted a Cave Rescue Orientation Program at Mole Creek. Ian brought his homemade sked style stretcher with him, which we now sometimes call the 'rescue wrap'. Three STC members, two Parks rangers as well as several northern club members attended.

We covered patient packaging, stretcher manoeuvring techniques, and ran mini-scenarios also using comms. We used the comms base station outside the cave with a non-active caver recording comms data.

Later that summer, Ian came back as we were so keen to learn. We used his ‘rescue wrap’ to haul a log across Abseil Hole. Again we had members from all Tassie clubs attending.

Over winter, I constructed a rescue wrap using Ian’s detailed instructions at a cost of about $400 and took it to show at the Galong conference in January 2013.

In February 2013, Deb Hunter arranged for two Police to come along and run a practice day. They brought all their heavy duty cliff rescue gear — Petzl IDs, No-Worries, ropes, rigging plates — and familiarised us with how they rescue things stuck down vertical holes. We were pleased to see their professionalism and how we all worked under them to achieve the objective of the day which was hauling Jessica Bayles and a Police barrow boy out of Abseil Hole at Honeycomb in a Police sked stretcher. We also had two cavers from Chillagoe Caving Club join us.

In October 2013, we all went back to basics, refamiliarising ourselves with the Michie phones and the different types of stretchers available — Police sked, homemade rescue wrap, and the paraguard, and did a couple of short stretcher carries in Honeycomb. We had three cavers from STC join us. We always get the Michie phones out at every practice and this shows what they look like inside the handset.

In March 2014, the SES brought along their comms bus, their outdoor kitchen setup and bathroom facilities, and we all enjoyed lunch courtesy of the Launceston based SES volunteers. We took them all underground, some for their first caving experience, and later that day, three of their keenest joined us for the short recovery scenario including comms and an official entrance controller counting the ins and outs. We will be working with the SES again in March 2019 and focusing on protocols and communications.

In October 2014, we were invited to Hobart for their first four days of vertical rescue training with Al Warild and about 15 members of STC. The format was two days at the Fruehauf quarry in South Hobart to learn the basics of counterbalance lifts and tyroleans, then two days in the Junee Florentine. The theory is detailed in Al's eBook *Vertical Cave Rescue Techniques*. David Butler and I travelled down to learn about this European lightweight way of removing a stretcher-bound casualty from the depths with a separate access line for the accompanying paramedic. We had a great time taking in the practicalities of transitioning from one lift to the next, and placing temporary anchors popularly known as 'concrete screws' for the first time. We went to Owl Pot and Growling Swallet and used a vertically rated stretcher that Al borrowed from NSW Cave Rescue Squad, which did the job better than anything STC had at the time. There were also two cavers from WA and one from VSA.

Later that year, we learned that Deb Hunter had been granted some money from the Bendigo Bank and Meander Valley Council Community Funds to buy a Petzl Nest, a $3000 specialised cave rescue stretcher to be kept at Mole Creek. The ASF also helped with this major purchase and in March 2015 we used it for the first time. The Petzl Nest has an internal harness seen here with individual adjustable foot rests, and then a vinyl cover that is strapped down to fit the casualty, usually with their arms out so they can fend off walls and protect their face.

We held a day at Hillwood rockclimbing area north of Launceston where we used the existing sport climbing bolts as anchors and did some basic counterbalance lifts and tyroleans. Four cavers came up from Hobart, and Alan Jackson ran through the techniques for the northerners who had not made it to the Al Warild weekends down south. The next day we set up a couple of stretcher lifts over Abseil Hole at Honeycomb using all natural anchors, as Honeycomb is in Mole Creek Karst National Park, so no bolting is allowed. We also perfected our tyrolean set ups between the gum trees.

The following November, four from NC headed down to Hobart to learn some more advanced rescue rigging from Al Warild along with some visitors from NSW cave rescue squad, VSA and Dr Mike from NZ. We recapped the techniques at the quarry on the Saturday and rescued someone from the third pitch of Khazad Dum on the Sunday. I was quite enjoying the social side of having 20 people in the cave at once. You rig your section for about two hours, then once everyone is set up and been checked by someone who knows what they are doing, you package the casualty into the stretcher and they slowly traverse them up the

ropes for another two hours. Then everyone derigs the cave and the temporary anchors are all returned to the surface.

Only four northern cavers had managed to travel to attend the southern rescue practice days and we realised that the remainder of the members from the three northern clubs would be able to experience similar training if we got Al Warild to come up north. We had a day at Hillwood again but with more adventurous rigging, and then a day in Honeycomb where, on all natural anchors, we rigged four counterbalances and tyroleans around a contrived route. We had one visitor from VSA and from from WA, about 20 cavers altogether.

In October 2016, no one from MCCC was available, so NC organised a vertical self rescue practice in a tree at Cath's house where we couldn't quite work out how to do a pick off. But we did get the heat tent up for its first trial. This very lightweight polyester tent is designed to keep out the draft and keep the casualty and waiting paramedics warm. It was donated by Al Warild and I cut it down to this smaller size for our purposes.

In December 2016 we joined 18 cavers down the bottom section of Owl Pot including two from Queensland and a few from NSW to rig three pitches and a long carry. This took three hours to rig and then 2.5 hours to get the stretcher up the waterfall pitch and the next couple of sections. There was a large amount of gear to clean up with the new Fordyce designed rope cleaner and a pressure hose at Andreas' place the next day.

Honeycomb Cave was out of bounds for several months due to flood damage. Even cavers weren't allowed in and our interclub rescue practice floundered. One good thing that happened around then was a through trip of Kubla Khan cave with this group of key people in order to ground truth a written rescue plan for Kubla.

July 2017 saw the very successful rescue of Swiss caver Isabella from Midnight Hole by Tas Police, SES, Ambulance and STC for which they won a national rescue services award.

In November 2017, we gained permission from Parks to drill some holes in the limestone of the disused quarry at Mole Creek, so we held a practice with NC's new hammer drill and rigged a counterbalance lift and a tyrolean. We hope that we will rig much more on Sunday when we return to the quarry with people from this conference. That afternoon we trialled the Petzl Nest floating on a pack raft and a lilo to see what worked best. This is for floating a stretcher up the River Alph or maybe in Croesus or across the river at Lynds Cave. The packraft worked best and has been added to the gear store with a lightweight pump.

In December 2017, we headed back to the Junee Florentine with a few from NSW, and practised rescuing someone from the middle section of Owl Pot including the vertical squeeze. This took a long time and we used the new STC Michie phones for their first time. STC has spent many thousands of dollars in the past two years to increase their vertical rescue capability after receiving a Tasmanian Community Grant. They bought a Petzl Nest stretcher for use in southern caves, and lots of other hardware which is for use by all Tasmanian caving clubs.

In April 2018 back at Mole Creek, Deb Hunter resigned as the northern ACRC coordinator after eight years of doing an excellent job sometimes under trying conditions. I took on the volunteer job to keep providing rescue training opportunities and liase between the clubs to make it all happen. I also aim to raise the awareness of the emergency services personnel of cavers' specialist skills.

We had terrible weather and very low attendance in May 2018, but we still managed to practise manoeuvring the stretcher in tight spaces, ran through the Michie phones with two new members, and set up the heat tent in Honeycomb with a few candles which raised the temperature inside the tent from 9˚C to 20˚C in just ten minutes.

In September 2018, we saw renewed enthusiasm with strong support from STC for a short search practice at Honeycomb. Groups of three realised how hard it is to properly scour the cave for the hidden 'targets', while also reporting back to the surface comms person. Having a decent sketch of the cave was invaluable, and we ran 300m of comms line out using a smaller reel recently purchased by STC. That afternoon, we took the six STC cavers to some regularly visited northern caves to discuss the practicalities of a rescue from Westmorland and My Caves.

This year's big southern cave rescue practice shifted from the JF to Mystery Creek Cave at Ida Bay south of Hobart. Cave managers at Parks decided to allow temporary anchor placement in seven segments of this popular cave which floods to the roof, and teams had plenty of tricky rigging to do albeit in a horizontal cave where many of the contrived obstacles we rigged are normally bypassed. The added benefit was that the 30 odd cavers didn't have to wait on pitches and more people could see what was happening during the stretcher movement stage. There were folk from NSW, VSA, the SES, NC and MCCC. Another first for STC was that we used the Michie phones on an hourly call in system and had a dedicated

caver at a comms base station in the cave. The ACRC's new commissioner Brian Evans was elevated from the back of the cave and I had a turn in the stretcher for the really tight bit.

The strengths of both the north and southern Tasmania's cave search and rescue groups complement each other. Our caves are different and in the south, the emphasis has been on the technical side of rigging to convey a stretcher up their more vertical caves. The north has a focus on comms, patient care and a wide range of scenarios including the technical stuff but on a smaller scale. We invite all Tassie clubs to participate in all events and have had plenty of cross-pollination from the mainland too. Personally I have learnt as much about the cavers and others who have been involved as I have about cave rescue techniques, but I think that's expanded the enjoyment of my caving overall and my understanding that it takes a lot of cavers to do a successful rescue, and that they don't all need to be experts to participate effectively, they just need to be familiar with the rescue methods we use and be used to normal caving, and they will be better for the caves than any non-caver trying to do a rescue in dirty, cold, wet, dark conditions.

ABSTRACT

The Midnight Hole rescue: insights into Tasmania's first vertical cave rescue

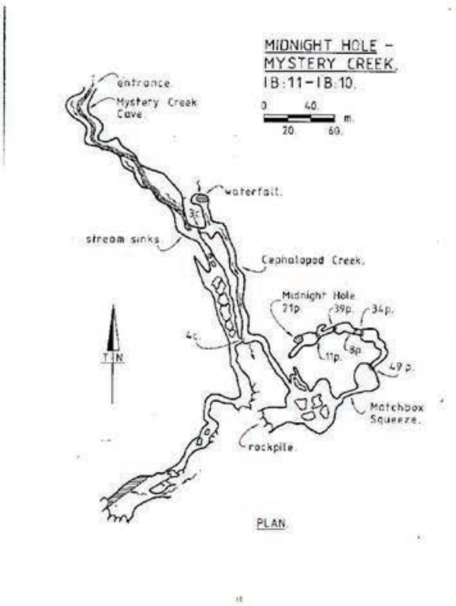
ANDREAS KLOCKER PhD, Southern Tasmanian Caverneers

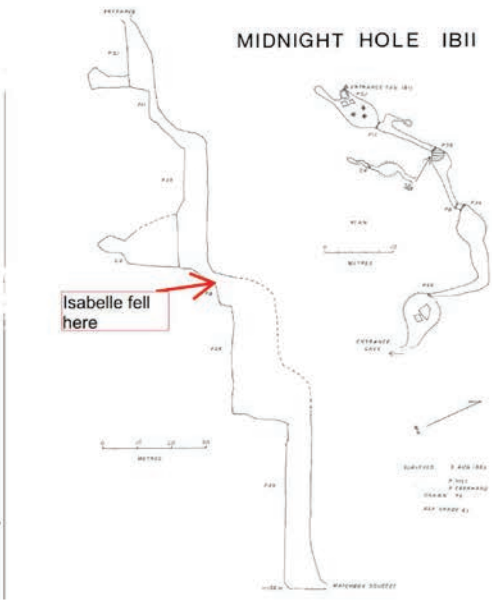
In July 2017 an international visitor fell down an 8-metre pitch in Midnight Hole, one of Tasmania's most popular through trips, and broke her femur. This resulted in a large call-out including Police Search and Rescue, cavers of the Southern Tasmanian Caverneers, paramedics and the State Emergency Service. About 12 hours after call-out, after a stretcher ride up ~100 vertical metres, the casualty was in a helicopter on her way to the Royal Hobart Hospital. This talk will outline details of this rescue and discuss what went well and what could be improved for similar scenarios in the future.

Another trip, another rescue

- July 13 2017, before the ICS congress in Sydney, Janine McKinnon and Ric Tunney, joined by STC members Gabriel Kinzler and Serena Benjamin, lead an easy through trip to Midnight Hole with overseas visitors Ola Lofquist (Sweden) and Isabelle Chouquet (France).
- All in the group have done a substantial part of vertical caving before.
- This was meant to be a very easy trip to get Ola and Isabelle used to caving in Tasmania – famous last thoughts!
- This cave is a classic, easy, well-bolted through-trip.
- At the beginning of the trip, Janine explained carefully a single rope on a pull down setup.
- Ropes were 9.5mm and were rigged with alpine butterfly knots with a carabiner clipped through the knot loop and across to the abseil side of the rope.

The accident





- Isabelle fell at 12:47.
- After giving Isabelle half a minute to adjust from her shock, Janine asked her a series of questions to ascertain her physical condition.
- Isabelle's assessment (she is a nurse) was that her right femur was broken.
- Serena and Janine started an external examination.
- It was decided that, as far as their current assessment could determine, she was unlikely to have any serious injuries other than a fractured right femur.

- Ric and Ole exited the cave, rigging the bottom two pitches, to raise the alarm. The ropes were left in-situ for the rescue. Gabriel stayed with Isabelle as well since he spoke fluent French and Isabelle's English was not great.
- The group used three emergency insulation blankets and several packs to keep Isabelle warm.
- At 13:25 the call went out, a text to Alan Jackson who was the call-out person that day, a call to 000 to formally advise Police, and a call to Damian Bidgood (Taspol SAR). It was also made clear to ambulance that Anna Ekdahl and Han-Wei Lee should be sent, both paramedics very capable at SRT.

Mobilisation starts

- At 13:52 Alan Jackson rings Damian Bidgood to ascertain what the Police response was.
- Damien suggested that helicopters would be the fastest way to access the site.
- Alan and Andreas, the paramedics Anna and Han-Wei, and Taspol SAR were going to fly to Ida Bay. Michael Packer and Stefan Eberhard drove to Ida Bay. Amy Robertson drove from Geevston.
- Loretta Bell (Alan's partner) drove Alan, Andreas, and lots of gear to Rotorlift.
- Alan and the paramedics went on the first helicopter, Police on the second, and one was going to return to get Andreas and more Police.
- The pilot and crewman instructed us on how to disembark the helicopter (hover landing).
- Landing procedures involved lots of circling and chacking; the second helicopter had some concerns with weight/power and decided to land in a paddock at nearby Southport to ditch a person and some gear.
- The first two helicopter arrived with some daylight remaining, while the last one arrived in the dark. Luckily those pilots are damn good....
- ~4.5 hours after the accident Alan and the paramedics arrive from above, and at the same time Michael and Stefan arrive coming up from the lower pitches.
- In the mean time Amy supports people at the quarry with warm food and drink.

The rescue begins

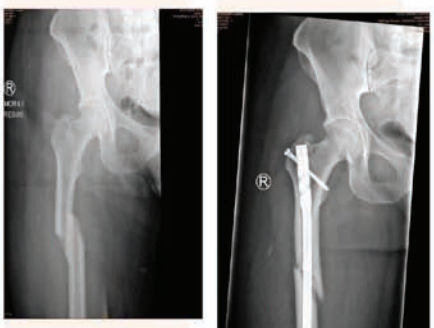
- The paramedics, Anna and Han-Wei, start looking after Isabelle. One of them were always on front/behind Isabelle on her way out.
- In the mean time cavers and Police start rigging the cave for the stretcher.
- The fourth pitch was rigged by cavers using a counterweight, the third pitch was rigged by police using a conventional mechanical advantage haul system, and the second and first pitch were rigged with one continuous counterweight lift. Guess which one was more efficient...
- A SKED stretcher was used, and minor difficukties were encountered packaging the casualty, and some improvised solutions were found.

- The lifts went relatively smoothly with no issues other than one redirect which required some fiddling.
- All lifts were done in vertical position.
- The conventional mechanical haul system was tedious, in particular with little space available on the pitch head for people to haul.
- The passage between the fourth and third pitch was very narrow, with ultimately two cavers (Anna and Alan) lying face down in the keyhole-shaped passage (maybe that even stopped Alan talking for a minute – thank god!) with the stretcher being dragged over them.
- The anchors at the entrance pitch were relatively low which made it hard to get the stretcher out, but at this point several SES and Police were available to use brute strength to get the stretcher the last bit.
- Isabelle in the SKED stretcher was then placed in a rigid basket stretcher for easier carrying down the hill.
- The casualty reached the surface approximately 00:30-01:00 and was airlifted to Hobart at 02:00.
- The cave was derigged, including all temporal anchors, and most people arrived back in Hobart around 4:00.

The end of a successful rescue

Postscript

- Isabelle arrived safely at the Royal Hobart Hospital approximately 20 minutes after leaving the rescue site.
- She was operated on at approximately 10:00 on 14 July 2017. The operation was successful with a pin placed inside her right femur, with no complications. She remained in hospital until Monday afternoon, 17 July.
- She was discharged to the care of Janine McKinnon and Ric Tunney, with whom she stayed and recuperated until Friday afternoon 21 July, when she flew to Sydney where she managed to attend two days at the UIS congress.



X-rays of Isabelle's break (above) and repair (right)

The reason for success

- Almost every person present knew a majority of the rest of the team and were on good personal terms – the whole thing was like an in-cave reunion.
- Many of the caver/Police/SES relationships exceeded 15 years. This was the result of a large of number of cave rescue exercises (almost annually since the late 1990s).
- The relaxed, confident and trusting nature of the team allowed for seamless organisation and execution of the extraction – we all knew that everyone else involved was competent and confident.
- Having two paramedics available who are both capable of technical vertical caving is an enormous luxury.
- There was even a lot of time for general banter, from which no one was excluded. The whole process was a delight to watch and be a part of and left one with a very warm inner glow.
- It is clear that we need to continue running inter-agency rescue exercises and make sure that the next generation of cavers, SES and Police SAR get to reap the rewards like the current generation just did.
- A massive thankyou to all those involved and all those that were on standby. It is a testament to the strength of the caving and professional rescue community that we are prepared to drop everything and help a friend or even a stranger in need.
- Despite what fun it all was, let's hope we never have to do it again!

Thanks for saving me

CAVE RESCUE

GRATEFUL: Isabelle Chouquet, who broke her leg in Mystery Cave, thanks police rescuers Damian Bidgood, left, and Josh Peach who came to her aid. Picture: SAM ROSEWARNE

PATRICK BILLINGS

IT was always going to be a trip to remember.

But for one French caver the memories of Midnight Hole will be about the people she met in the crisis not the crevices.

Isabelle Chouquet fell five metres, breaking her leg while abseiling Midnight Hole at Mystery Creek in the South-West last week.

An experienced caver and nurse, who also volunteers with Swiss Rescue in her adopted homeland, she knew she was in trouble.

"I think I am so stupid to do that because it will be so complicated to get me out," she said.

DRAMA: Isobelle Chouquet is treated and airlifted from the remote site. Pictures: OLA LOFQUIST

Midnight Hole has five descents ranging from 8m to 59m. Luckily, Ms Chouquet fell down the shortest of them.

Nevertheless, rescuing a seriously injured caver 100m down a black hole was never going to be easy. It would be more than 12 hours before Ms Chouquet was admitted to the Royal Hobart Hospital. She was overwhelmed by the support and care.

"The paramedics [Han-Wei and Anna] who came to help me in the cave, did an amazing job to lessen my pain, which was almost unbearable," she said.

She commended the other cavers and police "who came to me to help me along the way to the exit".

"Each of them has gone crazy for everything to go well," she said.

"I also do not forget all these people outside, including some SES people, waiting for me in the night and the cold to get my stretcher down through this steep and slippery forest. Also, the helicopter crew who worked in difficult conditions."

She also thanked the team of cavers she was exploring with and RHH staff.

"For all of you I have a lot of admiration, the population of this island is very fortunate to have such a hospital," she said.

Ms Chouquet left Tasmania yesterday to attend a caving conference in Sydney.

Mercury article from 22 July 2017.

Main photo taken on Spiel editor's balcony. Other photos supplied to Mercury by Ola.

ABSTRACT

Thailand lessons symposium

BRIAN EVANS, Illawarra Speleological Society

A report from a Department of Home Affairs symposium on the Thai cave rescue. The Tham Luang rescue was noticed by all. We present a report from the Lessons Symposium held by Emergency Management Australia to discuss the lessons that Australian emergency management learned from it.

EMA's Thai lessons symposium

Brian Evans, January 2019

Thanks

- NSW Cave Rescue Squad for the invitation
- Emergency Management Australia for putting on the event
- Dr Richard Harris
- Al Warild, both for correcting and clarifying what was said on the day.

A Timeline

23rd June	The boys and their coach take a post-training adventure
24th June	The world learns that the boys did not come out of the cave.
25th June	Vern Unsworth, British caver, on the spot, knows the cave well
26th June	Al Warild is contacted by Speleo Secour Francais to see if we can supply divers. Al in-turn contacts several divers and puts them on standby.

27th June	NSW Cave Rescue Squad captain gets a request to assemble a list of suitably useful cave rescuers.
	Al provides list to EMA via NSW Fire and Rescue but is told that they'll prefer to send paid professionals rather than volunteers who actually know what they are doing– AFP divers and a navy diver.
	Two British cave divers and a caver arrive.
28th June	Ric Stanton and John Volanthen find four park workers flooded in the cave where they had been attempting to drain it yesterday. They dive them out.
30th June	Australia sends: six officers in an AFP specialist rescue group
2nd July	Ric Stanton and John Volanthen find the team alive.
3rd July	Divers bring food and support to the team. Two Thai Navy SEALS now stay with the boys until they are rescued
	The rescue effort is trying to find a way to extract the boys – it is a given that diving them out is far too risky.
	The media barrage begins: ASF addresses and cavers or divers who have ever spoken to the media (or just were known by someone that had!) were being peppered with requests for background, details, or just a voive that knew something about caving. The world is taking a VERY big interest in a cave related event!
5th July	ACRC gets an email from Fairfax, via Andreas, asking for an opinion piece.
	Ric Stanton specifically asks for Richard Harris as a cave diving anaesthetist.
	DFAT finds a way to support sending Harry, and (even harder) Harry's dive buddy, Craig Challen.
6th July	Thai Navy SEAL, Saman Gunan, dies after a diving trip placing dive bottles in the cave.
	There are 13 foreign cave divers and five Thai navy seals involved in the diving part of the rescue. There are over a thousand others involved in everything from pumping and draining to administration.
8th July	The first four boys are successfully extracted from the cave.
10th July	The final group are successfully extracted from the cave.
13th July	The world's media interest evaporates.

Lessons discussed on the day

- Being part of huge, intense rescue effort
  - a very small Australian caver team
  - a very small Australian support team
  - intense media interest
  - the need for support to allow recovery and organisation
  - the jungle of politics being played out around the rescue
- International relations and what they mean for cavers
  - what Australia is trying to say to the world
  - overing Australian arses — liability

    - the competition of international politics
    - Australian public service and jumping through the hoops
    - pre-existing relationships — it would seem that an Australian military officer, who had previously spent two years 'embedded' in the Thai military, helped considerably in the administration of the rescuers
    - there was concern expressed, that, unlike the Thais, Australia would be unable to approve foreign specialists to operate in Australia, if we were the ones that needed help!
    - the Australian response to the media both governmentally, and not.
- Sending the right people
    - Why can the UK send specialist cave rescuers while Australia can manage no cave specialists? (until they receive a specific request)
    - 'What would these middle-aged foreigners be able to do that we can't?' (Thai rescue coordination). They eventually let them in but quite publicly stated that they wouldn't be pulling their dead bodies out.
    - Even after Harry was specifically requested, it was his insistence that saw DFAT find a way to send Craig. The foreign divers on site subsequently decided that it was easier to bring specialist cave divers in from various other countries, rather than any additional Australians.

What we should be taking away as cavers...

- Building relationships with those that control rescues is the key:
- Police, and maybe Emergency Management Australia, need to:
    - know what <u>they</u> can and cannot do effectively
    - know what <u>we</u> can (and cannot) do effectively
    - know how to <u>call</u> cavers and get an effective response
    - TRUST that we can do what we can do, without making it worse
- How we fit into a rescue incident — who commands, and how to get the support that we need
- If we need support from cave rescuers from overseas, DFAT warns that they may not be able to allow them in!
- There might be an enormous media circus about a cave rescue, or other event. We should think about how cavers and the ASF responds to that meaningfully
- How do we convince governments to recognise that volunteer cave rescuers are more likely to be able to satisfactorily rescue from a non-trivial cave, and that they need to support and recognise us?
- On the day Shane Fitzsimmons, RFS, NSW, (big public profile) said we should make a register, he'd get that happening, etc. Al Warild tried contacting him later, but no reply.
- Right now, Emergency services know something about, and are a tiny bit interested in, caving, although they are by no means expecting incidents.

ABSTRACT

Rescue in an iconic cave: the Kubla Khan Cave Rescue Plan V1 (2017)

DEB HUNTER, Mole Creek Caving Club

Kubla Khan is an iconic Australian cave of great beauty, with dizzying chamber proportions and a variety of physical challenges. Due to its verticality, it was not entered until 1947 and was not fully explored until the late 1960s. Kubla is still found challenging by many Australian cavers, with through trips typically exceeding 10 hours. Conservation measures such as track delineation, boot-wash stations and the approved leader requirement are in place. However, decades of diligence in protecting the cave's values could be undone if a rescue was ever needed. Realistically, rather 'when' not 'if'. It is hoped the 2017 formal Rescue Plan, developed in great detail and facilitated by professional cave mapping, will prevent damage to the cave even in the event of a rescue.

ABSTRACT

World Heritage values, Aboriginal heritage and conservation issues of the Mole Creek karst explained

DEB HUNTER, Mole Creek Caving Club

Several post-conference trips are in caves of the Tasmanian Wilderness World Heritage Area (TWHHA) at South Mole Creek (Sassafras/Mayberry divide). The TWWHA is believed to be one of only three properties world-wide possessing as many as seven of the possible ten natural and cultural criteria. Representation of the glacial history, written in the caves and surrounding landscape, was enhanced when the South Mole Creek karst area was added to the TWWHA in 2013.

While small squares drawn around cave mouths have been typical of local cave reserves, decades of documentation and liaison gradually secured more meaningful protection for these caves. The effort continues today, to address the significant omission from conservation tenure of part of the karst window and a group of magnificent heritage trees. The involvement of Aboriginal custodians, the potential for plantation forestry in corporate management for conservation and the function of the caves as glacial meltwater drains are discussed.

Thursday 3 January 2019

ABSTRACT

FORUM: Cave access, conservation and management

Coordinated by STEFAN EBERHARD (STC) and Nicholas White (VSA)
Facilitated by STEVEN MILNER (Cave Exploration Group of South Australia)

Talk 1: How does World Heritage change cave management?

STEVE BOURNE
Former Manager, Naracoorte Caves World Heritage Conservation Park
Former President, Australasian Cave & Karst Management Association

Talk 2: 'Navigating the Sunless Sea': caving access in South Australia, a caver's perspective

CLARE BUSWELL PhD
Flinders University Speleological Society Inc.
Adjunct. Women Studies, School of Social & Behavioural Sciences, Flinders University

Talk 3: Evolution of management, South Australian Nullarbor; from the past to now

NICHOLAS WHITE
Chair: ASF Conservation Commission
Victorian Speleological Association

Talk 4: Cave access and management issues in Victoria: successes and challenges

SUSAN WHITE PhD OAM
Victorian Speleological Association
Environmental Geoscience Latrobe University

Talk 5: Managing cave access in New South Wales parks and reserves

ANDREW BAKER
Project Officer, NSW National Parks and Wildlife Service

Talk 6: Cave management classification and access in southwest Western Australia's national parks

GREG THOMAS
Western Australian Speleological Group

Talk 7: Cave conservation, access and management: experiences, questions and opportunities

STEFAN EBERHARD PhD
Director, Subterranean Ecology Pty Ltd
President, Tasmanian Speleological Liaison Council

A strategic approach to improve cave access and conservation

STEVE MILNER, STEFAN EBERHARD and NICHOLAS WHITE

The 31st ASF Conference held in Devonport, Tasmania hosted a forum and panel discussion to raise awareness of recent developments in various States and Territories that impact access to caves for speleologists, including cave zoning and onerous permit systems.

It also sought to foster engagement, discussion and collaboration between speleologists and cave managers on matters of concern to ASF members.

To establish context, speakers representing cave managers, speleologists and researchers spoke about different karst areas and management systems from around Australia; they then formed the panel to discuss aspects relating to four key threads:

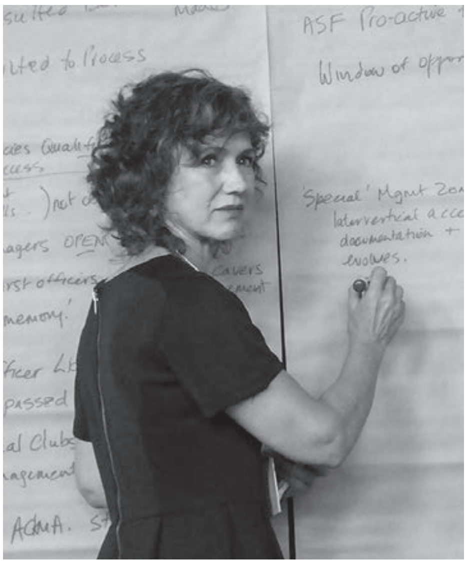
1 Common issues and challenges with existing cave conservation, management and access systems at state, territory and national levels;

2 Different perspectives and approaches on cave conservation and access management;

3 Opportunities for speleologists and cave managers to improve cave conservation practices; and

4 Strategic priorities.

The forum was very well attended and generated open and constructive discussions about key issues and challenges with existing cave conservation, management and access systems across most Australian states and territories. The panel responded to questions from the forum and from this public discussion, six key themes emerged.



Bronwen Prazak recording panel discussion points

Facilitator Steve Milner, with the panel (L-R): Stefan Eberhard, Greg Thomas, Andrew Baker, Susan White, Clare Buswell and Nick White (Steve Bourne is out of view)

Develop shared values and understanding with land managers and owners

There is no doubt that there are shared values between speleologists and land managers, yet these have generally been poorly acknowledged and promoted. Hence there is a need to commence dialogue in order to achieve alignment on values of caves, landforms, and the stakeholder groups who value them (i.e. general public, land owners, managers, researchers, speleologists, traditional owners, etc.), because each group has different perspectives and priorities. The panel recognised that the issue is further complicated as different parts of a cave and/or its environment may have different conservation values.

It was agreed that while the initial approach should be to develop and document common values, the question was raised who should this be with, as there is no single voice to deal with? A good start which was recognised was to develop a memorandum of understanding with the Australasian Cave and Karst Management Association (ACKMA)[1] and then follow this up with other organisations with similar values. A parallel approach should be to engage with land managers and owners on high priority conservation matters.

The forum acknowledged that there is a long way to go and the ASF has a responsibility to lead the conversation, including engaging with indigenous communities.

Build long-term relationships and trust

One of the challenges identified was that speleologists develop a long-term relationship with karst and caves, typically spanning decades per individual; however, over the same time periods, land managers in government departments typically change much more frequently.

The frequency of change results in a loss of corporate knowledge and trust in relationships (which is generally retained by an individual). This cyclical loss requires speleologists to rebuild relationships with new managers from scratch time and time again.

The panel considered that by raising the profile of the ASF and promoting the ASF's inherent knowledge and skills of its members, this would reinforce the status of members in the eyes of the land managers. It was thought that when supported by proactive communication, and a consistent approach from the caving community, relationships and trust could strengthen because it becomes more about the relationship between the organisations, as well as the relationship between the individuals.

To support this, the ASF has a role to ensure that its members are consistent in approach; techniques to do this include peer review of capability and the promotion of ASF Codes and Guidelines to guide its members.

Proactive, consistent conservation management

Across Australia there are layers of permits and a huge variability of access requirements; some regions have strong and lasting relationships, but others have *ad hoc* processes. Another problem is that there are conservative managers who choose to limit access (there are many reasons for this including lack of resources, or simply not knowing how best to manage their natural resources).

The panel discussed that on one hand, limiting access is a conservative conservation action but this limits legitimate exploration and science. On the other hand, unregulated access has the potential to damage the cave environment. Therefore, a balance needs to be achieved by the managers whose duty is to care for the land and the speleologists who access the land, and also care for it. The panel

ASF Values

- We are dedicated to safeguard and protect the cave and karst environment;
- We strive to bring together and represent those interested in caves and karst in Australia;
- We share knowledge; and
- We foster speleology in all its aspects.

The cave access, conservation and management forum at the 31st ASF Conference

conversation then moved to the work health and safety needs (employees vs. speleologists), insurance and the management of conservation.

It was also recognised that the quality and accessibility of access information is important, as usually one has to be a local speleologist to know access conditions in state-controlled parks and reserves. While this is a local or regional matter, each management authority has a duty to ensure that caves can be reasonably accessed without overly obscure, complicated or bureaucratic processes. In a practical sense, the sharing of values and building relationships and trust by the ASF, combined with consistent and user-friendly permit application processes put in place by land management authorities will benefit access and cave conservation.

State of caves, monitoring, and regional liaison

It was recognised that understanding of the overall 'state of cave environments' in Australia is inadequate. There are some local / regional patches of strong knowledge, but from a nationwide perspective there is no consistent approach, nor an examination of risk and threats to cave and karst environments at local levels.

The panel discussed that for the ASF to have one voice is difficult, but this may be addressed by State- or Territory-based cave access or advisory committees. In Western Australia for example, speleologists are well represented on the Cave Management & Access Committee (CMAC). In other states and regions however, speleologists are poorly represented or excluded. The panel postulated that an ideal outcome would be to have ASF representatives whose role it is to; (i) safeguard and protect their region; (ii) have a standing role on land and conservation management; (iii) be able to influence policy effectively. The ASF has a long way to go to achieve this.

The requirement to monitor the condition of caves was considered essential in managing conservation values of caves, to assess whether or not management actions are effective, or indeed whether or not the ASF's Codes and Guidelines are achieving intended outcomes e.g. Minimal Impact Caving Code.

The approach to assess, monitor and respond to environmental changes and threats requires coordination at the national level and commitment and energy by the ASF to deliver strong conservation outcomes.

Speleologists are citizen scientists

There is a distinction between recreational caving in the sense of a leisure activity, and (generally) what ASF members do, that is to explore, survey, research and document caves and their values. ASF members are speleologists who are almost always self-funded, they explore, map, record their findings and contribute to scientific knowledge. The panel reinforced that, by their actions, speleologists are citizen scientists and contribute thousands of hours every year to building knowledge about the cave environments, which ultimately assists professional scientists, land managers and conservation.

The value of speleologists as citizen scientists is under-played; the ASF has a role to communicate this valuable inherent capability of its members as speleologists first and foremost, and, the ASF as a federation of speleologists versus leisure-seeking cavers. The ASF has a further role to bring awareness of the Federation's scientific capabilities to professional scientific disciplines and encourage scientists to engage more with ASF members.

Preserving knowledge and mentoring

ASF members collectively have a deep resource of knowledge, yet this is currently inaccessible to many. The panel discussed that while existing knowledge is in the process of being preserved, it needs to become more accessible if it is to be useful for improving the conservation and management of caves.

Strategies to make speleological knowledge more accessible include digitisation and cataloguing; but this needs to be promoted to all stakeholders to ensure that the information is readily available when needed. This is particularly important as the aging demographic of speleologists passes its knowledge on to new generations of speleologists. At the same time, respecting and acknowledging intellectual property and protecting sensitive information (e.g. some cave locations) are big challenges both now and in the future.

The ASF has a role to improve leadership in this area, to have succession planning and mentor the next generation of speleologists.

The future — strategic measurable outcomes

How does one measure success? The panel identified that the priority **goal** is for the ASF to be front of mind when land managers and other stakeholders consider aspects of cave access, conservation and management. The measurable **outcome**, therefore, is for ASF representatives to be invited to the table as part of the process before change occurs.

The ASF Strategic Plan 2019–2024, which was approved by the ASF Council on 3 January 2019, has identified a range of pertinent actions to address cave access, conservation, and management. These include: access to knowledge and information (Actions #3 to #7 inclusive); integration of speleological research (Action #8); and the requirement for proactive advocacy (Actions #11 to #15 inclusive).

http://tinyurl.com/y2rn7jcn

As evidenced by the forum, there is a long way to go for the ASF to achieve measurable outcomes in the area of cave access, conservation and management; this will require a significant commitment of energy and resources, and leadership on all the points above, if we are to be successful.

We hope this article will stimulate further constructive discussion about cave access, conservation and management, including articles in *Caves Australia*, from the panellists and other contributors.

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Balancing access and conservation through collaborative relationships

STEFAN EBERHARD and BRONWEN PRAZAK

"... cavers find, explore and map caves. Their efforts make research possible for the scientists. The scientific results prove that caves have value and need to be managed properly ..."

Dr George Veni, President International Union of Speleology (*Caves Australia* 206, December 2018)

This article follows on from the preceding article and provides additional context and personal perspectives, and tables the key points recorded during the forum discussion on cave access, conservation and management, held at the 31st ASF Conference in Devonport, Tasmania, January 2019.

It then addresses the questions: What did the forum achieve? and 'Where to from here?'

Across Australia, a tension exists between speleologists and land managers. This is because land managers have the challenging task of protecting caves and cave values, while speleologists, by their calling, visit caves. People visiting caves may cause impacts which lead to irreversible degradation of cave values. Land managers typically respond to this potential threat by imposing limitations on access. This involves permit systems, which are sometimes onerous, and which discourage and even prohibit speleologists.

Speleologists appreciate caves. They explore, map, photograph, document and celebrate caves. Like land managers, speleologists want to protect caves. Speleologists use various methods to regulate their activities and impacts in caves, including codes of practice such as the ASF Minimum Impact Caving Code, and lightweight "infrastructure" such as string-lines, route markers, small signs and boot-wash stations.

Speleologists are the first and primary source of knowledge and expertise about caves, for both scientists and land managers. Speleologists provide scientists and land managers with maps of caves, and they identify sensitive values, such as speleothems, fauna and bones that need study or protection.

Ironically, the maps and knowledge that speleologists provide to land managers may ultimately result in onerous access restrictions being imposed on speleologists. This results in tensions in the relationships between speleologists and land managers, however both parties have the shared goal of protecting cave values (Figure 1).

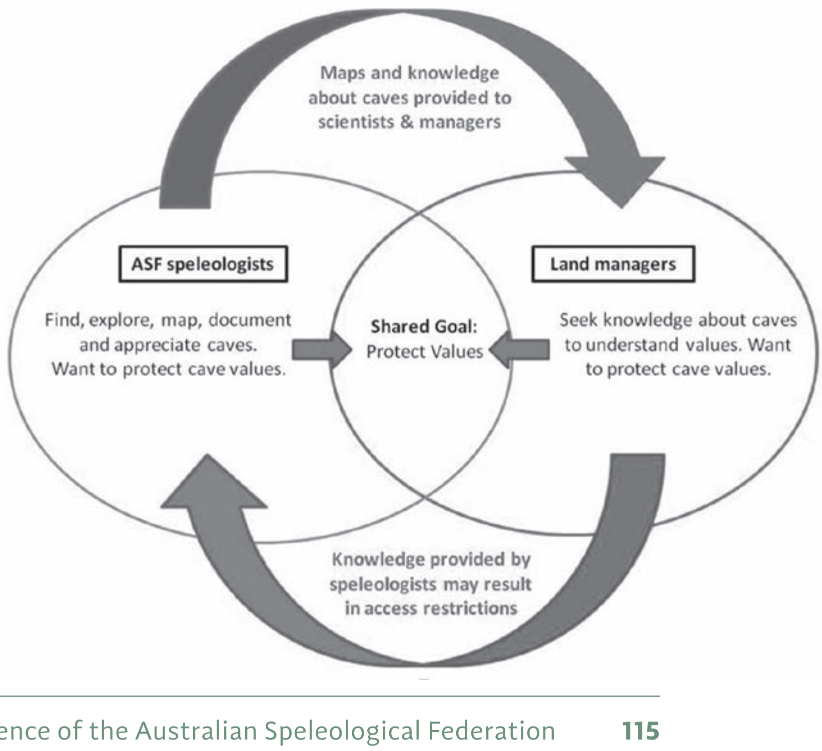


Figure 1. The maps and knowledge that speleologists provide to land managers may result in onerous access restrictions being imposed on speleologists, which results in tensions in the relationships between speleologists and land managers, however both parties have the shared goal of protecting cave values.

While acknowledging that access restrictions may be part and parcel of protecting cave values, across Australia in recent years there is a disquieting trend by land management authorities towards ever tighter and onerous controls on recreational caving and speleological activities (Figure 2). This reactionary shift in the policy climate rides on a two-pronged fork; one prong touts environmental protection, the other prong touts public safety, duty of care, risk management and litigious fear. Occasionally these two policies appear to be confused and misapplied, with putative safety concerns used as a rationale to prohibit access while indirectly protecting environmental or cultural values. These developments are unsettling because they are disproportionate, occasionally misguided, and they impact legitimate recreational and speleological activities.

The growing regulatory threats to access are spotlighted in the ASF's Strategic Plan 2019-2024 which was released in December 2018 and approved in January 2019. The development of the Strategic Plan included a contextual analysis to capture the factors that influence the organisation, both from an internal perspective and from an external perspective.

The contextual analyses identified two key threats facing the ASF, namely 'Access to karst' and 'Regulations' (Table 1). We suggest that these two threats (= old story) may also be taken as opportunities to effect change, namely:

1 Engage with land managers; and

2 Influence policy (= new story), and recommend they be integrated into ASF's Strategic Plan.

Separately from the Strategic Plan, concerns in the speleological community about the growing trend in regulatory threats to access catalysed organisation of the forum and panel discussion on cave access, conservation and management, which was hosted at the 31st ASF Conference held in Devonport, Tasmania in early January 2019. The conference was attended by more than 120 speleologists from around Australia, and the forum generated open and constructive discussions about key issues and challenges across most Australian states and territories (except Queensland and Northern Territory).

Different perspectives and regional approaches to cave conservation and access management were described and discussed. Perspectives were primarily from those of speleologists although numerous ASF members at the forum including the speakers (named in preceding article) have worked as, or closely with, scientists and land managers.

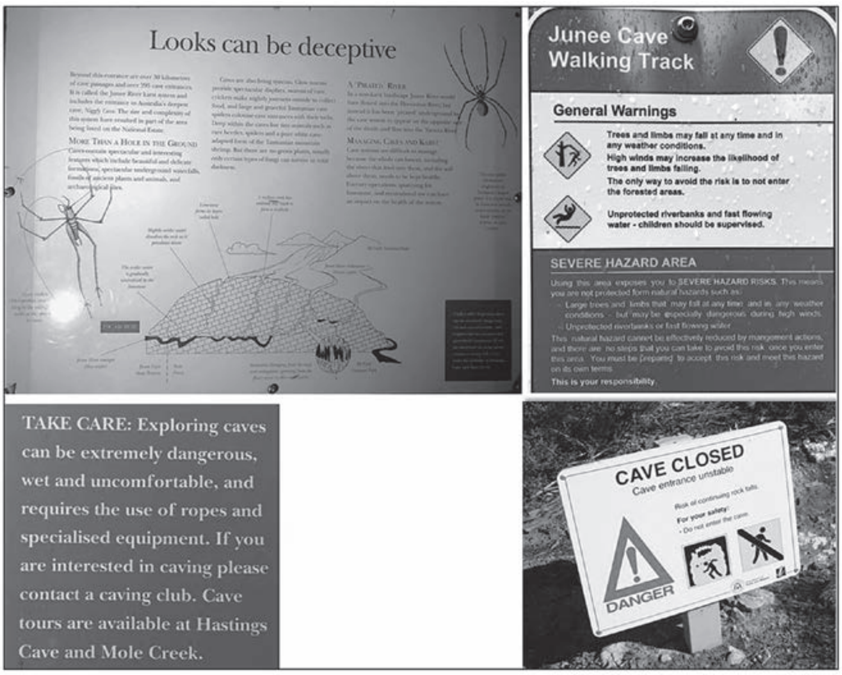


Figure 2. Examples of the trend in access and interpretation policy is reflected in sign "culture" which has shifted from being informative and inviting curiosity while taking due care, towards a litigious and fearful focus on the hazards and dangers that discourages curiosity and appreciation. Left (top and bottom): Junee Cave, Tasmania signs installed 1990s; Right (top) Junee Cave walking track installed > 2015; (bottom) Tommy Grahams Cave, Nullarbor, installed ca. 2018.

STRENGTHS	THREATS
Leadership	Access to Karst
Knowledge	Regulations
Advocacy	
Codes and Guidelines	
Dedication and Purpose	
WEAKNESSES	OPPORTUNITIES
Aging Demographic	Use Technology
Fragmented Activities	*Engage with Managers*
Engaging with Members	*Influence Policy*
Reduced Exploration	

Table 1. SWOT analysis reproduced from ASF's Strategic Plan 2019 – 2024 (Appendix VI, pp. 23-24). Recommended additional opportunities in italics.

Indigenous perspectives were under-represented at the forum but are noted here as important to bring on board as we move forward.

What did the forum achieve and where to from here?

Table 2 summarises the key points recorded during the forum open discussion, structured using Dr David Drake's Narrative Coaching framework and BEAM tool for individual and organisational change. Narrative coaching is a mindful, holistic and experiential approach that helps people shift their stories about themselves, others, and life itself to create new possibilities and new results https://www.narrativecoaching.com/what-is-narrative-coaching.html

The BEAM tool is useful for clarifying the current situation (=old story), and the shifts in mindset, behaviour and the environment that are needed if there is to be a new aspiration (= new story).

OLD STORY: problems with access, knowledge gaps, breakdown or lack of relationships, mistrust, limited collaboration, lack of recognition for what speleologists are contributing.

NEW STORY: collaboration, continued access, corporate memory maintained, knowledge, data and resources shared, speleological expertise recognised, utilised and appreciated, mutual respect.

What would it be like if in all of our speleological endeavours (on the ground, in the caves, in our interactions with other cavers and with the land managers) we were intentionally operating from this new story?

The overarching aspiration that came out of the forum may be stated as:

Balancing access and conservation through collaborative relationships

How could we use a common overarching aspiration such as 'Balancing access and conservation through collaborative relationships' as our individual and collective mantra to step up in whatever arena we are in and proactively be sharing, trusting, collaborating and respectful? The forum showcased some great examples of collaborative and trusting working relationships.

If we want this to be our new story and we really want to shift from the current situation and mindset, what are each of us going to commit to doing? Has this become an active movement for sustainable change and not just something we discussed or criticised in a forum and wrote up as an article?

Table 2 is a summary of key points recorded during the forum open panel discussion, structured using Dr David Drake's Narrative Coaching framework and BEAM tool for individual and organisational change. Prepared by Bronwen Prazak.

MINDSET

What is the current situation?

- Speleologists provide maps and knowledge to land managers
- Maps and knowledge may be used to justify restricting access to caves
- Access restrictions may be disproportionate or misguided
- Access policies may be applied inconsistently
- Permit systems may be onerous
- State of cave environments is poorly documented or monitored
- ASF expertise is under-recognised
- Alternative in-cave protective measures such as route marking are under-utilised
- Land managers move on and knowledge is lost
- Trust and relationships between managers and speleologists is inconsistent, often difficult

ASPIRATION

What is the aspiration?

- Balancing access and conservation through collaborative relationships
- Cave values are protected
- Access for speleologists is facilitated
- ASF expertise is recognised and sought by land managers and policy makers
- Improved leadership and mentoring within ASF
- Alternative protective measures utilised
- State of cave environments documented and monitored
- Access regulations are proportionate and relevant
- Access policies are applied consistently
- Collaborative relationships between managers and speleologists
- Trust

continued overleaf

BEHAVIOUR

What matters?

- Speleologists proactively initiate 'soft infrastructure' protective measures in caves
- Speleologists report on state of cave environments and monitoring priorities
- ASF clubs nourish relations with local land management authorities
- Speleologists consulted at start of access policy and planning processes
- Issues addressed through local standing management advisory committees
- Supportive leadership and mentoring within ASF clubs
- Speleology, in all its aspects, fostered by ASF clubs

ENVIRONMENT

What works?

- Relationships and trust between speleologists and land managers
- Consistent national policy on cave conservation and management
- Cave access permit systems less onerous
- Land management policy and processes are transparent and accountable
- Methods for monitoring and assessing state of cave environments; measureable outcomes
- ASF leadership, mentoring, peer guidance, ethics, minimal impact, best practices
- ASF recognised first and foremost as a speleological organisation versus recreational caving
- ASF, together with ACKMA, recognised as leading national bodies of expertise in caves and karst.

ABSTRACT

Chasing mega caves in Vietnam

ALAN JACKSON, Southern Tasmanian Caverneers

The Phong Nha-Kẻ Bàng National Park in central Vietnam is home to several of the world's largest caves. British expeditions to the area have been running since the early 1990s by Deb and Howard Limbert. More than 180 kilometres of passage has been surveyed to date. The area is endowed with spectacular river caves and one of the key-aims of the expeditions is to locate and explore them. The area is home to Hang Sơn Đoòng, considered the world's 'biggest' cave, which was explored during the 2009 expedition.

This presentation doesn't aim to get bogged down in scientific detail but rather delight the senses with spectacular photography and video of massive caves, spectacular speleothems and jagged jungle-bound karst.

Chasing mega caves in Vietnam

Alan Jackson

The Phong Nha-Kẻ Bàng National Park in central Vietnam is home to several of the world's largest caves. British expeditions to the area (and other parts of the country) have been running since the early 1990s, led by Deb and Howard Limbert. More than 180 km of passage has been surveyed to date yet no more than 30% of the total limestone massif has been prospected — the remaining potential is mind-blowing. Access is difficult (both politically and physically at times) with the particularly inhospitable jungle karst terrain often meaning the caves are a welcome relief from the rigours of the surface.

One of the key aims of expeditions is to locate and explore the base level river caves, which the area does spectacularly well. The area is home to Hang Sơn Đoòng, considered the world's 'biggest' cave, which was explored during the 2009 expedition.

Vital Statistics:

- 1990–present
- Around 30% of the Kẻ Bàng Massif explored
- Very remote and difficult access
- British cavers along with members of the Hanoi University of Science have explored since 1990
- ~20 major expeditions to Vietnam
- Over 600 caves explored in Vietnam
- 322 entrances in PNKB area — 186.5 km of survey

The expeditions have assisted in the following:

- Helped with National Park status in 1996
- Helped with World Heritage status 2003
- Caves now employ directly over 2,600 people
- Caving adventure tour companies now employ over 500 guides and porters
- Promotion of caving/jungle trekking as an adventure activity
- Work directly with National Park on conservation issues
- Work with UNESCO/IUCN
- Played a major role in promoting tourism in Quang Binh province
- 2.8 million visitors to the province in 2016.

When it all boils down this presentation didn't aim to get bogged down in scientific detail but rather delight the senses with spectacular photography, speleothems on steroids and jagged jungle-bound karst.

ABSTRACT

Caving in the far north — the 2018 recce to Ha Giang, Vietnam

ADAM SPILLANE, Sheffield University Speleological Society, UK

In November 2018 a small team will recce the caves and caving potential of Ha Giang province. Various groups have tried in the past, none have succeeded for more than a few days. Political problems have seen them ejected from the province. We have an invitation. Will it be different this time?

ABSTRACT

Oxalis — commercial cave tour operator in Vietnam
STEVE BOURNE, Canberra Speleological Society

Oxalis Adventure Tours operates in Phong Nha National Park, Vietnam and surrounding karst areas. The company was established by a local, Chau A Nguyen, who was born and grew up in the Phong Nha Village. He moved to Ho Chi Min City for education and following a successful business career, returned to his home village, establishing Oxalis in 2011 to fulfil a desire to improve opportunities for local people and showcase the amazing landscape he grew up in. Chau A has been greatly assisted by Howard and Deb Limbert and other members of the British Cave Research Association (BCRA), who provide technical training and assist with the development of cave tours. BCRA also provides an expert for each Hang Son Doong expedition.

Tours are led by guides trained by the BCRA, supported by porters sourced from the local villages. The overnight and multi-day tours include chefs who prepare high quality food for the tour group. All equipment is high quality, with caving lamps powerful enough to light up the enormous cave chambers visited on these tours. Visitor safety is paramount. Tour briefings are provided for each tour and safety assistants work with guides on tour to ensure all participants are comfortable on climbs and traverses. Visitors come from diverse backgrounds with experience levels ranging from decades of caving across many countries to those taking their first-ever cave tour.

This paper describes several of the Oxalis cave trips in the Phong Nha National Park and nearby Tu Lan karst area, and the role of the Oxalis staff in delivering these experiences. These include the Tu Lan and Hang Tien one day experiences, Hang Va two-day tour, and a four-day 'expedition' through the mighty Hang Son Doong — the largest cave in the world.

Oxalis — commercial cave tour operator in Vietnam

Steve Bourne
Canberra Speleological Society

Introduction

The descriptions of the cave tours taken with Oxalis are from a trip to Vietnam in March and April of 2018 with group of Brazlians: Augusto Auler, Alexandre de Oliveira Lobo (Lobo), Ezio Luiz Rubbioli and Lília Horta. Our group stayed with different several home stays, which have proliferated in the village following the opening of Paradise Cave and the establishment of Oxalis Adventure Tours. Oxalis was established in 2011 and is now the major employer in the region, offering jobs for guides skilled in English-speaking, marketing personnel and dozens of porters. This paper describes several cave tours and evaluates the experience as a first time visitor to this region.

Hang Tien one day tour

The Hang Tien Caves are about 70km from the Phong Nha village. Oxalis staff collect you from your accommodation to transport you to the Oxalis centre at the village — the start of the cave tour. Augusto and I were joined by 11 others for the tour. As we were an oversized group, two guides were provided for the tour. The guides, Dong and Thi, made an exceptional effort to learn everyone's name on the drive to the Oxalis centre, seemingly easily remembering a dozen names of multiple nationalities. Dong and Thi were really high energy, which I learnt was typical of Oxalis guides over my tours at Phong Nha. The attention to detail with Oxalis tours is excellent. We were provided a briefing of what we could expect on the tour, footwear for those with unsuitable boots and valuables locked away. Our cave was a 20 minute drive from the centre along a 4WD track, except we were in a mini bus. Half-way into the journey, we had a flat tyre. This was only a minor issue as the flat was quickly removed and the spare ... nowhere to be found!!! An urgent radio call back to base had a spare van to us quickly and we made our way to the drop-off point for the cave.

Then it started raining. A light rain for the entire 6km walk to the cave, up and down very steep and slippery paths through Vietnamese jungle. When the jungle parted to reveal the cave entrance, we were rewarded with an amazing view. An 80m high entrance disappearing into a mountain. A light snack at

Right: Approaching the 80m high entrance to Hang Tien.

Below,: The 100m+ high dome in Hang Tien

the cave entrance and some photos, and then we entered the cave. Not far in, the cave roof went up considerably (remember the entrance is 80m high!) with an enormous dome in the roof. At this point I started to slow the group as I started photographing the best scenes, which were plenty! The cave had bats, great cave decoration and some good scrambling to reach the end of the cave. Here we enjoyed lunch and some great daylights views from the cave exit. The longer tours — there are Hang Tien 2,3 and 4 days tours — continue and explore more jungle and caves beyond where we turned around. Then we made our way back along the 6km path to meet the mini bus, fortunately without the rain of the morning walk. Dong and Thi sang most of the way while the rest of us huffed and puffed our way home.

With the delays of the flat tyre, it was about 12 hours from pick up to drop off, and I thought fair value for the $88US paid for the tour.

Hang Va tour

This is a two-day trip visiting Nuoc Nut and Hang Va Caves, which are located within the Phong Nha National Park. This was just a short 15–20 minute drive from our accommodation but still time for the guides and group to learn each other's names. This time the 10 member group comprised German, South African, Canadian, Brazilian, English, Belgian and of course Australian. The walk to the cave was much easier than the previous trip and we were quickly into the darkness, and wetness. The tour information does warn you that your feet will be wet for most of the time and that good foot hygiene is important. I was well armed with powder and dry socks and didn't have any issues, but did see several examples of foot-rot during my time in Phong Nha. If you tour here, take warnings seriously about looking after your feet.

Nuoc Not Cave was mostly walking passage with some good photographic opportunities. As soon as I extracted my Canon 5DSR from my bag, I was the designated trip photographer. This was great as I had willing models for each shot. Our guide Annetta was brilliant, excellent knowledge of the cave and jungle plus a good eye

Below: As the designated photographer, I took many photos of the group. At scenes like 'James Bond', everyone wanted their picture taken.

Right: Nouc Nut had water most of the trip, which made for some excellent photos.


Left: Stream passage in Hang Va. Right: The extraordinary calcite towers and gour pools in Hang Va.

for where photos could be taken. I enjoyed the tale of the king cobra in the cave and lamented our group was not so lucky. It's difficult to judge the length of the cave we explored that day, but suggest it was more than 2km to the end and then the return trip. Nuoc Not and Hang Va Caves are very close together, but groups would exit one to enter the other. A guide had recently found a connection which Annetta was keen to try, as was our group, so we donned our life jackets and swam through a passage, quite narrow in places, and exited through the Hang Va Cave entrance to our campsite in the cave doline.

On this tour, participants are required to carry all of their clothes, cameras and any other personal items. The great thing is porters carry the tents, water and food, plus a chef is at the camp site to cook your food! We had a great night of food and the local rice 'wine' (= whiskey — a potent brew). The English girl was particularly enthusiastic on the rice wine and spent numerous trips outside of her tent overnight restoring fluid balances to the appropriate levels.

I awoke at about 5am the next morning and explored the jungle near the camp, spying monkeys, pygmy squirrels and other wildlife. By the time the rest of the group crawled from their tents, the best wildlife viewing was over. The chef and porters also woke early and prepared a breakfast feast. Caving trips have never been like this before!

We set off into Hang Va Cave at around 9am, and I was very keen to see the calcite towers that this cave is famous for and which feature on many promotions. We were instantly wet again, so no point in starting with dry clothes. As designated photographer, I was in high demand with some excellent scenes in the stream passage and at a small waterfall.

Partway back along the trip we donned harnesses for the climb to the site I was so keen to see. It was a reasonably easy traverse that many cavers would be more than happy to simply have a hand-line (or not) but Oxalis has set these trips up to cater for all levels of experience. We had some on their first ever caving trip and a couple of us who had seen a few caves before. One of the German girls became quite nauseous and needed to be taken from the cave. This is where the quality of training of Oxalis staff came to the fore again as she was quickly provided some medication to settle the problem and quietly escorted from the cave by one of the assistants. I felt very sorry for her as she still had to do the trek out to the bus meeting point.

The upper level of Hang Va is extraordinary. Massive gour pools that you need a ladder to climb up and down the other side, crossing what are large pools in the wet season, to reach the calcite towers. Annetta, the guide, was slightly deflated when she announced these were the only example of such a cave formation anywhere in the world. I quietly explained that

I had seen the same formation, albeit smaller, in Gastonia Cave on Rodrigues (which few people would have seen), and Augusto spoke of examples in Brazil. We all agreed that what we were looking at was absolutely outstanding and the largest we had seen. I was slightly disappointed that the water level was low and the fabulous colours generated in promotional images could not be replicated. I would love to go back in the wet season and see this cave! We were allowed a good deal of time to take photos but could easily spend a whole day just in this section of the cave.

Infrastructure in the form of individual steel platforms just over foot size are placed on the floor for protection with ladders in place to scale the gour pool walls — yes, you need a ladder to get over them!! All of this infrastructure is removed from the cave at the end of the season as it floods. This must be quite a logistical and physical challenge but ensures the cave is well protected. Price for this tour was US$353 so certainly not cheap, but fair value for the experience and caves that were visited.

Tu Lan one day

Augusto's friends Lobo, Ezio and Lilia joined us after we had completed the Hang Va trip. We joined a Tu Lan one day tour, back to the same area where we had taken the Hang Tien tour. Tu Lan is offered as one, two, three and and four-day experiences, exploring more caves and more of the jungle in this area. Our guide was once again Dong, who had led our first trip. The promotion of Tu Lan uses the movie *Kong — Skull Island*, as many scenes from the movie were shot here. We got to walk in the footsteps of Kong but he did not make an appearance! When I got home, I watched the film and could make out the location of some scenes and compared them to my photos. Kong's home in the movie was a cave with a rather uninspiring name — Rat Cave. It was a fairly gentle walk to the cave, most of it on the concrete road constructed by Hollywood moviemakers with a couple of small river crossings just near the cave entrance. Rat Cave is modest by Vietnam standards but with some nice decoration and a few hundred metres of passage to the exit point. We checked this out and retraced our steps. Of the Oxalis tours we did, this one had the least restrictions within the cave and the cave is showing signs of wear and tear. This could also be from locals as much as paying tourists too.

Left: Preparing to cross the river to Rat Cave, visible in the background.

Below: After the swim through Toon Cave.

We then walked to Toon Cave where the trip become a lot more interesting. Everyone was provided with a life jacket and we swam 150m into the cave to reach a dry point. The water is very pleasant and very clean so it was great fun floating through the cave. A green viper was spotted on the cave wall, but unfortunately no decent holds to stop and get a photo. I then realised that the only way the viper could have got there was also by swimming, so that gave us something to focus on.

Lunch was provided at the most exquisite camp site imaginable. A small waterfall as the cave exit falls into a crystal clear blue lake, with jungle 100m across the other side. Another swim and we reached our food. Yet another delicious spread of local delicacies, with plenty of pork again. The return trip through the dry section of the cave required the scaling of a 15m ladder. Once again, safety was a priority and everyone had a climb on a safety line.

On the return walk to the village, locals were feeding their water buffalo. I found it interesting that the people living within the Tu Lan Valley speak a language so different that our guides could not converse with them. An interesting custom is burying their dead in unmarked graves, although the grave site is carefully maintained. After around 15 years, the bones are excavated and placed in a small box with a concrete memorial and headstone.

Of the tours I did with Oxalis, this was the easiest and somewhat lacked the wow factor generated by the other trips. It probably would have been fine if I had done this trip first, but after Hang Va and Hang Tien, it was a second tier experience. Dong, our guide though, said the four day Tu Lan tour is his favourite and has lots to offer.

Hang Son Doong

After the show caves and three warm up trips with Oxalis, it was at last the date for the Son Doong expedition. There is no doubt Son Doong has an aura about it in the local village and among visitors to Phong Nha. Several visitors I spoke to were excited to meet someone visiting the cave and I exchanged emails with them to provide some pictures from my trip. It is very widely promoted as 'the largest cave in the world'.

Augusto, Lobo, Ezio, Lilia and I attended the compulsory briefing the afternoon prior to the tour commencement. Oxalis has a strict rule that if you fail to attend the briefing, you are not allowed on the tour. The briefing was delivered by Josh, a young member of the British Cave Research Association (BCRA). One condition of the permit for Oxalis to operate tours in Son Doong, is that they must have a BCRA representative on the tour. Other members who join

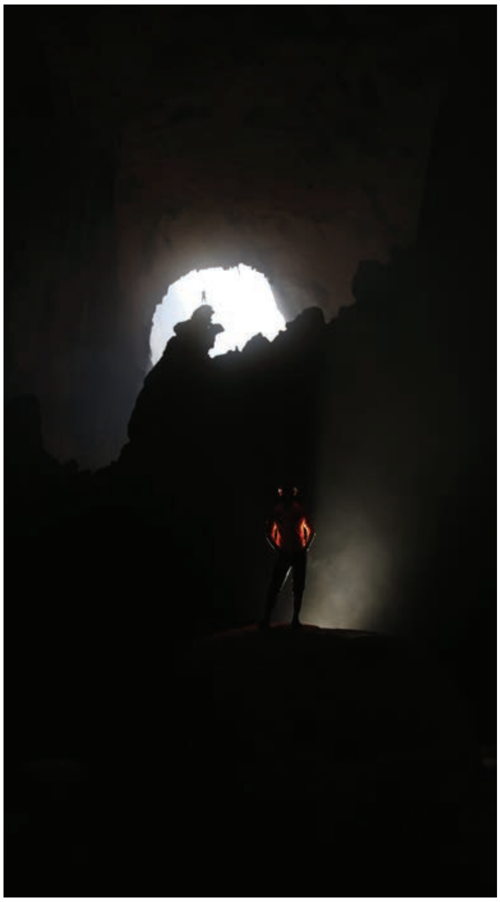
Below: Lobo, Steve, Ho Khanh and Augusto at the Home Stay.

Right: My Brazilian friends posing at one of Son Doong's iconic photo spots.

Exit to Hang En. Note the person for scale on the stream bed.

Cave pearls.

A river crossing in the cave.



‘Hand of Dog’. The guide on the back formation is several hundred metres from the camera.

the expeditions include Howard Limber and his wife Deb, and other cavers who were part of the initial exploration and mapping. Josh was good company on the tour, but the skill level of staff which are BCRA trained seemed to make the position redundant. Maybe a case of doing a job too well and not being required anymore?

Our accommodation for the evening prior to the tour (included in the expedition fee) was at Ho Khan's Homestay. Ho Khan has legendary status in the village as the discoverer of Son Doong in 1990. Over 15 years elapsed before he found the cave again with Howard Limbert. The expedition porters packed all of the equipment and supplies at Ho Khan's from early in the morning. The support crew was astounding — one guide, one BCRA guide, five safety assistants, 25 porters and two chefs. An additional two safety assistants joined us for the cave exit. Our group comprised my four Brazilian friends, four Vietnamese and another Australian, Peter Bayliss, who is originally from Western Australia but now living and

Above: Hard to believe this is actually inside a cave!

Right: Classic Son Doong sunbeam.

working in Laos. As with other trips, we had a range of caving experience. Two of the Vietnamese were on their *first ever* caving trip. They had plenty of jungle hiking experience which is how they were allowed to pass the entrance criteria, and did a good job through the cave.

Day one is nearly all above ground. It is a relatively easy 10km or so trek to the first camp site. Along the way, we stopped for lunch at Son Doong village. The village has just nine families and 45 persons, with a huge imbalance of young girls who will leave the village looking for partners. The village would seem to have reached a point where it will not function for much longer. Despite being quite remote, the village was equipped with solar panels and good battery storage, generating far more electricity than they can ever use.

The trek features many river crossings so feet become wet early in the trip. They remain wet for the next two days, with some respite of day three but wet again on the fourth day. Excitement rose when we set eyes on the entrance of Hang En from maybe a kilometre away. As we trekked closer, it grew bigger and bigger. Instead of climbing through the larger entrance, we accessed a smaller entrance to the right, and then climbed the rockpile for views of our campsite. This was a serious wow factor. Access to the campsite was gained via a raft across the river, although it was flowing so slowly it was virtually a lake.

Now we came to seriously appreciate the support staff. The porters had reached the site ahead of us and set up our tents, mattresses and sleeping bags, with names of expedition members on each tent. Toilet facilities were set up, with all waste collected in plastic bag lined buckets, with rice husks added. All waste is removed from the cave. The chefs had established their kitchen and 'dining room' and had begun preparing the evening meal. We had some free time before dinner so I spent about 30 minutes swimming in the lake/river. So much for caving for days without a wash — I was super clean!

Our chefs provided an excellent meal, and as we were to discover, it improved every night. After dinner, we spent some time taking photos, placing lights inside tents to give colour. I really appreciated Lobo's knowledge on photographing large cave chambers plus the large number of flash bulbs he had brought with him. We took some trial shots to get camera settings correct for the tent light and dining table lights, and then arranged porters and other cavers to set off multiple flashes. We managed a very nice result.

Early morning at doline 1 with porters preparing for the day.

The 'James Bond' hole.

A downside. Porters smoke at the camp sites and butts are left by tents. Most are collected in the clean-up but I did find butts from previous trips.

An amazing site descending to our night 3 campsite.

On day two I awoke early to a muted light coming through the enormous entrance to Hang En. What a way to start a day. The chefs were busy preparing breakfast, more of a morning banquet. As an early riser, this was frustrating for me as breakfast was at 8 with the caving to start at 9. I was ready by about 6.30! Hang En is the third largest cave in the world according to our Vietnamese guide (they have Deer Cave in Mulu at number 2). The exit to the cave is simply jaw-dropping, an enormous cave entrance with a sandy floor with the jungle creeping in on all sides and the cave walls. We were through the cave is quick time and then following the river, which was at a very low level, onwards towards Son Doong. Along the way we learnt why Son Doong remained 'lost' for so many years after Ho Khan discovered it. A limestone wall adjacent to the river had fallen and blocked the river and the original path he took to the entrance. We left the river and climbed a steep path towards our lunch site, conveniently close to the Son Doong entrance. It took a few minutes to realise the strong breeze shaking the vegetation was actually coming from the cave. I took some video later when we descended into the entrance and it looks like footage of a minor hurricane, such was the strength of the wind blowing through the trees and associated noise.

We were kitted with harnesses for the climb in by the safety assistants and checked by Josh. Then one at a time, we climbed the 80m of knotted ropes to the safety of the cave floor. The ropes are cleverly placed and you clip on to each section as you make you way down. The first part of the cave is a blur — I was in the largest cave in the world!

Dzung and Josh were brilliant at showing us good photo opportunities, but Lobo and I (and maybe others) were a little frustrated at not being able to look around to find our own shots. The group is kept to a strict path and there is little deviation from this, which is a good thing. We crossed the river in the cave and spent some time photographing this and not long after, we saw the first glimpse of light from accurately named doline 1. It was quite some time before we reached there though. At a point we could line up a safety assistant on a nearby formation, and another hundreds of metres in the distance on a formation called Hand of Dog, along an enormous passage. As we walked towards the entrance, another wow moment as the campsite came into view. We took a side passage to look at fossils in the rocks and take a swim — a fantastic way to finish off a day's caving.

Another gourmet dining experience and lots of storytelling. Most were off to bed early and I spent some time speaking with Peter, the other Aussie in the group. With the early night, I woke up at a ridiculously early hour which gave me a chance to photograph the first rays of light through the doline.

Day three was a dry day, so for those who had carried (or had the porters carry) an extra pair of shoes, a day of dry feet. I soldiered on with the same footwear, knowing I would be wet again the following day. In a trip of highlights, this was a special day. We split into two groups to photograph the 'James Bond' hole and another scene. We then had the opportunity to photograph one of the truly iconic Son Doong images, that of people on a very large stalagmite within the daylight zone of doline 2. When I look at the collection of images from this site, I noted that the promotional shots are taken with a very wide angle lens making the cave appear larger than what it is, which is really big!!

Progressing further, we could view back up into the doline as the sunbeams made an appearance. I had been in Vietnam for nine days and had not seen the sun, however at the appropriate time, the clouds parted and the doline was lit with an incredible shaft of light. I took dozens of photos at the point as did everyone else in the group. Amongst many nice images, my favourite was a reflection of the doline in a shallow pool of water. Once the sunbeam show finished, we ventured back into the darkness and some cave formations of unbelievable size, stalagmites up to 80m in height. The

Left: The fixed-ladder at the Great Wall of Vietnam.

Below: The view of the camp site in Hang En.

passage was enormous, but the feeling when we approached the next doline, filled with jungle, was certainly one of awe and amazement. Our guide Dzung made it very clear before we entered the doline that we were not to walk on the vegetation and that we were to strictly stick to the defined path. This appears to have been well adhered to, as beyond the defined path the vegetation appeared pristine. I learnt a new term here, when Josh informed us the vegetation exhibits *phenotypic plasticity.* This term describes where vegetation (in this case) exhibits different growth patterns inside the cave to the same vegetation external to the cave. Inside the cave, the plants are deciduous, a response to the reduced sunlight and nutrient levels, compared to their evergreen forms in the jungle above.

One of the Brazilians, Ezio, had brought a laser range finder with him to check the measurements of the cave. Dzung would explain a passage was 150m high so Ezio would check. After a few cases of overstatement of passage dimensions, Dzung would ask Ezio to measure for him. The floor of the doline to the edge of the cave was about 200m, the limit of Ezio's equipment. That's a really big hole!!!

We were allowed a generous amount of time to photograph the jungle doline before descending to the camp site. After a brief rest, we went towards the cave exit to enable us to view the cave and take our photos so we could move more quickly through this section on our way out on day 4. We found the centipede endemic to the cave and a few other invertebrates. The fields of cave pearls were amazing. I had run out of battery so photographed the pearls the following day. An important lesson in Son Doong — take plenty of batteries and cards for your camera.

The third night banquet exceeded the previous two nights as the chefs strove to outdo each other. Two additional safety staff joined us to assist with the climb out and kindly brought some cans of beer for us. Just when I thought the catering couldn't get any better, it did!

I awoke on day four to the sounds of birds flying around the doline. Lying in bed looking up out of the cave from around 400m, what an experience! While we were packing up, I took a close look around the camp site to see how much waste was being left and impact on the cave. I picked up a cigarette butt, some small pieces of paper and plastic. When the porters saw what I was doing, they became quite agitated and Josh suggested not to worry about it as the porters would clean up. I photographed butts on the floor outside their tents and later recommended that each porter should carry a suitable container to place their butts in rather than put them out on the cave floor. It is easy to suggest they shouldn't smoke on the trip, but smoking is so much a part of their culture, I doubt you would get any porters. They only smoked at the camp sites which are near the cave entrances and dolines. The only person I saw smoking in the cave's dark zone was the park ranger who came along to make sure protocols were being followed.

After everyone was packed, we set off the cave exit. When the passage has water, the group uses rafts to reach the Great Wall of Vietnam, an imposing wall of flowstone. It was dry so our group trudged around 500m along a narrow

View of the Hang En camp site at night.

muddy trench to reach the climb out. The wall was fully rigged when we arrived with the safety assistants in place. One at a time we climbed the 30m fixed ladder, before switching to knotted ropes and climbing the near-vertical wall. The flowstone has plenty of footholds, and you are safely harnessed and expertly guided by the assistants across each section of wall. While we enjoyed our lunch, the porters climbed the wall, each carrying large and heavy loads. I am sure all of us admired their strength and agility throughout the trip. It is a short and easy walk from the top of the Great Wall to the relatively small cave exit. From there it was a few kilometres walking back to the waiting bus. Partway along the walk out we joined a familiar path, the exit path from the Hang Va cave trip from a week earlier. I have searched and can't find a map showing the relative locations of the caves, which I imagine is deliberate to avoid having people trying to find their way to Son Doong themselves. Apparently this has happened a couple of times but with so many people at camp sites at the cave entrance and groups moving through daily, the chances of someone finding the cave and sneaking in would seem unlikely.

Each group is treated to a final banquet dinner to celebrate the trip at the Farm Stay. We had a great meal and celebratory drinks and were presented with medals for 'conquering' Son Doong Cave. After dinner, Peter and I did the Australian thing and stayed at the bar by the pool until staff decided it was time for them to go to bed and the Australians could please themselves what they did.

One aspect I did not like was that we were constantly reminded and encouraged to provide tips for the staff and porters. Each visitor was given an envelope to facilitate tipping and you feel very obliged to do so, which I did. We were told that the visitor season lasts only 8-9 months and guides and porters need additional funds for the offseason. In my feedback form, I suggested that the wages paid should allow for the seasonality and not rely on guests tipping for staff to have offseason money to get by. A little extra on the $4000 tour price would not make much difference.

$4000 is a lot of money to pay for a cave tour, but when you consider what is provided for this, it actually feels like value for money. The tour fee covers accommodation and meals the evening before and after the tour, absolutely everything during the tour, high end equipment, plus 30 support staff for the trip. How much would a cave tour in Australia or New Zealand cost with 30 support staff for four days?

Conclusion

I was most impressed with the Oxalis enterprise. The guides were well-trained, spoke good English and provided a balance of adventure and interpretation on each tour. I would have liked to have had a little more information at times, but it is very challenging on any cave to tour to find the right balance of interpretation to satisfy the group. On each tour we had experienced geologists (my Brazilian friends) and speleologists who have caved around the world, mixed with local and international visitors on their first-ever cave tour. That is challenging.

There is a focus on protecting the cave resource, and their attention to safety, without being in-your-face about it, was excellent. They employ large numbers of locals and have established the Oxalis Foundation to support local villagers. I enjoyed the experiences offered by Oxalis and their efforts to protect the caves they use, while providing employment for local people. The contrast between the caves Oxalis are using and the general show caves in the area is quite stark.

ABSTRACT

Taking the Tasmanian Cave Spider to the world

NIALL DORAN PhD, Bookend Trust

You might think that studying the biology of the long-lived and reclusive Tasmanian Cave Spider would be enough of a challenge, but *filming* that research in sufficient quality for the big screen was a challenge all its own.

Over a quarter of a century ago, Niall was lucky to be told by one of Australia's leading arachnologists that if he wanted to study spiders the he should look at the Tasmanian Cave Spider, because it was likely that the species would yield some fascinating information. This proved to be correct, and the information arising from those studies was lauded in scientific journals including the *Journal of Zoology* in London.

But such information stays in dry scientific papers, away from public eyes. Over a decade ago, had big documentary makers come calling, Niall would have happily handed that research over so someone else could tell the story more widely. Then a friend convinced him that it needed to be told by and from Tasmania, and that it needed to break the mould. So, began a wait for technology to reach a point that this was possible. And when it did, there would still be another seven years before the film would be completed.

This is an epic tale of challenge after challenge: of overcoming the physical and mental strain of filming in difficult environments with uncooperative animals and unforgiving caverns; of fighting against intentional copyright breaches of both footage and intellectual property; of resourcing and maintaining such an epic project from scratch, with enormous logistics from the field through to marketing and promotion; of open warfare with the national screen agency over how the film broke traditional stereotypes; and of finally completing the project for market on the barest of margins.

This story even involves one participant accidentally and unintentionally completing Dry July, much to his horror.

SIXTEEN LEGS has now received critical acclaim around the globe, has travelled from the deepest caves in Australia to the heights of global celebrity, and has spawned successful spin-offs in the form of books, education projects, an award-winning behind-the-scenes film and a travelling exhibition complete with two 18-foot wide courting spiders and a pulsating giant egg-sac.

To see more, go to https://www.youtube.com/watch?v=yzER3jF05T4 or visit Bookend Trust at https://www.bookendtrust.com/

ABSTRACT

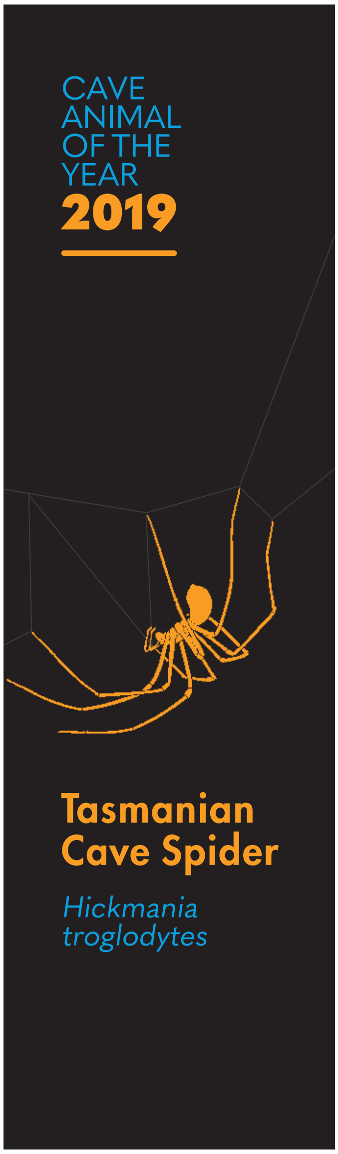
LAUNCH: Cave Animal of the Year

CATHIE PLOWMAN, Northern Caverneers, and NIALL DORAN

The German Speleological Society has had a Cave Animal if the Year program since 2009. It is linked to that country's Nature of the Year program and has built a wide-coverage on a low budget, with articles on cave animals featuring in a range of publications from school magazines to garden club newsletters.

Inspired by the efforts of our German colleagues and hoping to increase the profile of Australian cave animals and caves as habitat, Cathie has committed to coordinating Cave Animal of the Year in Australia for the next 10 years. Our inaugural Cave Animal will be launched this evening.

Thanks to the Karst Conservation Fund for financial support.



The Tasmanian cave spider *Hickmania troglodytes* is the inaugural Australian Cave Animal of the Year, a program announced during the recent ASF conference.

I have been inspired to develop this program by the German Cave Animal of the Year program, which was launched in 2008 and is now in its twelfth year and I have committed to working on this effort for the next 10 years.

Cave Animal of the Year aims to raise the profile of cave animals in the community and draw attention to the importance of caves as important animal habitat.

There is no popular competition to select the 'winner'. I have been guided by
Barbel Vogel from the German Speleological Federation to select a cave animal that can 'piggy-back' on to an existing campaign. The Tasmanian cave spider was selected as our debut cave animal to coincide with the international success of the film *Sixteen Legs*.

This award-winning Tasmanian-made film combines art, fantasy, scientific research, the dedicated photographic efforts of wildlife photographer Joe Shemesh and interviews with international celebrities to tell the story of this, until recently, little-known underground animal.

The intention over time is to have a range of cave animals from around Australia but, based on the advice from the German team, the selected animal will need to be photogenic and have a story to tell. The selected animal will be a 'flagship' for other cave animals.

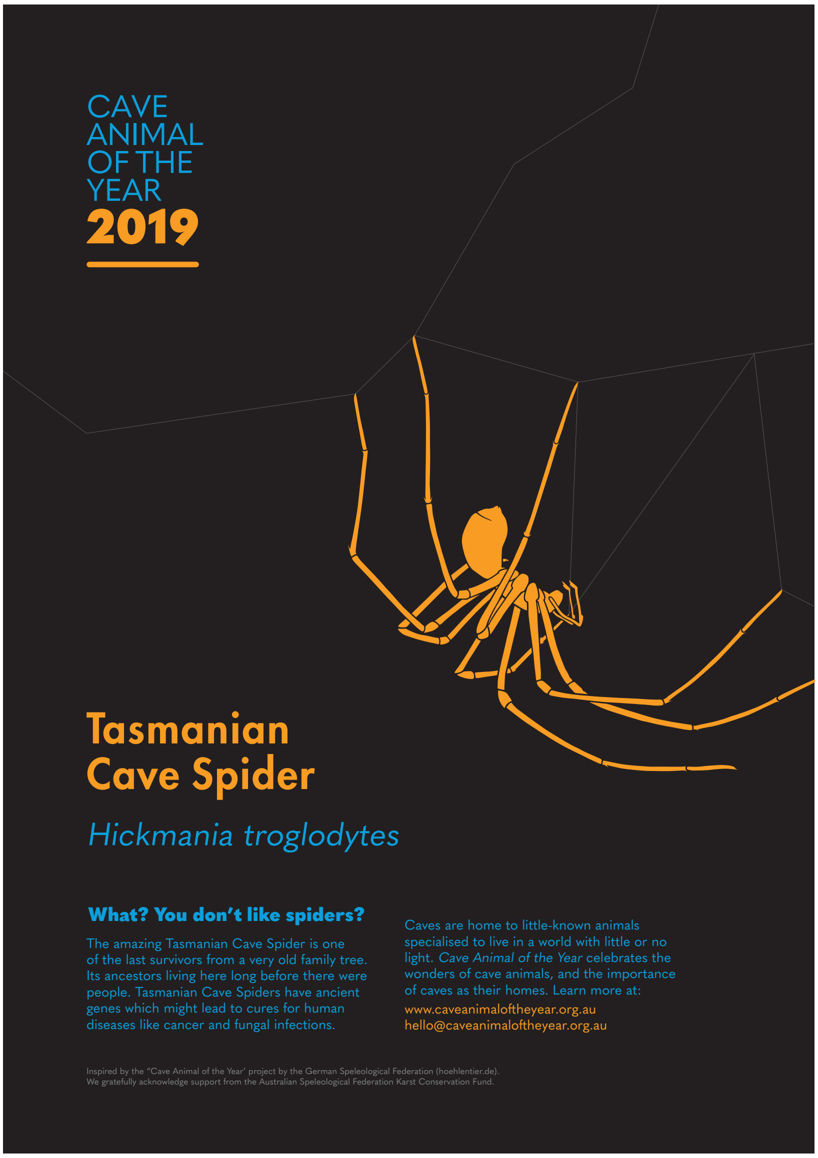
Some beautiful Cave Animal of the Year promotional products have been produced:

- Bookmarks and stickers are readily available. The spiders are 'raised' on the bookmarks. You will want to pat them.
- The A3 size posters are so nice that you'll want one for your kitchen or office. But, as they cost $5.00 each to print and we have limited supplies, they are only available for areas where they will be seen by good numbers of people. Classrooms, libraries, outdoor shops, Scout and Guide halls would all be excellent venues.
- Cups. Great for yourself or a gift for your caving friends. These are $10.00 each plus something for postage. Why not order a handful to on-sell at your club meeting?

You can help raise the profile of Cave Animals by helping distribute our wares. Please contact: hello@caveanimaloftheyear.org.au

It would be great if ASF members could also share the Facebook page and promote the website address to your friends in bushwalking clubs etc.: www.caveanimaloftheyear.org.au

Nothing is done without a team and my thanks to the Karst Conservation Fund for financial support, to the German Speleological Federation for their inspiration, to the International Union of Speleology for funding the stickers and to Poco People and Aeski in Hobart for their exciting art and design work.



Friday
4 January
2019

ABSTRACT

Concrete derived hyper-alkaline leachate creates calthemite straw stalactites, properties of which are compared to speleothem straws

GARRY K SMITH, Newcastle–Hunter Valley Speleological Society

Calthemites are secondary deposits, consisting primarily of calcium carbonate ($CaCO_3$), derived from concrete, mortar or lime. They are very similar in composition and form to speleothems in limestone caves, however beneath human-made concrete structures. $CaCO_3$ deposition occurs when carbon dioxide (CO_2) is a reactant as opposed to a product. Calthemite deposits typically take on the shapes and forms of speleothems e.g. stalactites, stalagmites, straws and flowstone.

This study compares calthemite straw stalactites with speleothem straws of comparable outside diameter and length. Calthemite straws grow in length, hundreds of times faster than speleothem straws in caves (Smith 2016). Measurements of both types of straws found that on average, outside diameters were within an equivalent range, however calthemite straws had a far thinner wall thickness. This physical attribute equated to calthemite straws on average having less than 50% the mass of speleothem straws. Hypotheses explaining the reason for such a disparity are considered.

Also measured was the carrying capacity and subsequent mass of $CaCO_3$ deposited from hyperalkaline solution (pH 13) leaching from a concrete structure.

Leachate solution drop breaking free from a calthemite straw.

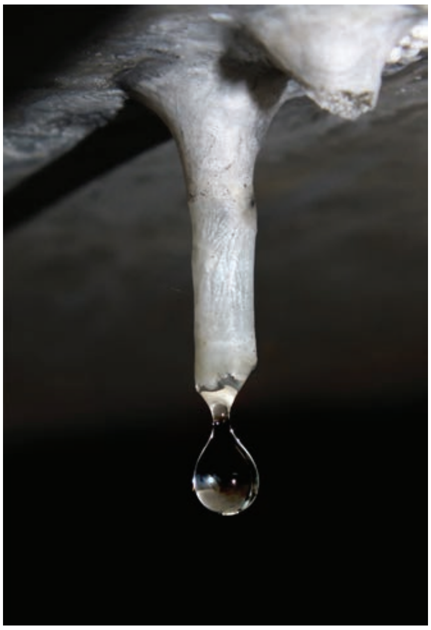
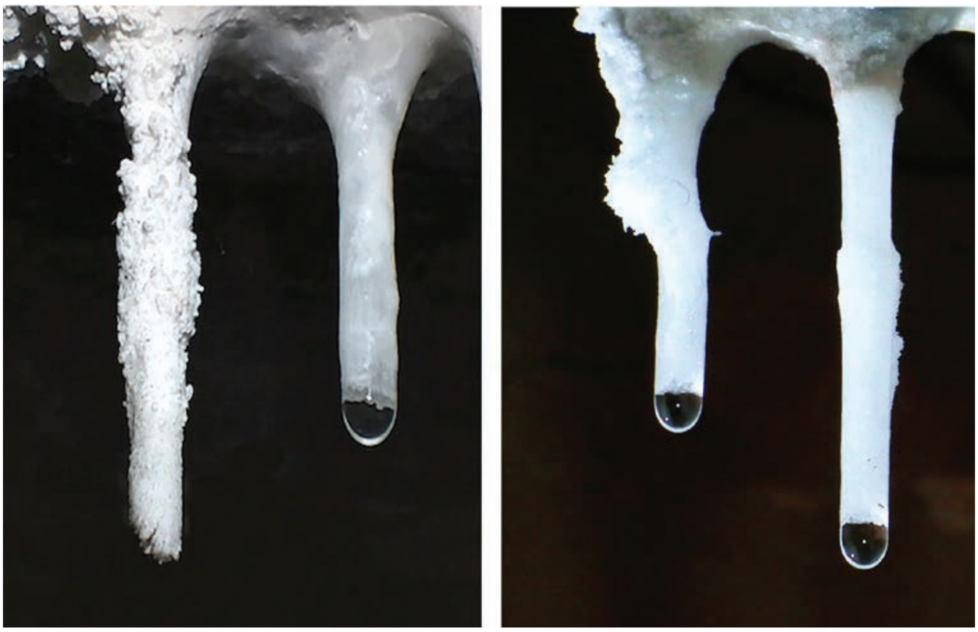


Figure 1. Calthemite straws on left, are similar to speleothem straws on right. Both are composed of calcium carbonate and approximately the same diameter, but the linear masses are significantly different.



Comparing calthemite to speleothem straw stalactites; solution drop mass and calcium ion saturation

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KEY WORDS: concrete, straws, calcium hydroxide, calcium carbonate, calthemite, speleothem, stalactite, pH, hyperalkaline, leachate

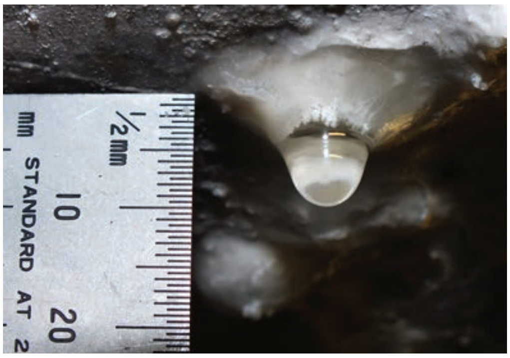


Figure 2. A cone shape deposit forms as the base of the new straw transitions into a parallel tube.

Introduction

Beneath concrete structures, calcium carbonate is precipitated from hyperalkaline solution to create calthemite deposits which mimic cave speleothems (Smith, 2016). Under ideal conditions, calthemite straws can grow in length hundreds of times faster than speleothem straws due to the greater calcium ion (Ca^{2+}) carrying capacity of the hyperalkaline leachate solution and different chemistry involved.

Ford and Williams (2009) state that, 'Rates of growth are usually quoted in terms of the extension of a given form rather than its accumulation of mass. Straw stalactites "grow" fastest because they have the greatest extension per unit of areas deposited.' Growth rates between 0.2 and 2 mm per year are quoted for speleothem straws (Ford and Williams 2009), where as calthemite straws can grow at rates up to 2mm per day (Smith 2016).

At first glance calthemite and speleothem straws look very similar (Figures 1), but on closer investigation there are quite a few physical differences, despite the fact that both are primarily made of calcium carbonate (usually calcite) and deposited from dripping leachate solution. This study compares the physical attributes (mass and diameter) of calthemite and speleothem straws. Also investigated, is the mass of calcium carbonate deposited by hyperalkaline leachate, discharging from straws beneath a concrete structure.

Many samples of different diameter were measured to determine the average mass per linear length of calthemite and speleothem straws. Individual solution drops were accurately

Figure 3. Typical cross sections of calthemite straws. They have a thinner wall, are more fragile and have a less dense crystal structure than speleothem straws. Image scale divisions are in mm.

Figure 4. Typical cross section of speleothem straws.

	Calthemite Straws		
Straw Length mm	Weight in g	Average weight (g) / unit length (mm)	Average straw diameter in mm
17.0	0.092	0.0054	3.70
23.0	0.079	0.0034	3.90
44.0	0.213	0.0048	4.10
33.5	0.288	0.0086	4.30
19.0	0.240	0.0126	4.35
58.5	0.460	0.0079	4.45
28.5	0.124	0.0044	4.50
16.0	0.084	0.0053	4.60
14.5	0.146	0.0101	4.60
10.0	0.061	0.0061	4.60
35.0	0.239	0.0068	4.90
20.0	0.263	0.0132	5.00
21.0	0.208	0.0099	5.10
38.5	0.607	0.0158	5.20
30.0	0.386	0.0129	5.30
27.5	0.489	0.0178	5.40
Total 436.0	3.979		
	Average g/mm using overall length		
		0.0091	

Table 1. Measurements of calthemite straws

	Speleothem Straws		
Straw Length mm	Weight in g	Average weight (g) / unit length (mm)	Average straw diameter in mm
45.5	1.096	0.0241	4.50
44.7	1.166	0.0261	4.60
36.0	0.608	0.0169	4.90
33.8	0.769	0.0228	4.90
60.7	1.572	0.0259	5.00
54.5	1.444	0.0265	5.00
29.2	0.872	0.0299	5.00
46.8	1.201	0.0257	5.10
35.8	0.943	0.0263	5.15
50.0	1.457	0.0291	5.25
66.0	1.604	0.0243	5.30
60.5	1.429	0.0236	5.35
46.5	1.217	0.0262	5.35
47.0	1.327	0.0282	5.55
49.5	1.707	0.0345	6.00
36.5	1.435	0.0393	6.45
Total 743.0	19.847		
	Average g/mm using overall length		
		0.0267	

Table 2. Measurements of speleothem straws

weighed to determine the relationship between a calthemite straw's diameter and the solution drop mass. Solution was collected and evaporated to obtain the mass of calcium carbonate deposited from solution, taking into consideration any deposition on the straw. These data are cross-referenced to a previous study at the same location, where calthemite straw growth rates versus drip rates, was recorded (Smith, 2016).

Straws of both types begin their development as a large diameter calcium carbonate ring around the area which has been wetted by solution on the underside of the concrete structure or cave ceiling. The exact size of the $CaCO_3$ crystal ring depends on the wettability of the host surface and surface tension supporting the drop. Over time a cone shaped $CaCO_3$ deposit forms (Figure 2), as the base of the new straw transitions into a cylindrical parallel tube growing down from the face of the host ceiling. The tube becomes parallel when an equilibrium is reached between the straw diameter, solution surface tension and other influencing factors as identified in this paper.

Study Site

A concrete building constructed in Belmont, NSW, Australia during 2008 (9 years old at the time of this study) included a partly enclosed undercover car park with supermarket area above. Straw stalactites began growing within months of the building being completed. Poorly constructed roof guttering traps rainwater and leaks a continuous flow through a minute hole, onto the concrete structure. The water then finds its way into the concrete, following microscopic cracks and internal porosity, gaining solutes until it emerges from cracks in the car park ceiling, where the stalactite straws are growing.

Although the stalactites were in a difficult location to access due to vehicle movement, the constant supply of solution water all year round, made it ideal to study the mass of $CaCO_3$ deposited from hyperakaline solution and drip mass compared to calthemite straw diameter.

Samples and methods

Fifteen calthemite straws were removed from the underside of the concrete structure. Many were still active straws so extra care was taken to avoid the highly corrosive hyperalkaline solution (pH 13) contacting hands or skin. Once removed the straws were placed in an oven at 60–70°C, to evaporate any solution still inside the straw. The straw length was trimmed to remove any portion with significant variation in outside diameter. The weight (mass) and length of each parallel straw section, was accurately measured with jewellers scales and vernier callipers to obtain average mass per unit length (mg/mm).

Several of the caves at Timor, north of Newcastle had been vandalised many years ago and provided an opportunity to make measurements of broken speleothem straws in situ. In addition, permission was granted to collect some broken straws from Cliefden Caves, NSW. This allowed a meaningful comparison between speleothem and calthemite straws.

Both speleothem and calthemite straws have small irregularities inside and outside, making neither absolutely uniform (Figures 3 and 4). Only straws with a near parallel outside diameter were considered in this study. Any straw showing signs of diameter enlargement due to $CaCO_3$ deposited from solution film or solution trickling down the outside was rejected from the sampling. The outside diameter of all straws sampled, varied between 3.7 to 6.45 mm (Tables 1 and 2).

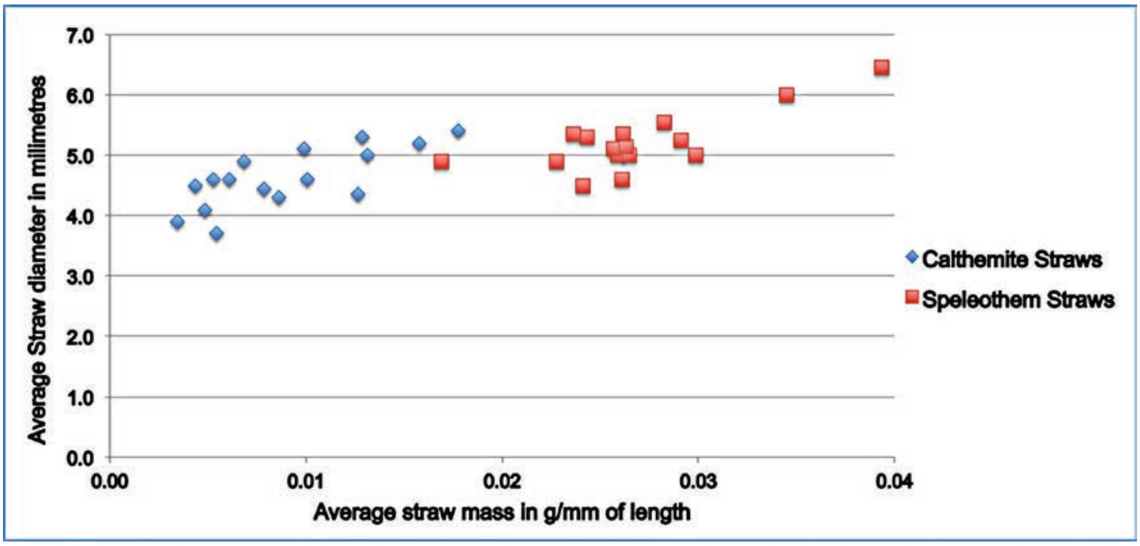
Two precision jeweller scales (0–10g and 0–30g), capable of weighing to 0.001g, were used to measure the mass of containers and their content. A precision engineering ruler and vernier calliper were used to measure the lengths and diameters of straws to within 0.05mm.

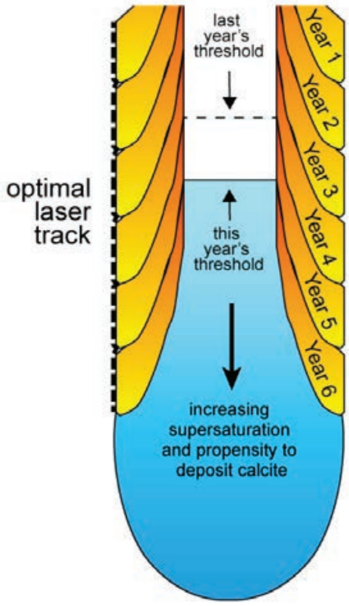
Results of straw linear mass measurements

Measurements over all straws sampled revealed speleothem straws are on average 2.9 times heavier than calthemite straws of equivalent outside diameter. Speleothem straws averaged 26.7 mg/mm (Table 2), while calthemites straws averaged 9.1 mg/mm (Table 1). This comparison is however biased toward the speleothems as two significantly larger diameter samples were collected (Figure 5). Considering only straws with outside diameters ranging between 4.9mm–5.1mm, the average speleothem straw is 2.47 times heavier than calthemite straws. Calthemite straws are on average just 40.7% the mass of speleothem of equivalent outside diameter.

In general speleothem straws have a denser calcite structure and a greater wall thickness, and thus a smaller solution canal down the centre than calthemite straws (Figures 3 and 4). The calthemite straws are generally quite fragile due to their thin wall thickness.

Figure 5. Straw mass (gm) per unit length (mm)





Left: Figure 6. Speleothem straw growth pattern. Image by Paul et.al. 2013. As the drip hangs from the tip, a combination of greater CO_2 degassing and lower nucleation energies occurs at the drip/straw-tip interface, producing wider layers at the edge of the straw.

Figure 7. Masking tape holds container against underside of concrete to collect hyperalkaline solution dripping from a straw. The mass (gm) of clean container is written on outside.

The large disparity in straw mass per mm, between calthemite and speleothem straws, appears to be due to the difference in the $CaCO_3$ deposition process, as discussed by Smith 2016. When $CaCO_3$ deposition occurs on a speleothem, CO_2 must defuse out of the leachate drop, thus the diffusion of the gas from the drop occurs slowly and more evenly throughout the drop. This causes $CaCO_3$ to be deposited along the inner wall of the straws solution canal as well as at the straw tip (Paul et al. 2013, Figure 6).

Therefore, the speleothem straw grows with a smaller canal and greater wall thickness than a calthemite straw. On the other hand, calthemite leachate has a higher Ca^{2+} carrying capacity and its chemistry facilitates much faster deposition of $CaCO_3$ at the drop surface in contact with atmospheric CO_2. There is not enough time for CO_2 to diffuse evenly throughout the solution drop to cause deposition for much distance inside the straw's solution canal. Therefore, the straw is fast growing in length with little $CaCO_3$ deposition in the solution canal. These two factors cause calthemite straws to grow more quickly in length but lack the wall thickness of speleothem straws.

Solution drop mass

As part of this study it was decided to investigate what factors influenced the mass of a leachate solution drop falling from a calthemite straw. In particular. to identify how or if, a straw's outside diameter is governed by the solution's surface tension, which in turn may be influenced by Ca^{2+} ion saturation and environmental parameters.

Collection containers were held with masking tape, hard against the underside of a concrete structure to capture a counted number of drops falling from a calthemite straw of known diameter (Figure 7). Evaporation of solution was negligible as atmospheric air could not freely enter the container during collection of the drops (less than 30 minutes). These samples were only collected in the late evenings after the shopping centre had closed, when there was minimal air movement, or vibration in the concrete structure due to vehicle movement and staff moving heavy stock pallets. This provided more consistent drop samples.

There were 48 samples collected covering a range of different straw diameters and drip rates. From the counted number of drops collected in each-container, the average drop mass was plotted against the straws diameter (Figure 8). The observed relationship is approximately linear.

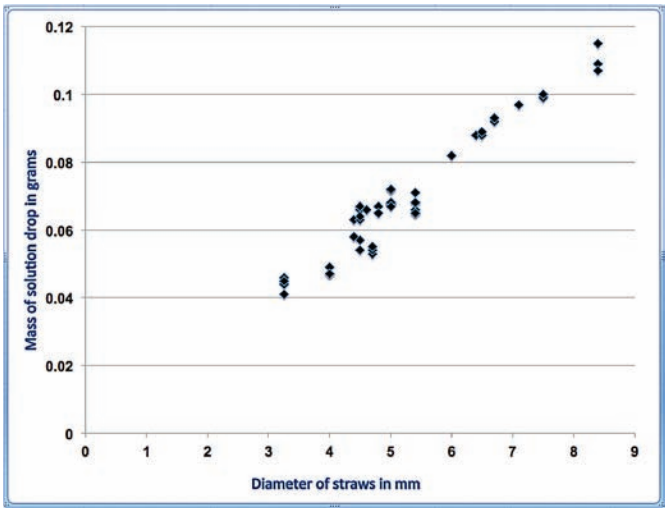


Figure 8. Graph comparing the mass of calthemite solution drops (grams), to the outside diameter (mm) of the stalactite straws from which they fell. The solution mass included Ca2+ and any other dissolved minerals.

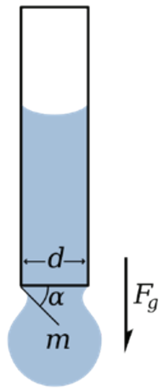


Figure 9. Solution drop mass calculation diagram. Sourced from Wikipedia. https://en.wikipedia.org/wiki/Drop_(liquid)

The theoretical mass *m* of a drop hanging from the end of a straw (Figure 9) can be found by equating the force due to gravity ($F_g = mg$) with the component of the surface tension in the vertical direction ($F_\gamma \sin \alpha$) giving the formula;

$mg = \pi d \gamma \sin \alpha$

where α is the angle of contact with the tube, and g is the acceleration due to gravity. Where d is the tube diameter in metres.

The limit of this formula, as α goes to 90˚, gives the maximum mass of a pendant drop for a liquid with a given surface tension γ. Note that the SI units for γ are millinewtons per metre (mN/m).

$mg = \pi d \gamma$

This relationship is the basis of a convenient method of calculating surface tension. More sophisticated methods are available, to take account of the developing shape of the pendant as the drop grows. More information can be sourced from 'Pendant drop test' https://en.wikipedia.org/wiki/Drop_(liquid)

Curl (1972) found that surface tension is sensitive to temperature changes and impurities in the solution. Impurities may be in the form of calcite crystals (rafts) which have been observed on the calthemite solution drip surface (Smith 2016) and their presence influenced by drip rate. There may well be minerals or other impurities within the solution, which influence the surface tension. Other impurities in speleothem straw solution may include: Mg, Sr, SiO_2 and SO_4, clay particles and organic matter (Borsato 2016)

In theory the 'drop mass' from a known diameter stalactite straw can be calculated using the formulae as detailed above, however there are many variables influencing solution 'surface tension' across a range of calthemite straws. Surface tension influencing factors may well include; saturation of Ca^{2+}, solution pH and impurities, serration of crystal structure around the straw tip (altering length of contact surface), solution temperature and $CaCO_3$ rafts on drip surface (Figure 10). Drips may be induced to fall prematurely by: solution flow rate, pulsation of solution, concrete structure vibration (movement of goods and people in supermarket) and air movement. If a drop is induced to fall prematurely, without reaching its maximum potential mass, this would translate into a false surface tension calculation when data is entered into the formulae.

Calculated ‘surface tensions’ from the collected calthemite leachate solutions, varied between 35.88 and 43.72 mN/m over an atmospheric temperature range of 15 to 25°C. As a comparison pure water at 20°C is 72.86 ±0.05 mN/m (Pallas and Harrison, 1990).

Data collected did not definitively indicate that leachate ‘surface tension’ had any appreciable influence on a straw’s outside diameter. However, as determined in a previous study (Smith 2016), slow dripping calthemite straws tended to be slightly larger in diameter than fast dripping straws. This may well be due to the drop surface angle α remaining larger for a longer period as the drop forms and deposits $CaCO_3$ at the straw tip. An example of a calthemite straw with changes in diameter, is shown in Figure 10 and an example of a straw growing in diameter in Figure 12. It is most likely that observations of calthemite straw diameters having a relationship to drip rate, may also be mirrored in speleothem straw’s diameter also being influenced by solution drip rate.

However, an extra fast drip rate does not instantaneously create a small diameter straw or vice versa for a slow drip rate. A straw changes diameter gradually as it grows in length. If we look at growth rates (Smith 2016), it may take a matter of days or weeks for a calthemite straw to significantly change diameter as a result of a change in drip rate. A speleothem straw may take many months to significantly change diameter.

Figure 10. Variations in calthemite straw diameter, due to changes in solution surface tension, influenced by solution saturation of $Ca(OH)_2$ and usually associated with changes in solution supply (drip rate).

Background and methodology to determine $CaCO_3$ deposition from Hyperalkaline Leachate

This part of the study was undertaken in order to try and understand how much $CaCO_3$ is deposited by hyperalkaline leachate as it is often cited that the appearance of calthemite deposits under concrete structures is a sign of degradation of concrete, causing a loss of strength. A search of literature found that according to Fagerlund (2000), *‘About 15% of the lime has to be dissolved before strength is affected. This corresponds to about 10% of the cement weight, or almost all of the initially formed Ca(OH)$_2$.’* This would mean that a large amount of $Ca(OH)_2$ must be leached from the concrete before structural integrity is affected. The other issue however is that leaching away $Ca(OH)_2$ may allows the corrosion of reinforcing steel to affect structural integrity.

The Ca^{2+} carrying capacity of speleothem leachate is approximately 200 times less than calthemite leachate (Sefton 1988), so only calthemite drip water was sampled in this study. Small containers were taped over short active calthemite straws on the underside of the concrete structure, so as to capture solution drips over periods of time ranging between 1–3 days. The containers were held with masking tape, hard up to the flat underside of the concrete to restrict the ingress of fresh air containing CO_2, which would cause deposition of $CaCO_3$ at the straw. This attachment method did not provide a perfect airtight seal, so variations between container and atmospheric pressure could equalise, without influencing the outflow of leachate solution from the straw. This attachment method also minimised solution evaporation, however it was noted that on each occasion upon removing a container, there was a thin calcite raft floating on the collected solution. This indicated that some atmospheric CO_2 was entering the containers and allowing $CaCO_3$ to precipitate at the solution surface.

The length of each straw was recorded prior to and upon removal of each leachate collection container. These measurements were critical when identifying if $CaCO_3$ was deposited on the straw instead of remaining in solution collected in the container.

Sample number	Mass (g) of calthemite solution collected	Mass (g) of CaCO3 remaining after solution evaporated	Calculated mass of CaCO3 deposited as straw growth	Mass (g) CaCO3/kg of solution (including straw growth).	Calculated average Time (min) between drops
1	7.304	0.018	0.0036	2.9500	9.03
2	16.830	0.041	0.0071	2.8580	3.98
3	6.434	0.017	0.0071	3.7460	10.70
4	11.909	0.030	0.0142	3.7110	11.70
5	28.740	0.101	0.0142	4.0080	7.14
6	12.924	0.039	0.0142	4.1160	10.84
7	13.203	0.052	0.0107	4.7450	15.64
8	48.692	0.039	0.0000	0.8010	0.15
9	28.964	0.020	0.0000	0.6905	0.15
10	2.659	0.003	0.0000	1.1282	1.55
11	1.748	0.001	0.0000	0.5721	2.46

Table 3. Calthemite leachate samples were evaporated to determine $CaCO_3$ deposited from solution. Also considered is deposition of $CaCO_3$ at the straw tip. Samples 8 –11 had very fast drip rates with no measurable $CaCO_3$ deposition at straw tip.

The collected solution was weighed in the container and the empty container mass deducted to ascertain the solution mass. The solution was left in the container and allowed to evaporate in the sun over several days. The dry container (with $CaCO_3$ deposited inside), was then accurately weighed and the container mass deducted to determine the $CaCO_3$ mass. The accurate mass of each collection container had been recorded prior to commencing the study.

The diameter and change in length of straws was recorded and factored into calculations to arrive at the overall mass of $CaCO_3$ deposited from the hyperalkaline solution (Table 3).

Samples 1 to 7 (Table 3) were collected during a relatively dry period when drip rates were slow at between 4 and 16 minutes per drop. It took several days to collect sufficient sample in the containers. Samples 8 to 11 were collected after a severe rain event, which significantly increased the drop rate of all active straws. Those sampled were faster than one drop every 2.5 minutes and even as fast as one drop every 3 seconds. This meant there would be no straw growth (Smith 2016) and sufficient solution could be collected from each straw in less than 30 minutes.

As was expected the mass of $CaCO_3$ deposited per kg of hyperalkaline solution was significantly less in the period with an abundance of leachate. The greater flow rate through the concrete after the rain event, meant there was limited time to leach calcium hydroxide from cracks and micro pores within the concrete and transport Ca^{2+} to the under surface of the structure.

The linear relationship of time between drips and $CaCO_3$ deposited from solution (Figure 11), depicts the dissolution kinetic of the

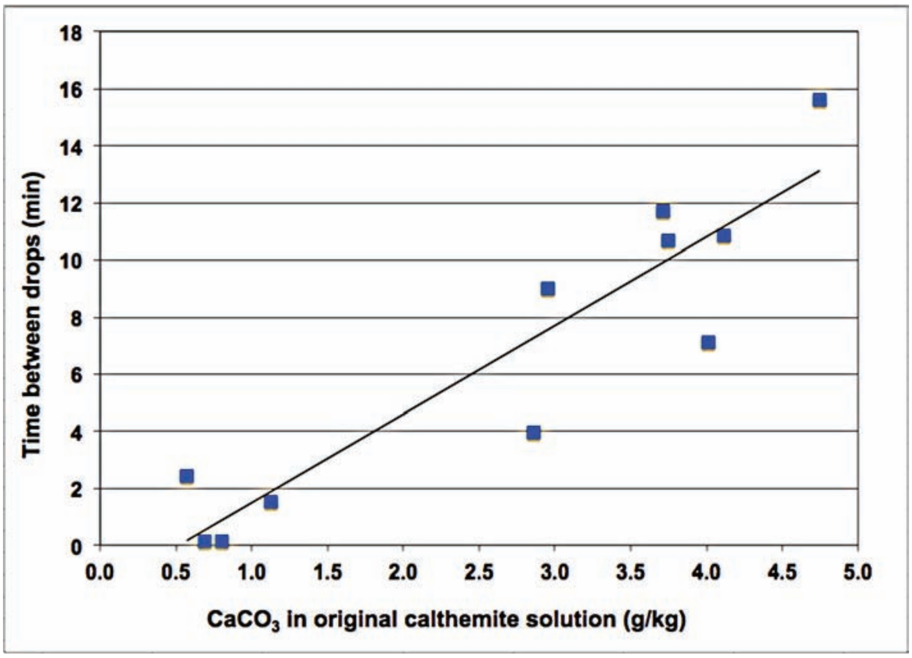


Figure 11. Relationship between time (min) between drops and mass (g) of $CaCO_3$ precipitated from mass (kg) of solution. Linear regression is shown.

concrete: as the residence time of the fluid inside the concrete increases we observe a steady and linear increase in the Ca^{2+} concentration in solution (deposited as $CaCO_3$). Overall the mass of $CaCO_3$ originally present in the hyperalkaline solution varied greatly from 0.572 to 4.745g/kg of leachate.

The regression line on the graph (Figure 11) highlights that there is a reasonable deviation in sampled solution concentrations, which are likely influenced by other factors besides drip rate (flow-rate). It is reasonable to surmise that solution seepage path, resonance time, and availability of Ca^{2+} along the seepage path play a large part in the leaching of Ca^{2+} from concrete structures. These results indicate there is no simple way of accurately calculate how much Ca^{2+} is being leached from concrete and deposited as $CaCO_3$ by measuring leachate flow rates.

As a comparison, Moore (1962) collected solution from a speleothem stalactite dripping at a 23 second interval and measured the flow rate at 30 ml/hour, in a cave atmosphere at 12.7˚C and near 100% humidity. Calcite rafts were forming on the surface of the pool beneath the stalactite, so he assumed that the drip solution was near 100% saturation. Moore calculated that the total calcite deposition from the solution was 0.014g/day which equates to 0.0194g/kg of speleothem leachate. This figure is in line with the expectation that speleothem solution Ca^{2+} ion saturation is an order of magnitude hundreds of time less than calthemite solution.

Conclusion

On average calthemite straws examined had thinner wall thickness and a less dense calcium carbonate structure than speleothem straws of equivalent diameter. It appears that the chemistry and slower deposition rate of calcium carbonate from mildly alkaline solution (low Ca^{2+} saturation) associated with limestone cave (speleothem) straws, creates a more-dense structure than hyperalkaline solution creating calthemite straws. This is well explained by the speleothem straw growth pattern image by (Paul et.al. 2013). Measurements revealed that calthemite straws are on average just 40.7% the mass per linear length of speleothem straws of equivalent outside diameter.

Calthemite straws can grow up to 2mm per day when the drip rate is 11 minutes between drops. As determined (Smith 2016), when the drip rate is more frequent than one drop per 11 minutes, the deposition rate (gain in length) is reduced. This present study identifies that the changes in leachate residence time within the concrete (expressed by the drip rate), greatly influences the uptake of calcium ions in solution and subsequent amount of $CaCO_3$ deposited at the straw tip. Hence in periods of fast flow, the concentration of Ca^{2+} in solution is less than when there is a lower solution flow rate.

The time a drop remains at the tip of a calthemite straw affects the ability of solution to uptake carbon dioxide from the atmosphere and deposit $CaCO_3$, however the leachate saturation also plays a significant roll. The Ca^{2+} ions carried by solution is influenced by the leachate solution pH, flow rate, length of seepage path and time taken to travel through the concrete's micro cracks and pores, and availability of Ca^{2+} along the seepage path.

The mass of a leachate drop falling from a known diameter calthemite straw is directly proportional to the end diameter of the straw from which it fell; i.e. the larger the straw diameter, the greater the drop mass.

Figure 12. A longer period between drips allows more time as a developing drops bulges, to deposit $CaCO_3$ at a greater circumference to increase straw OD. Note the calcite raft lattice on the calthemite straw drop.

The drop mass could not be accurately predicted without knowing the solution surface tension at the precise time. However, there are many variables (temperature, impurities etc), which can influence surface tension and in turn the drop mass. Provided the possibility of a drop prematurely falling because of vibration, air movement or other factors, a drop mass could be approximately calculated using the formula $mg = \pi d\gamma$ if the straw diameter and leachate solution surface tension γ is known.

There appears to be sufficient variation in leachate surface tension to have a small influence over the maximum diameter range of calthemite compared to speleothem straws. Calthemite leachate drip rate appears to influence the resulting calthemite straw outside diameter, and the drip rate may well influence a speleothem straw's diameter.

Sampling and analysis of solution drip rate from straws and the Ca^{2+} ions leached from concrete (precipitated as $CaCO_3$) showed that a slower drip rate had a higher solution saturation. However, the deviation of results, indicated that other factors such as solution seepage path, resonance time and availability of Ca^{2+} along the seepage path, has an influence over the calthemite leachate saturation.

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The author thanks Dr Ken Turner (Ken Turner Consulting) for providing particularly helpful and constructive review and comments about the chemistry surrounding deposition of calcium carbonate derived from concrete.

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The author dedicates this paper in loving memory of his wife 'Sonia Taylor-Smith', who patiently supported the tedious collection of data during 2014–15 and writing of the first paper about calthemite straws published in 2016.

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ABSTRACT

OzKarst and GIS — the big picture with a Nullarbor perspective

BOB KERSHAW, Illawarra Speleological Society

With many clubs undertaking survey work on the Nullarbor and those clubs using OzKarst to store the data, the question arises as to how to present the data to club members.

OzKarst has the ability to export some of the data as a Published Map (pmf) for use in ESRI ArcReader. This workshop brings together the OzKarst database and the full GIS program to show you possible uses of GIS to graphically present all your work in a cave area. The workshop uses the Nullarbor as an example, but due to licencing conditions, the data is shown in ArcReader.

Though bits of your work can be done in separate programs, like OziExplorer and Illustrator, GIS brings all your work — maps, survey data, GPS references, your surface tracks and aerial maps data — together to present your work to your club.

The author has presented data in this fashion for the Ning Bing Range, Bullita and cave areas in New South Wales.

WORKSHOP

OzKarst export feature and using GIS with the Nullarbor area as an example of the output that can be presented

Bob Kershaw

Illawarra Speleological Society

With many clubs undertaking survey work in various karst areas in Australia and a few of those clubs using OzKarst to store the data, the question arises as to how to present the data to club members? Though some of your work can be undertaken in separate programs like OziExplorer and Illustrator, Geographical Information System (GIS) programs bring all your work – sketch maps, survey data, GPS references, your surface tracks, and aerial photographs and topographic maps together to present your work to your club.

OzKarst now has the ability to export some of the data as a shapefile for use in ESRI's ArcMap, if you wish. This workshop brings together the OzKarst database and the full GIS program to show you possible uses of GIS to graphically present all your work within a cave area. The workshop uses the Nullarbor data as an example to show relationships between various karst features.

The aims of this workshop were to:

- Briefly describe how to use exporter from OzKarst to GIS;
- Explain what you can show and do in the GIS;
- Examine how many of what Feature types are on the Nullarbor using the data in OzKarst and show the distribution of them on a topographic map.

The recent export function of some limited data from OzKarst provides a linked table for use with GIS. There is a full explanation of how to undertake this exercise in the OzKarst Manual available for users of OzKarst or GIS users.

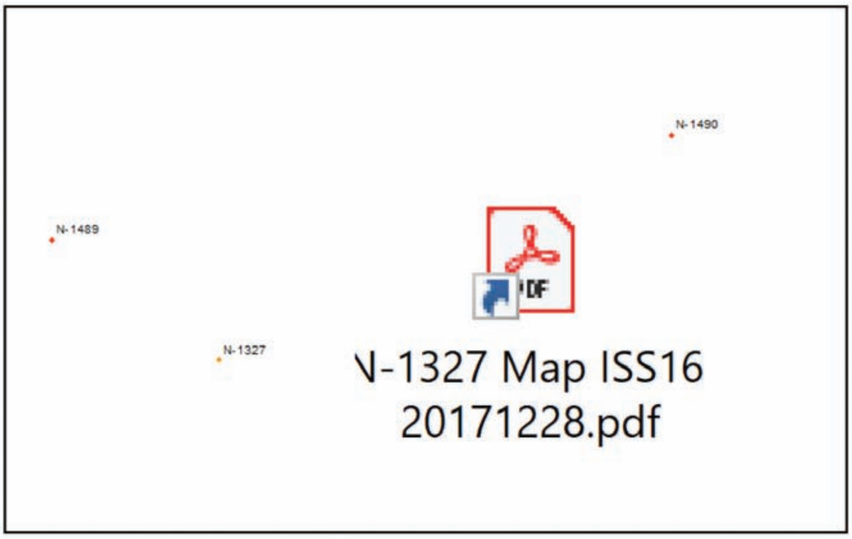
The information or data of the karst area you wish to use is selected and exported for use in your GIS is: Region, Karst Code, Feature Type (Ftype), Tag location, Named, Description, Location, datum, UTM Zone, Easting, Northing, Accuracy of the GPS reading, date, and elevation. This information is shown in the GIS program as in the box below.

Field	Value
FID	1896
Shape	Point
Region	AU5
Karst_Code	N-1659
s	1
Kkey	3032
Ftype	Blowhole cave
Tag_locati	Under N lip of BH 0.5 down.
named	
Descriptio	In rock pav at base of rock/rubble sided doline 14x11x1.65m @320. BH has be
Location	500m NE of SE/NW track which S of the Sleeper Camp to Forrest track, at aro
ZEN_datum	AGD 66
UTMZone	52
Easting	269205
Northing	6644061
ZEN_Accura	75
ZEN_date	20 Apr 2000
elevation	Australian Height Datum
Elevatio_1	220

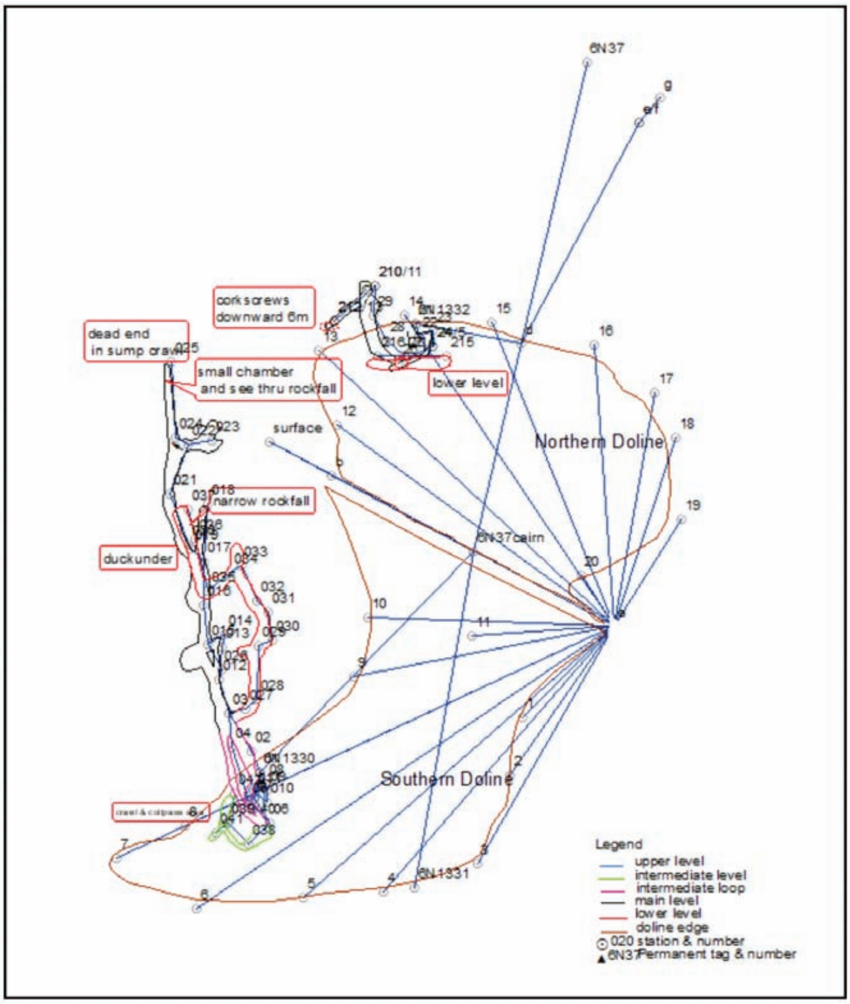
This is sufficient for use in the GIS and enables checking of the feature in the GIS using the information arrow icon.

The newest version of the OzKarst database includes latitude and longitude rather than Easting and Northing.

Using the GIS program you can add a link to an existing map you may have drawn,



or draw your map in the GIS.

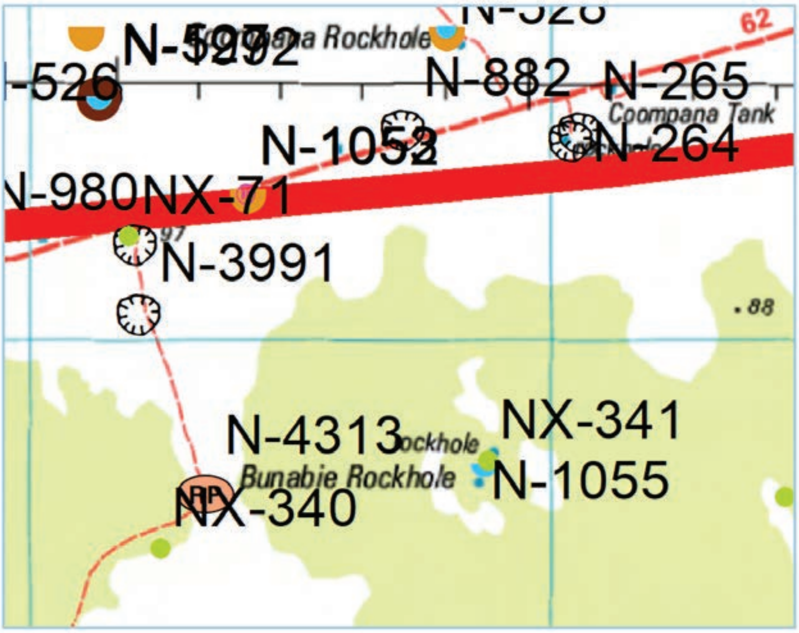


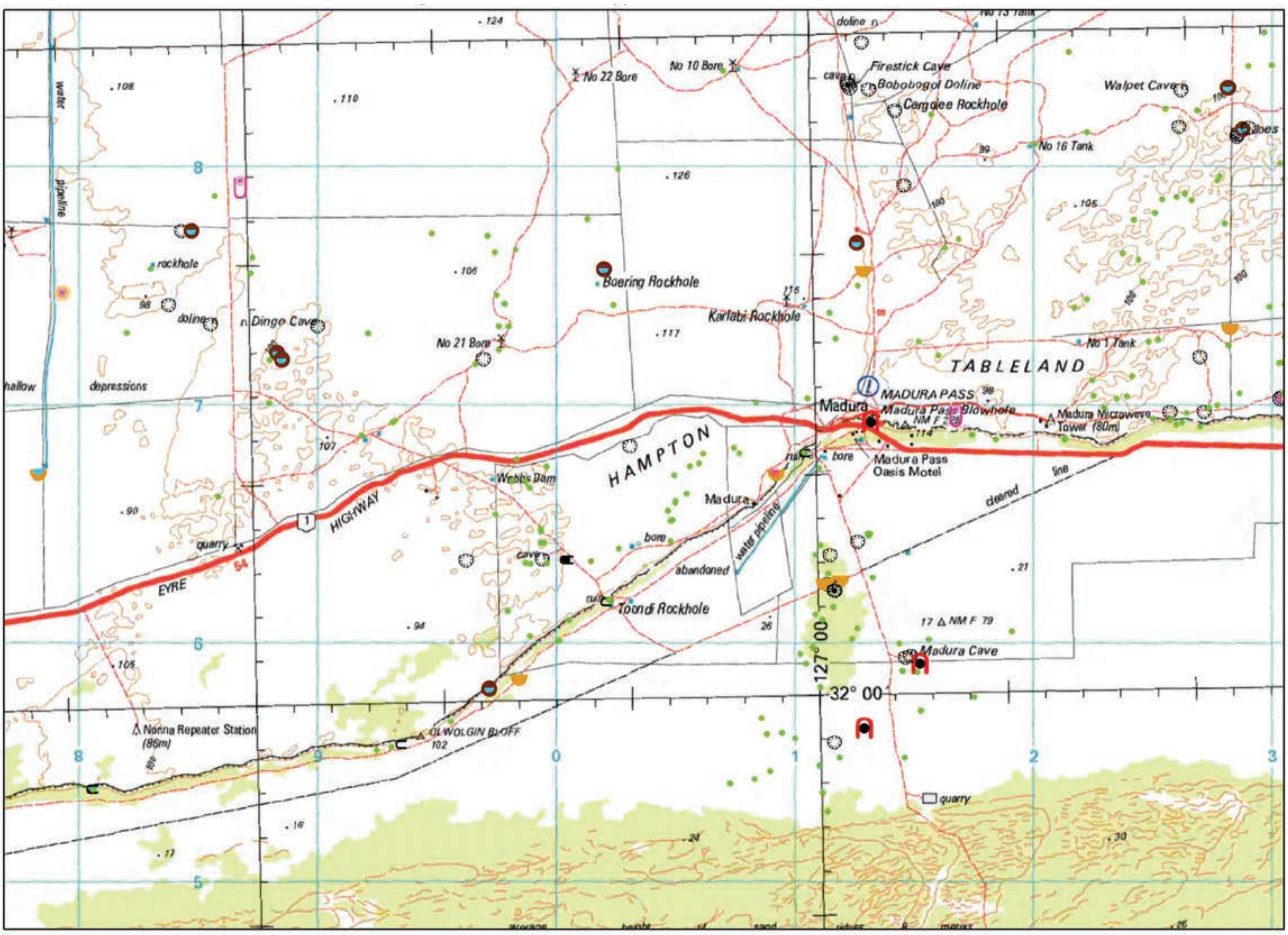
You can present your information with a topographic map and produce a georeferenced map for use in Avenza Maps as you walk over your area or the Nullarbor as shown below.

But the greatest benefit is being able to look at the distribution of the various karst features in your area of interest.

A section of the Nullarbor around Madura is shown in the map below.

The background map below is from Geoscience Australia.



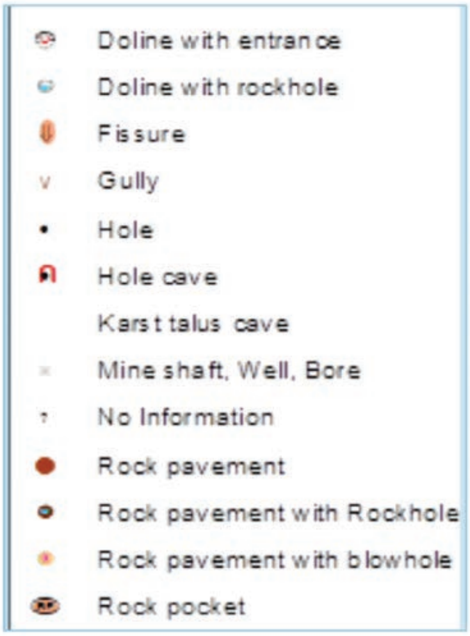


You can develop your own legend for features if you wish as shown on the right.

But just as interesting is the ability to quantify your features.

The table below is based on the OzKarst Structure Version 5.2 dated: 30 Sep 2018.

Many of the descriptions of each feature type were made by the author and a few have been changed by the Nullarbor coordinator. Note that the Victorian Speleological Association (VSA) has many more recorded features which are not included in the statistics below.



Feature Type	Description	Number of features	% of Nullarbor features
		12413	
NXK	Ken Boland — airborne	1168	9.41
NXP	Paul Devine	4539	36.57
NX	General X	653	5.26
NXC	Plane Cavers	30	
NXD	Nullarbor Dongas	33	
NXG	Graham Pilkington	49	
NXPRD	Peter Dykes	37	
NXU	Extra Ken Boland	67	
NXH	Max Hall	7	
NXI	Illawarra Speleos	2	
NXL	Ian Lutherborrow for HCG	83	
No information	*Blocks of numbers allocated to Paul Hosie, Peter Ackroyd and VSA but counted in allocated features*	790	6.36
	NO OF ALLOCATED FEATURES Not including 790	4955	39.92
Arch	Arch, mainly sea caves	3	0.06
Basin in rock	Rock basin in pavement; a shallow broad hollow in rock	3	0.06
Blind valley	A valley that is closed abruptly at one end by a cliff or steep slope	5	0.10
Blowhole	Blowhole with no significant cave passage	466	9.40
Blowhole cave	Blowhole with cave present (>3m long passage)	625	12.61
Blowhole shaft	Blowhole enlarged and squared as a shaft	2	0.04

Boulder cave	A cave in boulders; compare with a Talus cave	2	0.04
Caprock		5	0.10
Caprock cave	Cave under caprock. Often rabbit or wombat excavated.	22	0.44
Caprock entrance	Caprock with possible entrances (air photos)	6	0.12
Collapse	Subsidence of surface into cavity	2	0.04
Crater	Not a karst feature, but a crater	1	0.02
Crevasse	Crevasse or crevice probably formed by solution	2	0.04
Depression	Missing overburden; smooth dirt sides, slope typically < 30˚; D/W <0.2	108	2.18
Depression with Blowhole	Depression with Blowhole within the Depression	664	13.40
Depression with cave	Depression with cave present rather than blowhole	5	0.10
Depression with hole	Depression with hole rather than blowhole	19	0.38
Depression with Rockhole	Depression with Rockhole rather than a blowhole	56	1.13
Doline	Doline; normally with exposed rock on one or more sides	488	9.85
Doline & rockshelter	Doline with rockshelter(s)	5	0.10
Doline cave	Doline with cave present	245	4.94
Doline hole(s)	Doline with hole(s) and/or draught, no cave visible	525	10.60
Doline with blowhole	Doline with blowhole	577	11.64
Doline with entrance	Entrance of unknown type from Doline	9	0.18
Doline with rockhole	Doline with rockhole rather than blowhole	13	0.26
Doline with rocket pocket		1	0.02
entrance	Entrance of unknown type	3	0.06
Fissure	Fissure or slot formed by rock movement or any other process	14	0.28
Gully	Gully, especially of escarpment	1	0.02
Hole	Hole, undifferentiated, often impenetrable	63	1.27
Hole cave	Hole with cave present (e.g. roof-hole into cavern)	38	0.77
Karst talus cave	A cave formed in talus with solutional features	1	0.02
Mine shaft, Well, Bore	Excavated feature, essentially vertical	2	0.04

Rock pavement	A flat horizontal area of clear rock	10	0.20
Rock pavement with blowhole	Rock pavement with blowhole	282	5.69
Rock pavement with Rockhole	Rock pavement with Rockhole	479	9.67
Rock pocket	Small hole in pavement	14	0.28
Rock shelter	Shelter height at the dip line is < shelter recess	33	0.67
Rockhole	A shallow small hole in rock outcrops often rounded and holding water after rain	115	2.32
Runaway hole	Where water gathers and sinks; compare to Streamsink	2	0.04
Sea cave	A cave in present-day or emerged sea cliffs	30	0.61
Solution pit	Significant pitting in rock	1	0.02
Talus cave	A cave formed in talus (collapsed rock); compare to a Boulder cave	1	0.02
Window	Karst window into a cave	3	0.06
Wombat warren	wombat warren, doline or diggings	4	0.08

Recommendations or ideas for those members undertaking future survey work in Australia

- There are more than 7000 NX features still to examine on the Nullarbor;
- Find ways to use your Database, GIS and smartphone when exploring and caving.
- Acquire an up to date copy of OzKarst before travelling to the Nullarbor
- Place the GIS information on your laptop using ArcMap or at a minimum as a PMF and using ArcReader if you don't have OzKarst on your laptop
- And make georeferenced pdf maps that include your cave maps or plotlines of your caves within your area for use with Avenza maps as you walk over the surface of your area if you don't have a GPS with topographic maps on it.

References

Kershaw, R., *New Ideas in Cave Mapping and Navigation* in Caves Australia. No.204 June 2018, p6. Australian Speleological Federation

ABSTRACT

The collapsing Nullarbor: Weebubbie Cave 6N-2

NORMAN POULTER OAM, Northern Caverneers

This paper is designed to complement a recently-published article in *Caves Australia* relating to a rockfall that occurred just inside the entrance of Weebubbie Cave 22 years ago.

The collapsing Nullarbor. Nullarbor Plain — South and Western Australia

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Straddling the border of South and Western Australia, the Nullarbor Plain at 250,000km^2 is the largest expanse of limestone in the world. The climate ranges from semi-arid in coastal regions to hot-arid in the northern sectors. While average temperatures can be 'mild' — annual temperatures at Eucla [near the border with South Australia] for example can vary from 18˚C to 26˚C although I have experienced one blistering summer's day of 53˚C while on nearby Mundrabilla Station.

Rainfall can be infuriatingly spasmodic and tightly concentrated. The average rainfall at Eucla is 255mm and 231mm at Nullarbor Station in South Australia. Droughts are common. A lot of moisture is delivered to plant life by way of early-morning dew. On numerous occasions, however, I have witnessed intense rainsqualls less than a kilometre across ranging over the landscape and once shared the discomfort of having a year's supply of rain dumped on a campsite at Cocklebiddy Cave in the space of an hour.

The Nullarbor Plain was first sighted from the sea by Dutchman Francois Thijessen in 1627 and charted by Matthew Flinders from the decks of the *Investigator* during January 1802, and traversed by Edward John Eyre in 1841. [Collins 2008]

The Nullarbor Plain is principally made up of two layers of limestone, a relatively hard crystalline caprock commonly known as Nullarbor Limestone that varies in thickness from 12–45m, and the underlying pale, chalky polyzoal limestone known as Wilson Bluff Limestone, that can be 55m or more thick and interspersed with flints, that in some cases were mined by the aborigines for tools and trade.

Being the first and ultimate DIY-er, once Mother Nature created the Nullarbor, she set about changing it, with all the tools and time at her disposal. As a result, the Plain is interspersed with numerous caves, multiple environmental zones and, where it meets the Great Southern Ocean, spectacular 80m high cliffs. Until the arrival, colonization and exploration by Europeans, the changes to the various features of the Nullarbor went largely un-noticed. Many Europeans considered it a hostile, featureless and waterless obstacle to communication between the eastern and western seaboards — a view still held by many today. The vastness of the Nullarbor was ultimately 'conquered' by the construction of the 'Inter-Colonial Telegraph Line' [in the 1870s] and the Transcontinental Railway during the early part of the 20th century. This encouraged pastoral pioneers to venture throughout the region to pit themselves against the unforgiving environment.

Others also pitted themselves against the seemingly insurmountable distance between Israelite Bay [WA] and Fowlers Bay in SA, some on foot while others utilized bicycles and later, primitive motor vehicles. There was no road as such — if anything, just a service track following the telegraph line.

In the summer of 1897-98, Frenchman Henri Gilbert spent three months trekking the Nullarbor, aided only by a linesman who left supplies of water at strategic locations and the fact that the telegraph poles were numbered, later commenting that the Nullarbor was 'the most difficult part of my [trekking] journey round the world ...' He had been preceded by Arthur Richardson, who in 1896 had become the first person to ride a bicycle across. [Collins].

With the dawning of the 20th century and the entry of 'reliable' motorized vehicles though still with no recognizable road, the potential for disastrous crossings was always present — and they occurred. There were, however, many examples of 'bushman's ingenuity'! One such occurrence was in 1928 when Mr and Mrs Turner and their four children attempted the journey in their 1924 Buick, striking serious engine problems halfway across. They completed the journey after Mr Turner re-ground the engine valves using a mixture of sand, oil and sugar. [Collins]

The Eyre Highway between Norseman [WA] and Ceduna [SA] did not come into existence until 1942 as a wartime measure. With the exception of the Madura and Eucla passes, it was a dirt road for the entire 1,200km distance. The 690km Western Australian section became a sealed road during the early 1960s, while the sealed and re-aligned South Australian section of the highway was not opened until the mid-1970s — which had a devastating impact on the 'virgin' wombat population.

With the re-alignment of the highway, and its closer proximity to the coastline, the South Australians took the opportunity to upgrade the existing [now shorter] ad-hoc spur roads and built several new spur ones [five in all and unsealed], giving easy access to view the spectacular Bunda Cliffs and three for the Merdayerrah Sandpatch region. Infrastructure in the form of information and warning signs along with some barricades were included — and largely ignored. It did not take long for travellers to begin creating additional tracks, especially one running parallel to, and very close to the cliffline. Cliffline vegetation was denuded, allowing erosion of the thin soils. Several years later, Mother Nature began to make her remodelling talents visible.

The caprock of the Nullarbor limestone could be tough, but not so the underlying strata. Exposed to the full force of the Great Southern Ocean, storm winds, rains and intrusions of salts, the 80m cliffs periodically broke down. It was not unusual to see relatively thin flakes of surface caprock jutting out from the cliffline with no support underneath. Huge cracks began appearing in other quarters: some subtle, others quite obvious. Visitors seemed oblivious to or contemptuous of these hazards and continued to walk up to the very edge of the cliffs to get their 'perfect' cliffline photographs and selfies. At one viewing point, still in use, a small undated memorial has been discreetly placed that may indicate that at some stage, a girl may have fallen over the cliff edge. By 2013 the authorities had moved in to begin protecting the public from themselves by closing most of the suspect viewing points, to the extent of using heavy ripping equipment to thoroughly destroy the road surfaces, and in some instances installing chain barricades across at the highway's edge. As a result, determined travellers walking in from the highway can often have a challenging though rewarding experience.

But what of the Nullarbor caves? Have they suffered similar collapses? I cannot comment on the caves within the South Australian Nullarbor National Park or Regional Reserve as I have rarely visited those regions due to the difficulty of gaining permission for entry. However, I have frequently visited caves in the Western Australian sectors, particularly those on pastoral leases. Collapses and rockfalls have naturally occurred with some documentation, unfortunately resulting in a history of managerial closure.

The first 'very public' cave collapse occurred in 1988 just east of the Cocklebiddy Roadhouse, when a sudden, short and concentrated cyclonic rainstorm event dumped an estimated two years supply of rain over nearby **Pannikin Plain Cave** [within the Nuytsland Nature Reserve administered by the Department of Conservation and Land Management — CALM] as a party of cave divers were in the process of de-rigging the cave following a successful program. The subsequent entrance collapse trapped the party in the cave until a relatively safe passage through the unstable rockfall could be found. The cave is still officially closed to this day — 30 years after the event.

Cocklebiddy and **Murra El Evelyn** caves, to the west of Cocklebiddy Roadhouse, are also in the Nuytsland Nature Reserve. Cocklebiddy Cave, with its long, valley-like collapse doline, became internationally 'famous' due to its long underwater passage that has ranked it as being the longest in the world [6.4km], along with its ultra-clear waters. Despite CALM expending considerable resources and presenting it as a passive tourist attraction, shortly after it was 'opened', a subsequent rockfall led to its premature closure.

Murra El Evelyn Cave suffered a similar fate. Situated much closer to the Cocklebiddy Roadhouse, this cave with its flat, circular, vertical collapse entrance was most likely mined for bat guano during the early part of the last century, as when I first visited the cave in 1972, it had a thick wire rope used for hauling strung from a convenient tree running down the entry slope to an anchor point. To aid entry, a primitive, 'thought-provoking' 'bush ladder', made from three tree trunks, with genuine 1m rung spacing, all held together with generous amounts of fencing wire, was propped against the 4-5m cliff entrance. This cave quickly reached the water table, which made it an attractive cave dive site. There seemed to be little or no evidence of surface rock disturbance, suggesting that any collapse was perhaps beyond the daylight zone.

Mullamullang Cave has also suffered a rockfall in the recent past, an internal one this time. It happened some time prior to 2003, which was when I encountered it. In a cave that has multiple rockpiles along its entire 5km length, how do you determine that there has been another fall? Following the marked trail in from the entrance to the Smoko Junction–Sandschute region between Stations 73–84, evidence of freshly fallen rock was readily seen, right across the trail, and cleared away. Anybody walking under it at the time would have ended up with a terrible headache! Another minor fall near Station 84 was made up of fossil lake-levels. A strange sort of structure to fall out from a ceiling? [Poulter 2004] What could have caused this fall?

The answer could be quite simple — **salt intrusion**. It can be difficult for some people to accept that many caves of the Nullarbor are still actively forming, via salt exudation. Strangely enough, the first example I saw of this phenomenon was in Edie's Treasure of Tasmania's Exit Cave back in 1971, where I saw an extruded gypsum needle that had lifted a flake of limestone. The best Nullarbor examples I have seen are seams of salt intrusions more than 50mm thick slowly wedging between bedding planes in Witches Cave on Mundrabilla Station, and the steady destruction of ancient calcite decoration in many other Nullarbor caves. An easy experiment in Nullarbor cave chambers is to hold a single bright light beam above one's head to see if the air is filled with ultra-fine particles drifting towards the floor. These particles will be made up of salts and rock, the ingredients of the decoration commonly referred to as 'Coffee & Cream'. It can also be attributed to many 'dud' photographs using 'flash on camera Happy Snappers'.

And so we come to **Weebubbie Cave**, the very first Nullarbor cave that I visited in January 1972 and have been associated with ever since. The cave comes with an even longer history. I advise at this juncture that an abridged version of the following is appearing in the December 2018 edition of *Caves Australia* #206.

Weebubbie Cave [6N-2] is located some 12km north-west of the present-day 'township' of Eucla on the Hampton Tableland of the vast, arid Nullarbor Plain, a short distance west of the South Australian border. The ruins of the Eucla Telegraph Station, only 20km south of the cave, are situated close to the beachfront on the Roe Plains. This was once an important communications centre of the 'Inter-Colonial Telegraph Line', the only telegraph station between Israelite Bay [180Km east of Esperance] in Western Australia and Fowlers Bay in South Australia [885km] to be serviced by a jetty enabling supplies to be delivered by sea.

From a historical aspect, Weebubbie Cave has probably been known to Aboriginal Australians for thousands of years. They reputedly mined flint from the cave walls for use as stone tools and to trade with. The cave is a registered archeological site as was designated by a small plaque placed near the cave entrance, as seen by myself in early 1972, but long since disappeared.

The cave was not 'discovered' by European Australians until two employees [Clayer and Junken] of the South Australian Telegraph Department chanced upon it in early 1900 [Poulter 1987]. They were no doubt impressed by the sheer size of the collapse doline but, more importantly, the volume of water the cave contained. The pair then lodged an application for a 80,000 acre [32,375 hectare] grazing lease encompassing the cave.

While granting the pair a 40,000-acre [16,187ha] lease on August 2 of the same year, the Surveyor-General also placed a temporary reserve of 5,000 acres [2,023ha] around the cave. Clayer and Junken then sought compensation for 'finding' the water resource in an otherwise waterless environment only to lose access to it. The government favoured granting a reward [provided a government-appointed inspector submitted a favourable report as to the water quality], suggesting the pair nominate a suitable sum. The government's friendly attitude changed when the pair applied for a £500 reward [a huge sum in those days] and despite much telegraphic prodding from the pair, the government failed to dispatch an inspector to sample the water.

However, during March 1901, John Muir, Inspector of Engineering Surveys PWD, was examining the country between Kalgoorlie and Eucla in relation to either constructing a future transcontinental railroad direct to Eucla and thence to Tarcoola in South Australia, or sending a spur line down to Eucla from a more northerly east-west route. The reasoning behind such an idea would have been to carry supplies for the railroad construction utilizing the already existing Eucla jetty. On meeting Muir, Clayer and Junken persuaded him to inspect the cave's water and forward his opinion to his superiors. Muir's October 1901 report to parliament, accompanied by three interior photographs of the cave, concluded the lake to be a 'small underground reservoir' due to the 'impervious character' of the surrounding strata and that the estimated 3 million gallons was of highly mineralized water not suitable for stock.

On the strength of this report, a no doubt relieved Surveyor General refused a reward to Clayer and Junken, despite their protests that Muir's observations were no more than casual and that he was not qualified to pass judgment on the water quality. The government, however, was unmoved and shortly afterward Clayer and Junken left the area.

Attitudes change with time and in December 1927, a proposal was made to give the reserve permanent status and lease it in order to raise money from the resource. On 4 January

1928, Water Reserve #19713 was duly leased to JD and OD Jones for grazing purposes at 10 shillings/year, subject to the **public having free access** to the water. The lease was cancelled in 1930 due to non-payment of fees. Subsequent attempts to re-lease the cave's resource appear to have been short-lived.

During 1964 there was a minor panic when, on referring to the relevant Army 1:250 000 survey map of the day, it was discovered that the cave was no longer in the centre of the reserve that had been thrown around it in 1901. In fact it was a respectable distance outside the boundary. That revelation and rectification later in the year would no doubt have done justice to a latter-day 'Yes Minister' script.

Before leaving this gem of comedy and for those interested in modern PRECISION surveys where accuracy to the nearest millimetre is expected — and even demanded — here is the official 1967 description of the cave reserve boundaries:

> 'All that portion of land (being **about** 2560 acres) with (Weebobby) cave as its centre bounded by lines starting from a point situated **about** 987 chains and 53 links west from north-east corner of pastoral lease 393/512 (Moopina) and extending south **about** 160 chains; thence west **about** 159 chains and 98 links thence north **about** 160 chains and thence east to starting point.'

Then, to round out all those approximations, the reserve was metricated in July 1976 to **APPROXIMATELY** 1035.9952 hectares!

Prior to 1964, the cave had been periodically known as Weebobby. There is also a reference that it was referred to not only as Weebubby, but Weebobby Pool [File #5431/00 P.52] and reputed to mean 'Place of Hidden Feet' in the dialect of the traditional Mirning aboriginal language. [Hadland 2018]. The name Weebubbie did not appear in correspondence until 1967 when F.E.B. Gurney sought permission to use the cave's resource to water stock on his nearby Moonpina Station.

The name Weebubbie is apparently derived from the Jirkla-Mirning Aboriginal words Wipa [ant] and Kapi [water] meaning 'trails of ants leading to the cave's water at night'. [Readon 1996] Formal approval of the name Weebubbie was granted in April 1968 following representation from David Lowry, then of the WA Geological Survey.

There is no record of Gurney taking up the water lease from Weebubbie. Initially, water was extracted by a pipeline laid from the cave's minor lake out through the entrance of the cave. A small but heavy Lister diesel pump unit located at the edge of the lake provided the power. Prior to 1972, a hole was drilled through the ceiling of the main lake allowing easier access to the water, utilizing an electric pump to supply water to the nearby Eucla Roadhouse, the pipework appearing in many published works. [Deacon 1985, 1986, Morrison 1981] The ceiling pipework was removed prior to 1985, although some lengths had fallen through into the lake.

Weebubbie had been used as an ad-hoc tourist attraction during the 1960s and into the early 1970s. In addition to the Eucla Roadhouse exploitation, it is possible that the cave's water resources were also utilized during the sealing of the Western Australian section of the Eyre Highway in the early 1960s. All these activities resulted in a considerable amount of rubbish being dumped in the cave, including a lot on the bottom of the main lake. This took the form of the already mentioned steel and PVC pipework, Lister diesel-powered pump as well as oil drums, timber, light fittings, wire and insulators as well as tourist-generated litter both in the cave and the entrance doline. A few 'dead' tyres had been thrown into the doline for good measure.

Systematic exploratory cave diving did not occur until 1971-72, when Ian Lewis conducted the first Cave Exploration Group South Australia [CEGSA] Nullarbor cave diving expedition. At Weebubbie Cave, in addition to discovering the mysterious underwater growths and extensions, extensive side passages leading off from the entrance doline were also discovered. [Lewis 1972] The waters of Weebubbie Cave [in addition to other caves containing ultra-slow moving water of the Nullarbor] are world renowned as being of the utmost clarity, rivaled only by South Australia's famed Piccaninnie Ponds.

During the Christmas period of 1985-86 and again in 1989-90, the Speleological Research Group Western Australia [SRGWA] organized a multi-society expedition to remove the several tonnes of rubbish from the cave [Poulter 1987, 1990]. Since the cleanups, very little tourist-generated rubbish has been noted — this could be partly attributed to the cave falling off the 'tourist radar' and removal of infrastructure.

Some notes on the Reserve #19713

Following the European discovery of Weebubbie by Clayer and Junken in 1900, the Surveyor-General placed a temporary 5,000 acre [2,023ha] reserve around the cave. A permanent reserve was established in 1928, a partial description of which follows:

The legal area of Reserve #19713 is 1,035.9952ha [2,560ac] whose purpose is 'Landscape and Aboriginal Culture and Heritage Protection and Conservation of Fauna'. It is a Class 'C' reserve and the responsible agency now being the Dept. of Regional Development and Lands [Landgate]. The date of the last change was April 20, 2011. The 'Additional Reserve Information' lists the reserve as 'Comprises of Lot 300 on DP69595 limited in depth to 20 metres (L566764)'. [McDonough 2018]

Quite apart from the size of the reserve being seemingly whittled down by almost half over the years, what about the DEPTH! 20m? The depth of 20m doesn't even 'protect' the bottom of the doline, let alone the Cultural, Heritage and Conservation of Fauna values inside the cave!

Due to the fact that Weebubbie Cave is home to colonies of swallows living in the entrance zone and bats congregating at the far end of the main lake and elsewhere, guaranteeing a constant input of surface energy, there is a naturally diverse fauna regime also present. 'Caves of the Nullarbor' [1967] listed the following species from Weebubbie:

Araneae indent.,
Acarina indet. [bat parasite],
Rhaphidophoridae sp.,
Speotarus sp.,
Lathridiidae sp.,
Spinturnix sp. [bat parasite],
Polyzosteria pubescens Tepper (accidental),
Psyllipsocus ramburi Selys-longchamp,
Brises acuticornis Pascoe,
Chalinolobus morio (Gray).

Since that publication, four more troglobites have been discovered from the cave:

Possibly 1971 — **Janusia muiri** (spider) — most likely the first discovery of this species.
1981 — Isopod (undescribed) — Robert Poulter
1982 — Cockroach (undescribed) — Norman Poulter
1985 — Beetle **Speozuphium poulteri** — [Moore 1995]

The lead-up to the Weebubbie collapse

The cavernous coastline of the lower South-West of Western Australia between capes Naturaliste and Leeuwin [as well as further north] is made up of what is commonly known as Coastal or Dune Limestone. Rich in silica, it can be quite porous and extremely friable. At Gracetown, a small coastal village just north of Margaret River, there is a popular surfing beach with adjacent limestone cliffs. Amongst the cliff-line was an overhanging ledge [approx. 6m long and 2-3m deep (Paice 2018)] that provided beachgoers with a convenient, elevated all-weather shelter and sandy viewing point that ultimately became a safety concern to some residents and land managers alike. Unconfirmed reports suggested that 'remedial actions' may have been undertaken at various times, and may have unknowingly partially destabilized the ledge.

During a high school surfing event, held in inclement weather[1] on **27 September 1996**, while numerous people were sheltering underneath, the ledge suddenly collapsed, killing nine people, four of them children. It was ironic that an event organizer, whose wife was earlier imploring him to call off the event, was among those killed[2]. [De Poloni & Woods 2016] There were other minor injuries. The effect on the regional communities was to be devastating and long-lasting.

The collapse at Weebubbie Cave, 9 October 1996

TWELVE DAYS LATER, a roof collapse occurred just beyond the weather line of Weebubbie Cave. A party of cave divers from South Australia was in the cave at the time — though nowhere near the collapse site. A power cable and 6mm copper airline passing from the surface were buried under the collapse. A group of Girl Guides, led by a WA caver, had visited the cave the previous evening between 7:30 and 9:30pm, camping overnight, leaving the area the morning of the collapse.

At the time of the collapse, Weebubbie Cave was under the jurisdiction of the Department of Land Administration [DOLA] who readily admitted to being administrators, not managers. No doubt influenced by the Gracetown tragedy, DOLA immediately closed access to the cave and sought advice from the Department of Mines as to what other action should be undertaken.

The cave was promptly visited by Ian Misich [Geotechnical Engineer, Mining Operations Division] of the Department of Mines. He submitted a short report accompanied by several photographs. On the strength of the Misich report, DOLA now permanently closed the cave, had the uppermost ladders removed and commissioned five large signs to be erected in strategic locations advising the general public that the cave was closed. **There was no distinction between untrained members of the public and experienced speleologists or cave divers.**

The closure signs were apparently installed during early December, 1996, one unfortunately within view of the Eyre Highway [acting as an attractant] and another adjacent to the nearby microwave tower, which served as the beginning of the rough track leading to the cave. Two signs were placed at the cave itself, one adjacent to the doline access point, with the other in the camping area. The fifth sign was erected at a track junction of the Eucla-Reid road.

At the time of the collapse, SRGWA was already preparing for an expedition to the Nullarbor and in early December began negotiations with DOLA to gain access to the cave in order to ascertain for itself the severity of the collapse and potential for further rockfalls. This was prompted in part by conflicting media reports immediately after the October collapse. Those reports inferred that several thousand tonnes of rock were involved. The Albany-based Regional Manager of CALM, [Department of Conservation and Land Management, the Western Australian equivalent of a National Parks Authority], supported the SRGWA application. CALM manages the Nullarbor's Nuytsland Nature Reserve, which contains numerous caves, several of which are highly significant and embody lakes. CALM also administers access to other Nullarbor sites of interest to cave divers who were accredited by the Cave Divers Association of Australia [CDAA]. Given the WA Government's enthusiasm for expensive departmental amalgamations, CALM has since been merged into the Department of Biodiversity Conservation and Attractions Parks and Wildlife Service. Pity the poor receptionists who have to repeat that mouthful over the telephone multiple times a day.

In what could only be described as an '11th hour event', this author signed an indemnity form at 11:15am on Christmas Eve [1996, 45 minutes before the traditional knockoff time for the

1 There is no Bureau of Meteorology weather station at Gracetown, but a short distance away and slightly inland, there is a recording station at Cowaramup [#9636 est. 1926] where 150mm of rain had been recorded between 1–23 September 1996.

2 In the hours leading up to and including the time of the collapse, 35mm of rain had been recorded at the Cowaramup station. It may have been a more severe event at Gracetown.

Christmas–New Year holiday break] on behalf of the ASF Inc. that enabled all members of ASF [cavers and cave divers] who subscribe to the ASF's insurance policy to have access to Weebubbie Cave and all other caves on DOLA territory throughout Western Australia.

SRGWA visited the cave during 28–29 December 1996. Initial inspection revealed that, contrary to some media reports, the collapse occurred inside the cave, beyond the weather line and that the amount of rock involved proved to be significantly less than they implied. For a rockfall that was less than 3 months old, the newly fallen rock was remarkably stable.

Over the next two days, members conducted a survey of the rockfall area, the conclusion being that the collapse involved the natural weathering of a roof-step through salt wedging or the drying out of clay interbeds. This weathering process is common throughout the Nullarbor as the caves continue to evolve.

The survey also found that approximately 97m^3 of rock was involved in the collapse, creating another roof step, of which Weebubbie has several. As indicated in diagrams submitted in the SRGWA report to DOLA, the rockfall took place approximately 4-5m from the inner lip of the entrance cliffline and extended along the ceiling for 13.5m varying in thickness from 0.4–0.6m with occasional spurs up to 1m. The width of the collapse was determined to be 18m, approximately 80% of the passage width.

The entrance rockpile at the region of the collapse sloped at 27° and rubble from the fall occupied about 20m of the downslope area indicating that very little rolled downslope [approximately 7m]. The vertical distance that the rock fell varied from approximately 4m near the entrance to about 11m at its furthest point. For such a 'young' rockfall, only 2 or 3 rocks were found to move when trodden on or leant against. The determination was that the entire 97m^3 'step' fell more or less as one piece, breaking up on impact.

Laboratory tests in Perth later revealed that the density of the fallen limestone was much less than that of pure limestone. Pure limestone weighs 3,140kg/m^3 while the rockfall sample indicated a weight of 2,066kg/m^3. This placed the estimated weight of the Weebubbie rockfall at about 200 metric tonnes, considerably less than the 2,000 metric tonnes bandied about in the media.

SRGWA's report to DOLA was confident that the entire rock strata fell during the October collapse and that further rockfalls were unlikely in the immediate future, although as stresses built up or were relieved in other bedding planes as a result of that fall, minor falls could occur from those strata.

2018 and beyond?

In company with a Tasmanian neighbour, this author camped at Weebubbie Cave on the evening and morning of 11–12 September 2017 — almost 21 years after the rockfall. Although I wasn't looking out for them as we drove in from Eucla, in the darkness I did not notice the two signs that had been placed near the Eyre Highway or the old microwave tower. I didn't see any indication of the sign at the Reid Junction the next day as we departed.

The closure sign placed right near the cave entry point disappeared a long time ago. The remaining sign at the camping area looks quite sad, having fallen off one of its support posts, with the other quite rusted at ground level.

I would speculate that the removal of the short wooden 'bush ladder' at the very surface and the long fixed steel ladder further down has acted as a suitable deterrent, preventing most casual visitors from attempting to venture into the cave.

What has happened with Weebubbie Cave during the intervening years?

Have there been further rockfalls? None that I have heard or read about! It would be interesting to find out if speleological activity in the cave has declined since the rockfall.

SO! Is Weebubbie or any other Nullarbor cave more dangerous today than they were prior to their respective rockfalls?

I don't think so.

Cavers and cave managers alike must appreciate the fact that just because water isn't constantly flowing through Nullarbor caves, it doesn't mean that other more subtle factors aren't at play actively forming the caves around them. A rockfall or collapse is, after all, part of a cave's natural evolution.

A question that naturally arises with the closure of these four caves — was the ASF consulted before the closures, advised afterwards — or at all?

A quick solution to a 'reported' perceived, actual or general collapse is perhaps to erect a fence around it and install a few relatively cheap 'cave closed' signs — problem solved.

But who in management, in this modern climate of liability and its insurance implications, is prepared to deem a cave **'SAFE'**, and **WHEN**?

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2018 McDonough L. Pers. Comm., Customer Service Officer, Landgate

2018 Hadland T Pers. Comm. Snr. Geospatial Officer, Topographic, Names and Addresses, Landgate

2018 Paice C. Pers. Comm., Margaret River resident

2018 Climate Data *Daily Rainfall Graph* — 9636 — Bureau of Meteorology Online Archival, September 1996

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ACCESS NOTES for Weebubbie Cave

Applications in writing or email for permission to visit or dive at least **4 weeks** in advance of trip to:

Ms Shannon Alford
Department of Planning, Lands & Heritage
PO Box 1143, West Perth WA 6872
Phone: (08) 6552 4661
Fax: (08) 6552 4417
Email Shannon.Alford@dplh.wa.gov.au

A site indemnity form must be filled out for **each visit** to the site. Forms can be downloaded from the website. Diving permission acknowledged by official letter from Land Owner

ACKNOWLEDGEMENTS

In relation to my earlier articles on this subject over the last 22 years, I wish to thank the following people for supplying additional information or corrections to this updated version.

Some information from earlier articles/reports has not been included.

Dr John Watson, CALM Regional Manager — retired

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Therese Hadland, Senior Geospacatial Officer, Topographic, Names And Addresses, Landgate

Tony Culberg OAM

Brian Combley

I extend special thanks to Nigel Collins for permission to extract information on the Nullarbor's early history from his excellent book, *The Nullarbor Plain — A History*. It's a great read.

Norman Poulter OAM, December 2018

ABSTRACT

Bunda Cliffs — exploration update 2017

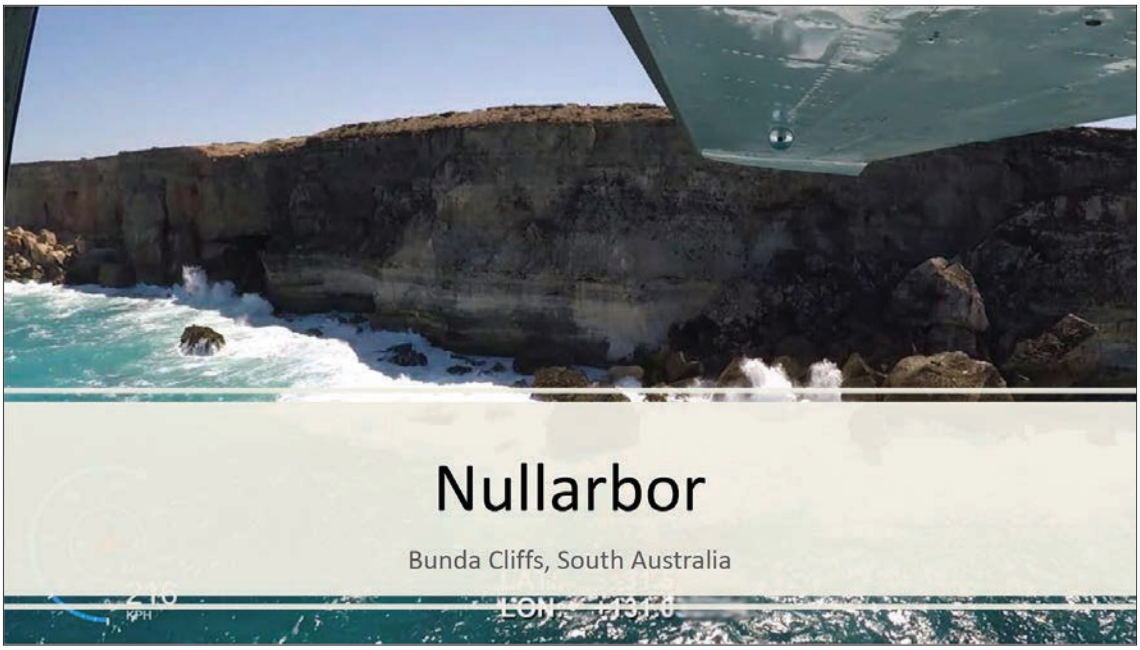
STEVEN J MILNER PhD, Cave Exploration Group of South Australia

Four separate trips to the Bunda Cliffs of the Nullarbor were undertaken in 2017. The Bunda Cliffs are unique, reaching up to 100 metres above sea level for a 173 kilometre stretch in a semi-arid coastal region; they present a unique opportunity to investigate relatively recently exposed karst features. Around 15,000–18,000 years ago sea levels were around 100 metres lower than today's levels and, since then, rising sea levels and erosion have resulted in retreat of the cliffs, exposing the caves.

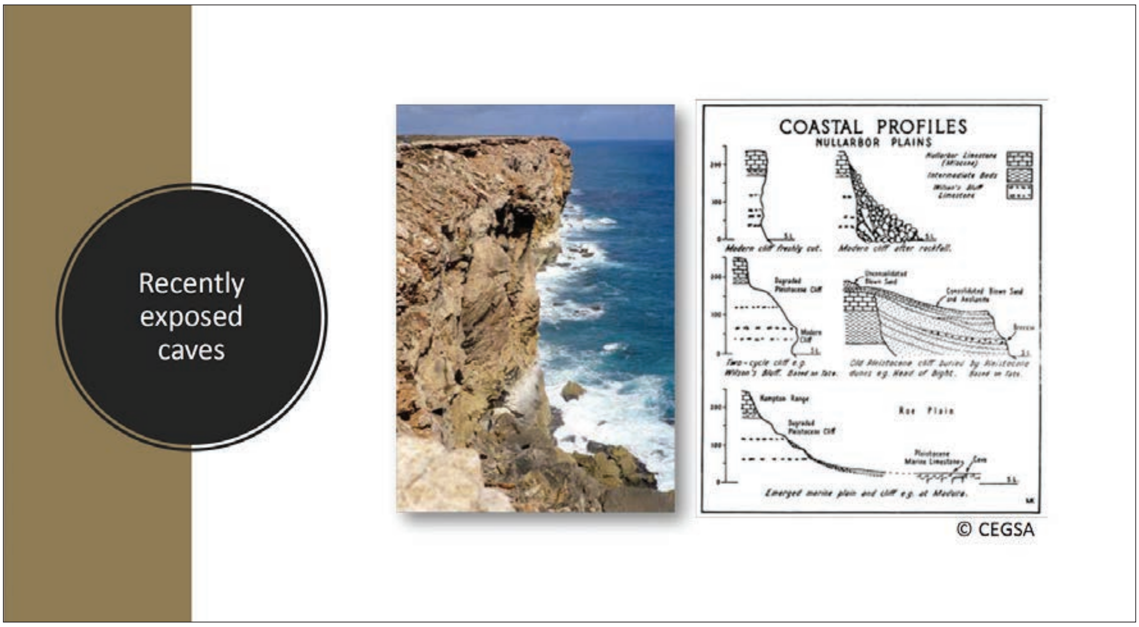
The prospects are fascinating, especially as it is possible that when the sea level was lower, the modern-day cliffs were accessible from the surface or from low-lying land (now eroded away), much like the escarpment above the Roe Plain to the west. In the Bunda Cliff caves there are remains of extinct animals, heightening the possibility that evidence of human activity might also be discovered.

The first trip of 2017 was an aerial mapping project to identify new cave targets, followed by a short reconnaissance trip to evaluate a potential 'walkdown' site. The third trip was the main expedition in August which included cavers who attended the International Speleological Congress in Sydney. The last field trip in November took place to recover some extraordinary animal bones.

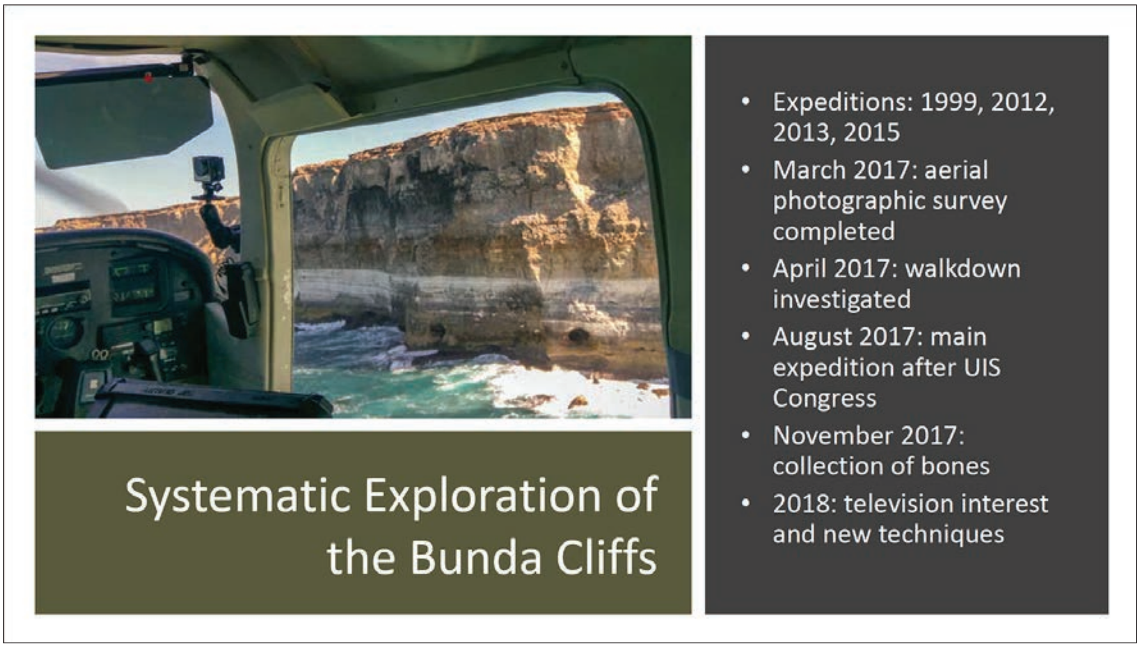
To date, 89 cliff caves have been investigated during the Bunda Cliffs project. This presentation will cover a brief history of exploration, the 2017 results and the plans for future exploration.

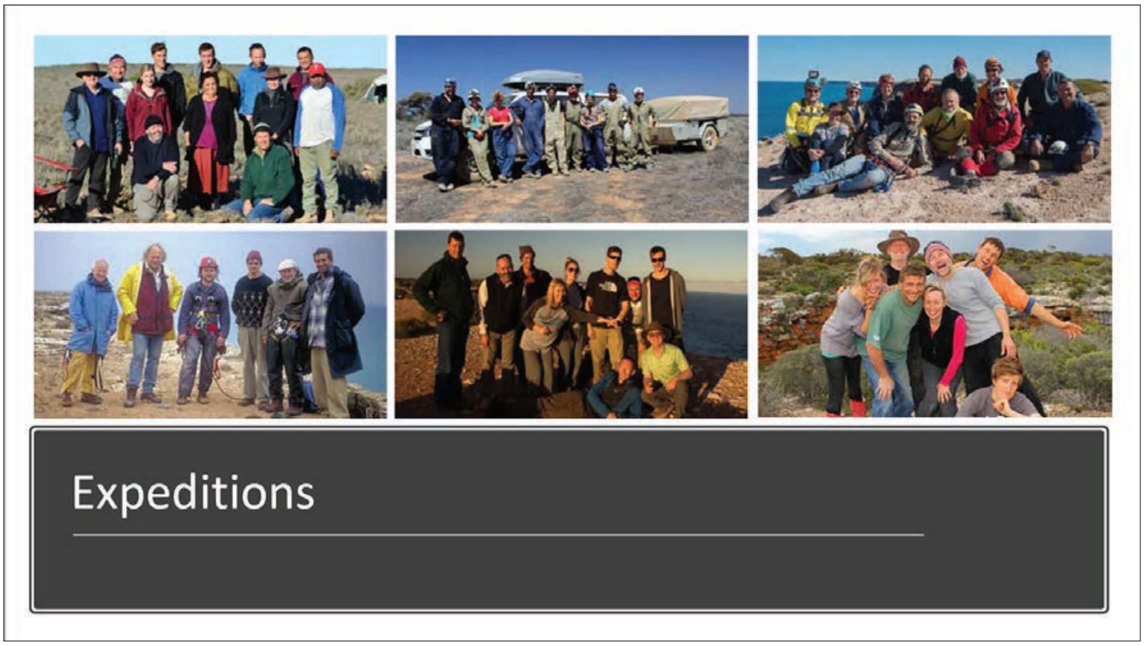

Nullarbor
Bunda Cliffs, South Australia


180km of cliffs, up to 100m high
Western Australia
South Australia
Great Victoria Desert
NULLARBOR PLAIN
Ooldea Range
Watson
Cook
Trans-Australian Railway
Loongana
Rawlinna
Old Homestead Cave
Abrakurrie Cave
Mullamullang Cave
Nullarbor
Madura
Cocklebiddy
Eucla
Head of Bight
Roe Plain
Bunda Cliffs
Eyre Highway
Balladonia
Baxter Cliffs
Great Australian Bight
Israelite Plain
Modern and Ancient Cliffs
Outcrop Locations
Settlement
Modern Rainfall Isohyets
AUSTRALIA
Kilometers
Miller et al. (2012) Sedimentary Geology v261, pp33-49

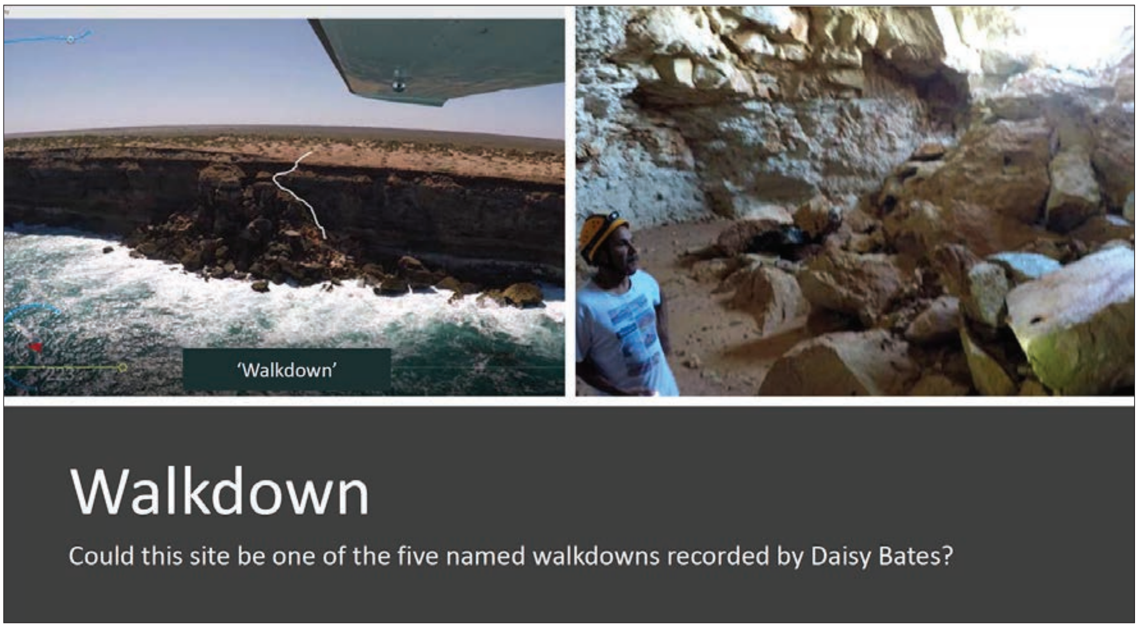

Recently exposed caves
COASTAL PROFILES
NULLARBOR PLAINS
Roe Plain
© CEGSA


Over 200m of cliffs fallen to sea in 2 years!


Systematic Exploration of the Bunda Cliffs
- Expeditions: 1999, 2012, 2013, 2015
- March 2017: aerial photographic survey completed
- April 2017: walkdown investigated
- August 2017: main expedition after UIS Congress
- November 2017: collection of bones
- 2018: television interest and new techniques

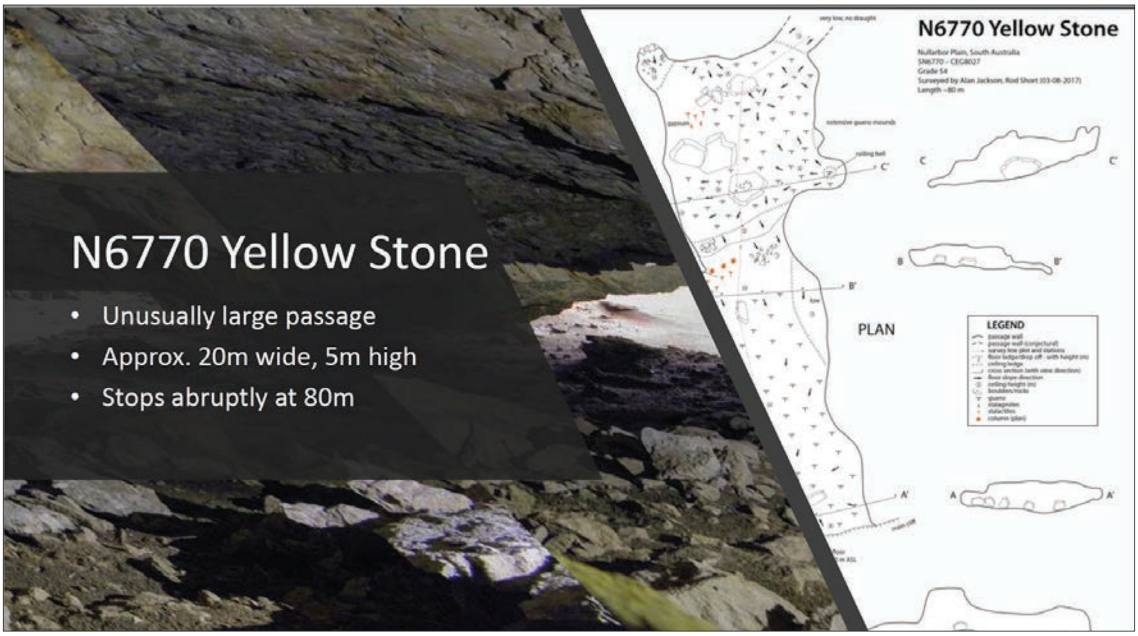

Expeditions

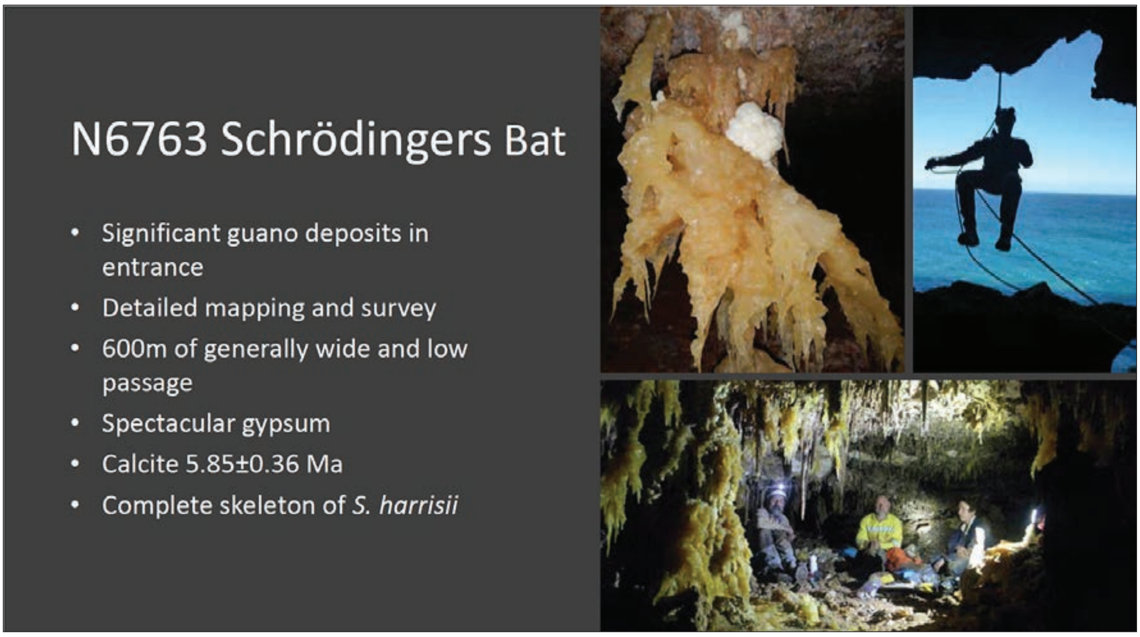

Aerial Survey
New 4k and 2.7k video
3,500 high-resolution stills
GPS encoded data
New targets for main expedition
(Same pilot and aircraft as 1999 expedition)


'Walkdown'
Walkdown
Could this site be one of the five named walkdowns recorded by Daisy Bates?


2017 Expedition

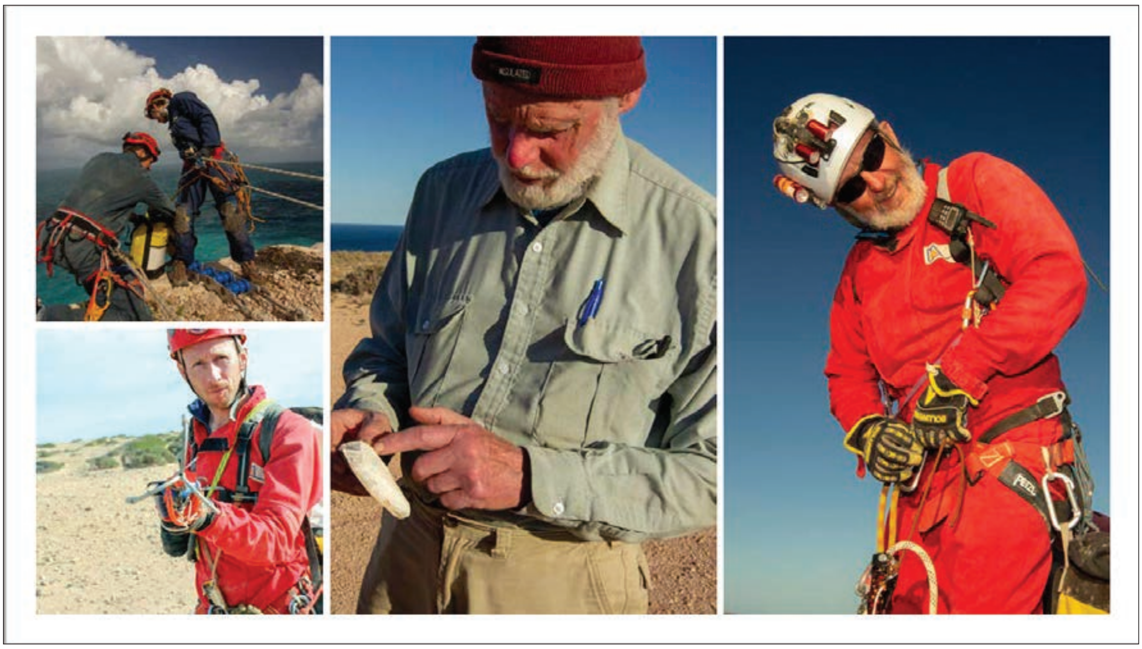

N6749 Swallows and Amazons
• Large recess behind rockpile
• Old cave between Wilson Bluff LS and limestone above
• Eroded calcite 2.85±0.14 Ma
• Skeletons
• Approx. 100m long, draughting (lead)


N6770 Yellow Stone
• Unusually large passage
• Approx. 20m wide, 5m high
• Stops abruptly at 80m
N6770 Yellow Stone
PLAN
LEGEND

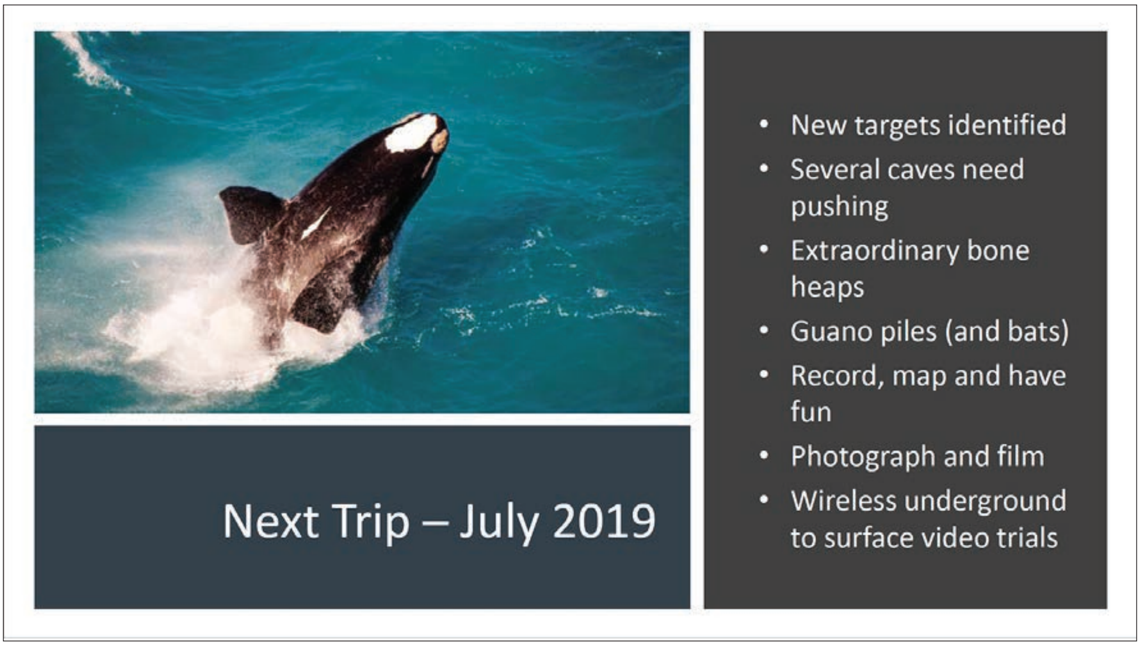

N6763 Schrödingers Bat
• Significant guano deposits in entrance
• Detailed mapping and survey
• 600m of generally wide and low passage
• Spectacular gypsum
• Calcite 5.85±0.36 Ma
• Complete skeleton of S. harrisii


Collection of the
'Nullarbor' Devil


Cliff Caves
Visited in 2017
• 89 cliff caves so far
• Mapping
• Plenty of targets and follow up
• Increasing the knowledge of the Nullarbor




A new tool in development
Lots of interesting finds need expert assessment
A proof of concept IP camera with two-way audio comms was developed and tested inland
This technology will be evaluated in wireless format for the investigation of finds in the cliff caves


Next Trip – July 2019
New targets identified
Several caves need pushing
Extraordinary bone heaps
Guano piles (and bats)
Record, map and have fun
Photograph and film
Wireless underground to surface video trials

ABSTRACT

35 years under the Nullarbor

STEFAN EBERHARD PhD, Southern Tasmanian Caverneers

This slide and video presentation will share a selection of cave diving experiences, stories and highlights, starting with the 1983 world-record six-kilometre penetration dive in Cocklebiddy Cave and the dramatic 1988 collapse and entrapment in Pannikin Plains Cave.

The presentation features spectacular video footage from a recent trip to Pannikin Plains which followed up on a major exploration breakthrough, using side-mount rebreathers, long-range scooters and powerful video lights.

ABSTRACT

A simple field technique for measuring streamflow and some examples from NSW and Tasmania

HENRY SHANNON, Northern Caverneers

Mostly cavers are at a loss when it comes to making an estimate of streamflow volume. Yet the phenomenon of the hydraulic jump makes it possible to get a fix on flow velocity, simply by 'stopping' the flow so that its kinetic energy becomes potential energy. The velocity-head rod is an accepted device in hydrology but used in larger streams than are common in caving situations.

The writer is used to the imperial units where a jump of 3/8" = 1 ft/sec, 3/4" = 32ft/sec, 3/2" = 3ft/sec and 3" = 4ft/sec. It is normally possible to find appropriate cross-sections to apply these rules and one can memorise hand parts to simply use the fingers. Metric conversion is 1 cu.ft/sec = 28 litres/sec. Applications at Windy Gap, Kempsey hinterland, NSW, and Mole Creek, Tasmania, are given as illustrations of what can be discovered using this method. It was also used in work at Jenolan and Mt Arthur, New Zealand.

A simple field technique for measuring streamflow and some examples from NSW and Tasmania

Henry Shannon

Northern Caverneers

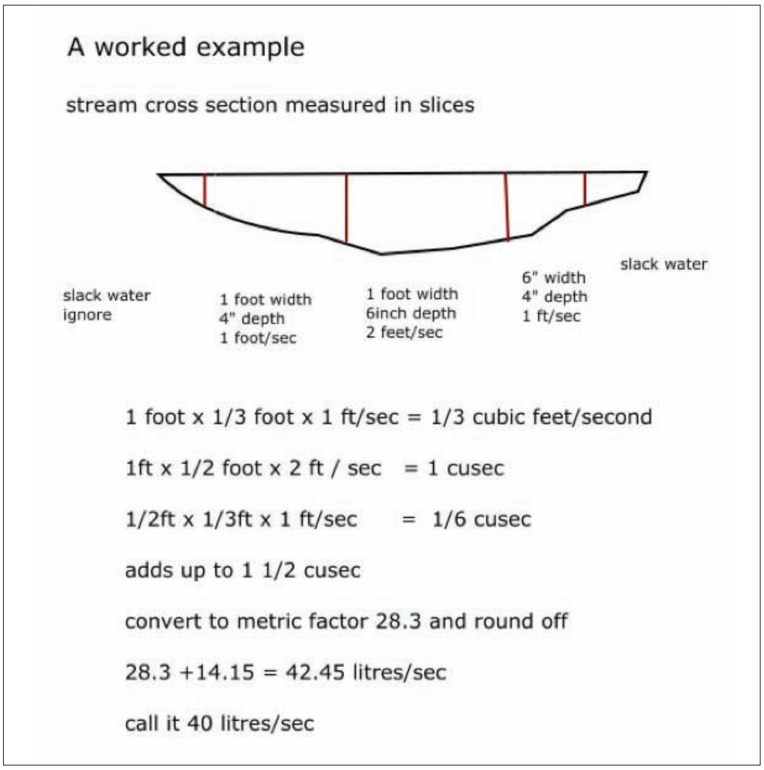
The method of measuring a flow volume that first comes to mind is the "floating stick" method, which requires a regular section channel going for enough of a distance to work; and this normally can't be done in caving situations. Not so well known are methods utilizing the hydraulic jump effect. This happens at an obstruction to flow which forces movement in the horizontal to go vertical; a transfer from kinetic to potential energy. The v you need to get is proportional to the square root of h. For a measuring point all that is required is a clean cross section or ideally a group where different cross sections and velocities can be compared in the hope of getting converging flow measurements. The point is that such conditions usually can be met in caving situations.

The basic instrument used by those primarily interested in stream gauging is the velocity head rod, a device you can look up on Google though an earlier version in a textbook, *Meinzer's Hydrology*, is the basis for my adaptation. I started using the method before metrification and since I find the old units convenient I use them in the field and convert to metric later on. Anyway the basic rod is rectangular cross-section modified to make a sharp edge out of one of the narrow sides and with measuring scales up the long axis. Then the rod is placed in the stream sharp edge upstream so as to get a depth measurement — the sharp edge is to prevent the hydraulic jump occurring — then the rod is turned 180 degrees to measure the hydraulic jump itself. The observer then does a traverse across the stream taking repeated measurements for slices of a cross-section of the stream. The method assumes something firm on the bottom and depth and velocity the observer can survive but overall, streams bigger than cavers normally deal with. A professional hydrologist would be using a rod of say 5 to 6 ft which is a bit much for a caver to be carrying around. Very small streams can in principle be measured with a v-notch weir but this is often impractical as a field device when the bed materials won't cooperate. The device is cumbersome and can't be bedded in properly in stony ground. The common situation is to be wanting to measure streams mostly of intermediate size and with no device on hand, or perhaps with say a photograph of a party wading across a stream as the only data. In this case you can make a depth estimate from the degree the various people are sunk in the water and flow velocity from the bow wave induced by their bodies.

The typical situation is to be dealing with flows of the order of 1/12 to 20 cusecs in imperial units and flow velocities that can be shoehorned into 1, 2, 3, 4 ft/sec using hydraulic jumps that correspond: 3/8" = 1ft/sec, 3/4" = 2ft/sec, 1 1/2" = 3ft/sec, 3" = 4ft/sec. Higher flow velocities, up to 12" = 8ft/sec become hard to read because the pile up jumps around a lot. In principle some velocities lower than 1 ft/sec could be reckoned from another phenomenon; the little wave that appears out from an obstruction, moves closer with increasing velocity and merges into the regular head jump a bit before 1 ft/sec.

I find it easier to work in the old imperial units, then convert to litres/sec. Conversion factor is 1 foot/sec = 28.3 litres/sec.

The usual situation is to have no device with you when you want to take a flow measurement. To cope with this situation I have memorized enough hand/body parts features to do the head jumps and channel sections. And to allow for drag effects I prune the section a bit. To do the flat bit of the velocity head rod I use two fingers. It's a good idea to take more than one measurement and do different combinations of cross-section and flow velocity. Also slice up the cross-section if there is enough velocity variation. The critical value of the technique is in coping with far from optimum sites for measurement. Some examples from Jenolan: Lower River in Mammoth Cave, Jenolan emerges from two holes in a wall, crosses the floor into a gutter then into deep water. Back in the days when Central Lake was normally present normal flow was 6 cusecs it could be measured by combining readings from both holes. At that time the gutter overflowed too much for measurement. In recent years the flow is confined to the gutter and can be measured there. It is only necessary to get a cross-section of the stream. Another difficult but fudge-able measuring point used to be the outlet weir for the Jenolan underground river with the complicating factor being discharge under the weir. But the way the water moved into Blue Lake meant that the flow under the weir could be estimated as a quarter of the whole and the remainder could be measured. But it's worse now.

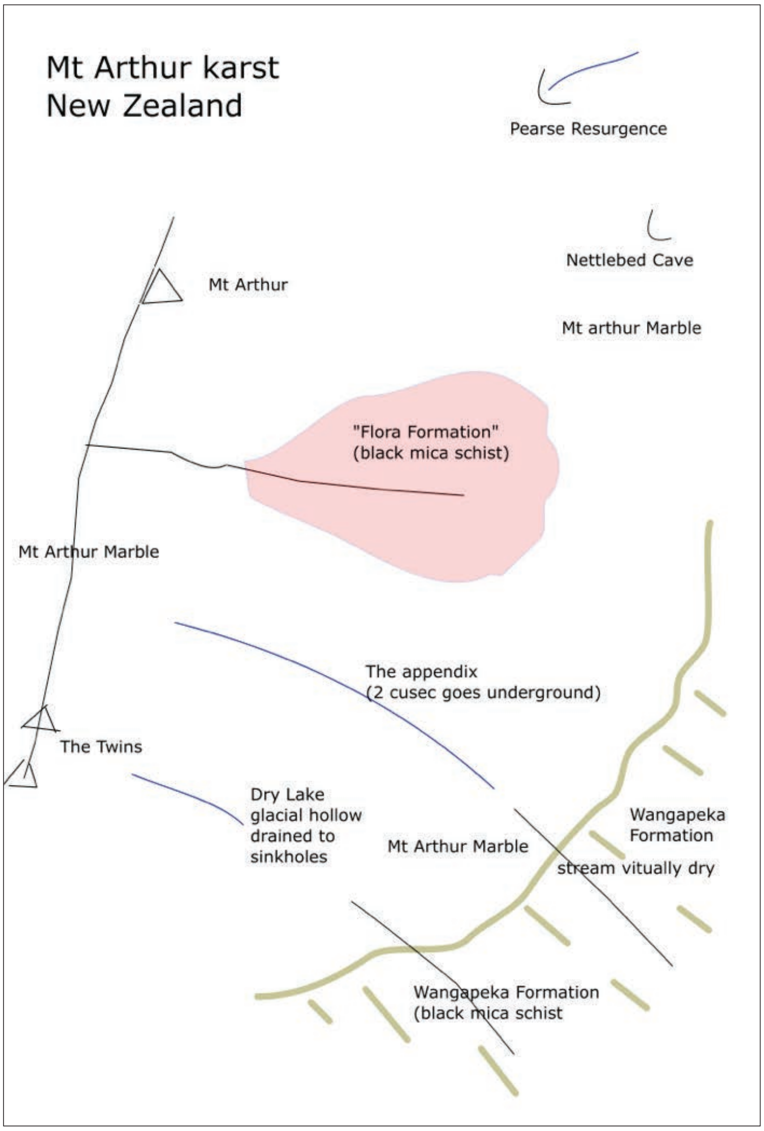


Right: Slicing a cross section since velocity is likely greater in the middle.

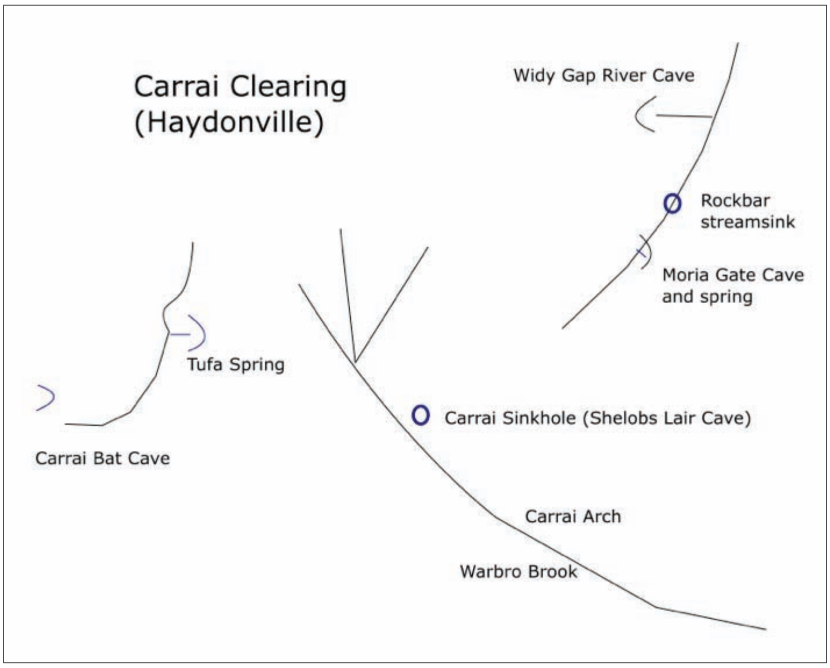
Some examples

MT ARTHUR KARST, NZ SOUTH ISLAND: The camp on the 1966 expedition was at Dry Lake, a glacial basin drained by small swallets. The ground accessed from this camp is remote from the Pearse Resurgence; the known large spring for the area, and going on the published geology map the local underground drainage appeared to be blocked off by a schist formation supposedly coming to the surface from below the marble. But on the walk in I noticed a group of sinkholes near the contact that were in the schist itself, showing that the marble must be underneath. The new version of the geology coming from this observation meant there was no impediment to the local drainage heading underground to the Pearse Resurgence and Nettlebed Cave. It remained to check out the possibility of resurgences at low points on the marble contact in the local area and to see how they matched up with measurable stream sinks, which I could do with velocity head measurements to prove that at least 2 cusecs were going under in the next valley. The creeks just off the marble were mere trickles so the 'it all goes to the Pearse' model was proven.

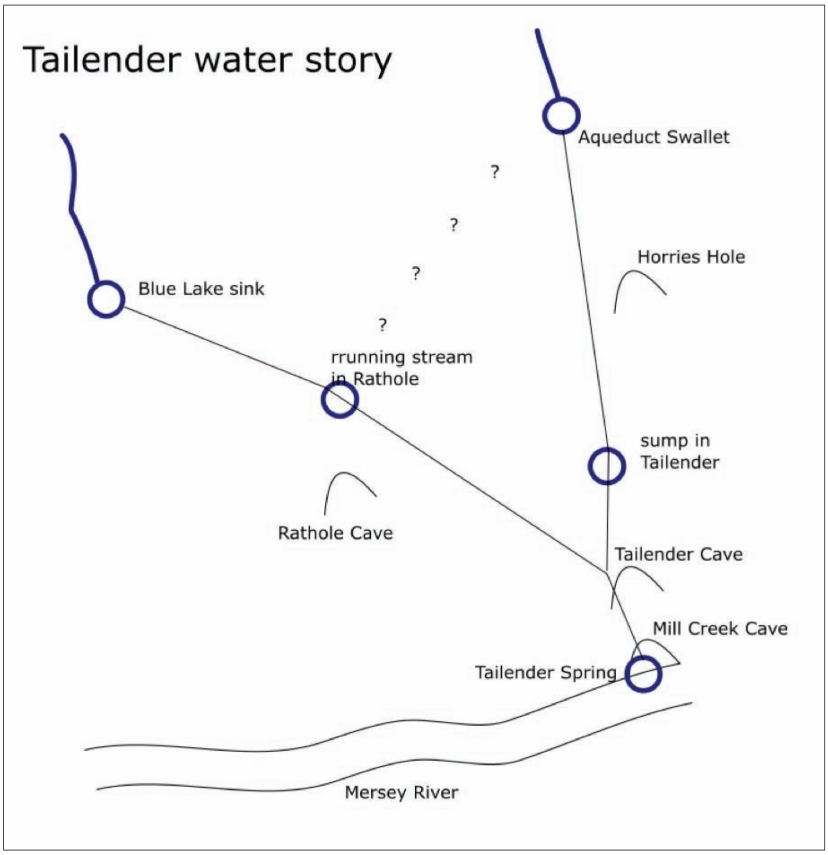
CARRAI-WINDY GAP, NSW MACLEAY VALLEY KARST: The limestone belt here can direct underground drainage along strike and though obscured with superficial cover much of the time it does seem that the belt can contain more than a single bed. Because of the cover situation inflow points can't be located generally but in Carrai Clearing, at a highish point on the belt, Warbro Brook crosses on an alluvial flat that is assumed to be leaking. At the margin of the flat adjacent to limestone outcrop there is an open sinkhole so situated that water from the creek can be diverted into it, and this was done as part of a water tracing experiment with home-made



fluorescein. The questions to consider were whether the extra water would go West to Tufa Spring near Carrai Bat Cave (not likely but checked with a charcoal bag) or East to River Cave, Windy Gap (likely) but with an extra complication: the cave is not just over the divide but on the opposite side of the next valley. A bar of limestone crosses this creek and water sinks into it which is then expected to go to River Cave (proved later with rhodamine) and this water comes from a spring in what appears to be a different limestone bed near Moria Gate Cave. This spring is on the expected side of the valley but isn't as big as River Cave. So, would the water go directly to River Cave, or take the indirect route by first coming to the surface at Moria Gate Spring then sinking again at the rockbar? This is where flow measurement would help and as it happened, the extra water appeared at River Cave and the situation at the rockbar was as before. Ergo the connection is direct.



MOLE CREEK — FEEDERS TO TAILENDER SPRING: There was a dye test run (published in Forestry) in which rhodamine was placed in Aqueduct Swallet and fluorescein was placed in the outlet of Blue Lake. The rhodamine was never seen again except in a fancy fluorimeter but the green stuff was seen in Rat Hole and in Tailender Spring. (It was measurable at the time, but no more since 'environmental flow' is now released from the Hydro dams.) Tailender Spring flow was as expected from the sum of the two identified sources but where did the join occur with respect to Rat Hole? The strong fluorescein response could have been masking a rhodamine positive if the join was upstream. But the flow in Rat Hole made perfect sense if Blue Lake was the only feeder.



ABSTRACT

Unusual or isolated caves in Victoria: karst or pseudokarst?

SUSAN WHITE PhD OAM, Victoria Speleological Association

Caves are usually considered to be predominantly karstic features found in highly soluble host rock such as limestone. Associated solutional features, both underground and surficial are characteristic of karst landscapes. However similar features including caves are found in host rocks that not very soluble in normal surface conditions or are due to other formation processes e.g. lava caves, granite caves. These features are generally classified as pseudokarst. However the boundary between karst and pseudokarst is vague as solution occurs in a range of host rocks and the chemical conditions are highly variable.

This paper will discuss the nature, formation and processes of a number of Victorian cave and related features that are not karstic in the usual understanding of the term. They are unusual in that they are either in a host rock that is not generally known for caves, are in a number of unusual situations and are isolated compared to the caves in most karst or pseudokarst areas.

Unusual and isolated caves in Victoria: karst or pseudokarst?

Susan Q. White[1 2]

1 Victorian Speleological Association
2 Environmental Geoscience, Department of Ecology, Environment & Evolution. La Trobe University, Victoria 3086

Introduction

Victoria has a range of karst and pseudokarst caves and features. Most caves in Victoria are in either Palaeozoic or Cainozoic limestones or are basalt lava caves. It does not have the most spectacular caves in Australia but there is variety in the rock types that caves and related features occur in. The most common reason for this phenomenon is that caves sometimes form in host rocks that are not regarded as highly soluble e.g. granite, siliceous sandstone, silcrete, and also may be formed by processes other than solution e.g. sea caves. As well as caves in other host rocks there are some very isolated caves. Some have only one cave; others a couple or very few.

Types of unusual host rocks

The less soluble host rocks include granite and granodiorite e.g. Warburton Granodiorite (Britannia Creek Cave), siliceous sandstone e.g. Grampians, Mt Speculation area, silcrete e.g. Taylors Creek Cave, metamorphic siliceous rocks such as shale e.g. Mt Sugarloaf, and Mt

Bogong, and the Cretaceous siliceous sediments of the Otway and Strzelecki basins. There are piping processes, which form caves in dispersive clays at Smiths Gully, St Andrews to the north east of Melbourne.

The caves in very small isolated small patches of limestones include the Paleozoic 'hard' limestones at Walkerville and the softer dune limestones in isolated dunes such as Puralka and Strathdownie in western Victoria.

The volcanic caves in basalt, which are generally found in clusters, however have isolated examples such as the inner Melbourne suburb of Clifton Hill, and at Parwan and other basalt areas.

Processes of cave formation and examples

The most common cave formation process is solution and although in some of the caves such as at Walkerville and Puralka, solution is the major process, many of these unusual caves are not formed predominantly by solution. Solution is a chemical process and in many cases the hollowing out of cavities is the result of mechanical rather than chemical processes.

However solution is not exclusively solution of calcite (limestone) and solution does occur on siliceous (quartz rich) rocks. Examples of this can be found occasionally in granite caves where small speleothems composed of the clay mineral allophane in association with opal-A indicate evidence of precipitation of solutes (Webb & Finlayson 1984), However, no such speleothems have been found in Victorian granite caves and the evidence for solution as a major process is conjectural.

Removal of dispersive clays by suspension of clay particles (piping) has resulted in interesting caves at Smith's Gully near St Andrews (north east of Melbourne) and flowing water has removed weathered material from fissures resulting in Goat Cave (Mt Sugarloaf, Buxton GP-11) and probably the NE-2, the cave on Mt Bogong.

Granite caves are not rare in Victoria, and are also present in other granite outcrops around Australia (e.g. Finlayson 1981; Smith 2019). Generally they are boulder caves where significant areas of granite boulders are either the result of landslides (e.g. Britannia Creek Cave GP 10) or granite intrusions have been weathered and then eroded leaving large tors (e.g. Melville Caves NW 1). The best known and probably the best caving in granite is at Labertouche Cave (GP 7) a 710m long granite-boulder cave valley-infill cave in Gippsland, consisting essentially of intricate spaces between hundreds of large boulders. This cave has 3 or 4 'levels' as the spaces between the boulders result in 3-dimensional spaces. The Underground River (NE1) is a stream cave through a granite rock pile at Mt Buffalo. Most of these caves are where the fine weathered material has been mechanically removed, generally by water action rather than by solution.

Fissure caves are where slabs of rock have separated from a steep slope or cliff resulting in a narrow squeeze. These are often not very long and are often not documented as caves but if we are going to document all caves and cave-like features they should be included. An excellent example is Goat Cave (Mt Sugarloaf, Buxton GP-11) where the fissure does have a short dark zone and is documented by VSA.

A 'caprock' of more resistant material than the underlying rock may result in a cave forming under the caprock. The more common type results in a cave behind a waterfall e.g. the Den of Nargun (GP 5). Den of Nargun is a large overhang 10m deep, 25m wide and up to 3m high at the entrance with no real dark zone. The cave is formed in horizontal beds of red alternating sandstone and conglomerates, typical river deposits (Upper Devonian/Lower Carboniferous), mainly sandstone. The roof is a flat-lying bed of resistant sandstone, and the cave has formed by erosion of the underlying crumbly red mudstone. It contains a sandy floor and a fallen large stalagmitic mass with a couple of upright columns nearby. This calcite speleothem has been derived from carbonates in the overlying sandstone. The cave receives water during flood events on the Mitchell River so occasional extension may occur. The cave forms when the current stream, a tributary of the Mitchell River, is actively down-cutting in a situation with its very resistant sandstone roof (Webb, 1984).

The second example of an unusual cave with a similar resistant cap rock roof is Taylor Creek Cave (NW 2) in the north-western suburbs of Melbourne. The cave is formed within relatively soft sediments of the Pliocene Red Bluff Sand, overlain by Newer Volcanics basalt and silcrete. The cave consists of a single low chamber, 12m long and 5m wide, that has been excavated in friable sandstone under a resilient silcrete roof; it has formed by an unusual combination of piping and stream erosion. Taylor Creek initially exposed the silcrete surface, and then piping below the silcrete caused tunnel formation in the sandstone. Collapse of overlying material into this tunnel captured Taylor Creek, causing it to flow beneath the silcrete and thereby enlarge the cave to its present size (Webb & Joyce, 1984). When the cave was visited recently the stream was sufficient to prevent access to the cave without getting very wet but it is often dry in the summer months.

Sea caves along the Victorian coast occur in a wide range of lithologies. In particular the Cretaceous sandstones and siltstones of the Otway and Strzelecki Groups have many sea caves. Sea caves are generally the result of mechanical weathering and erosion rather than solution and the high energy Bass Strait coast shows abundant evidence of this. However as well as the standard small sea caves, there are several larger joint enlargement caves, particularly in the Cretaceous sandstones. The most significant example is Ramsdens Cave, which has two chambers joined by a narrow passage; a total 60m in length. The entrance is concealed and almost blocked by fallen rock from the overlying slope and cliff. The cave floor is approximately 12m above sea level and is mainly concealed by large pools of water. The cave is formed as a joint enlargement and is probably the result of a higher sea-level.

As well as caves there are a large number of large and small overhangs in a wide range of lithologies, which are identified as 'caves'. Most of these are small but there are several with significant indigenous art work e.g. on the Grampians, as well as some very impressive large overhangs e.g. Mt Buangor, near Beaufort, where the overhang is at least 40m long and over 10m deep.

Conclusion

Isolated caves in a variety of lithologies occur around the state. Many have been listed above e.g. Goat Cave, but others include a cave on Mt Speculation in the Gippsland Alps, a fissure cave in granite on Mt Bogong, and a small basalt cave in the inner Melbourne suburb of Clifton Hill where the entrance is exposed in the cliff valley sides of Merri Creek. There are small patches of limestone where a small number of caves can be found e.g. Bear Gully at Walkerville where there are a few caves.

Caves can exist in almost any rock type; in most cases these are just one or 2 caves in the right geological situation for cave formation. However it is important to realize that limestone is not the only host rock, they are of interest and importance and that fun can be has exploring them. There is real merit in exploring for and documenting these features.

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ABSTRACT

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

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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.

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

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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.

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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

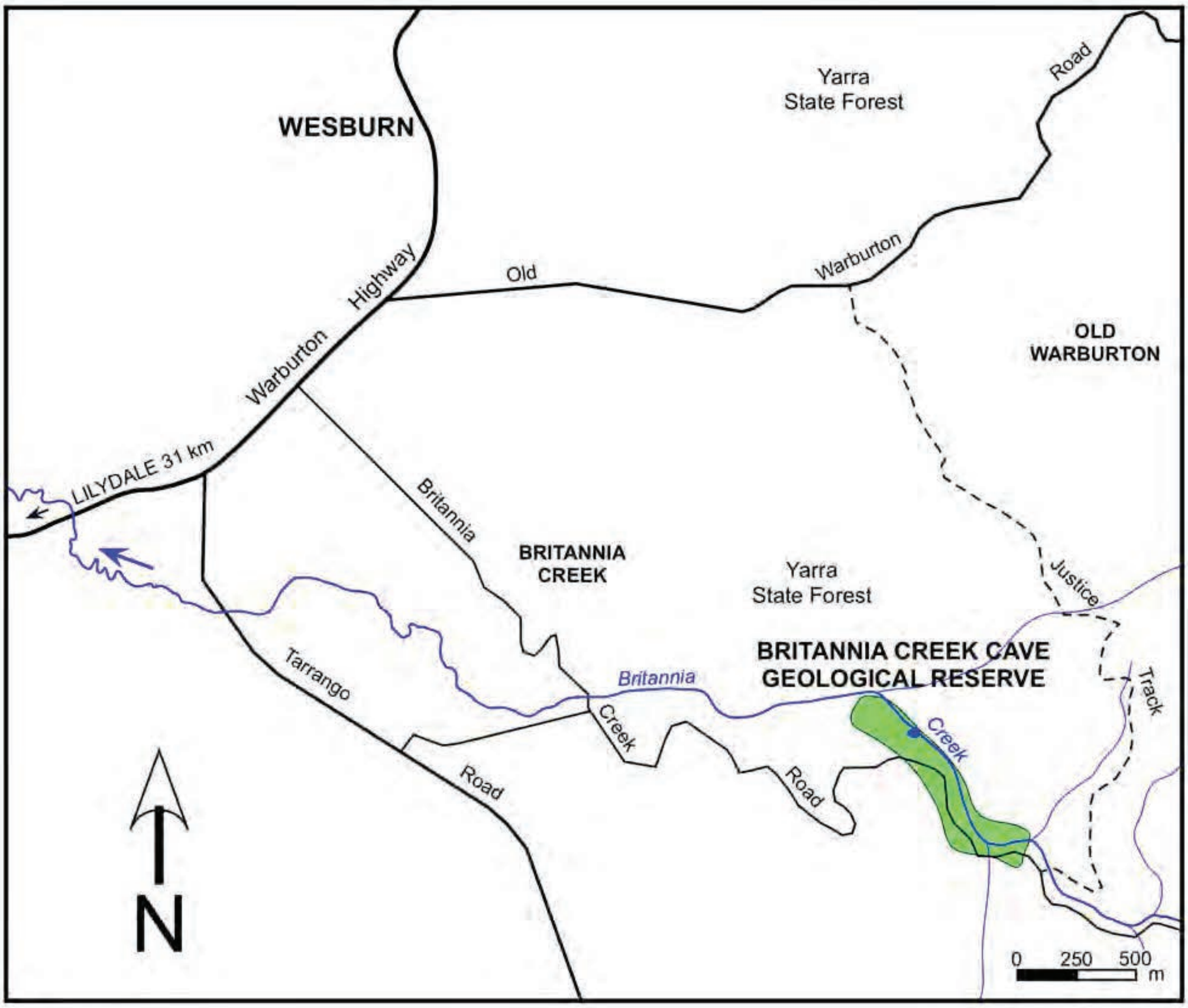

Figure 1. Map of part of Victoria, Australia, showing location of the Britannia Creek Cave Geological Reserve.

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.

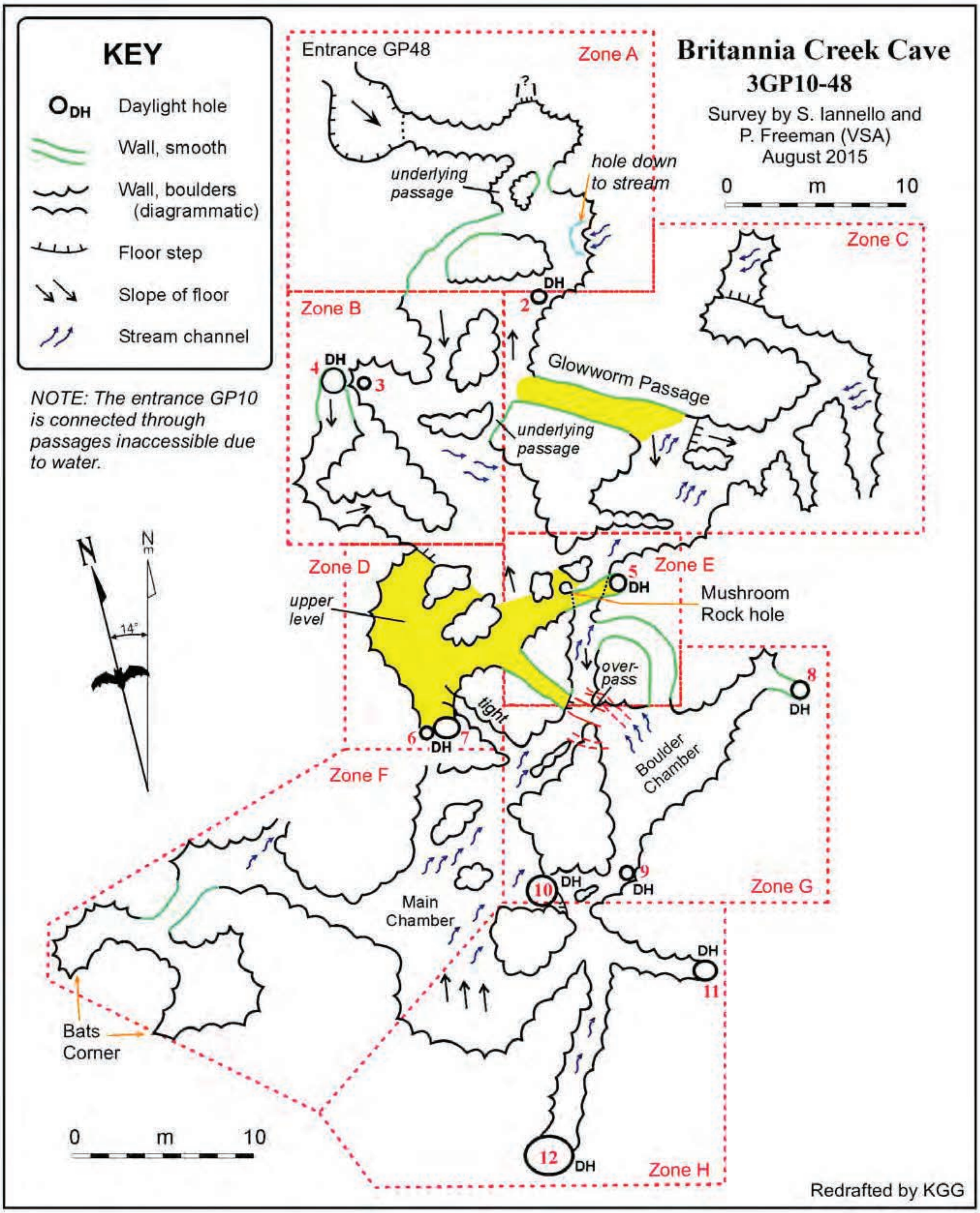

Figure 3. Map of Britannia Creek Cave with boundaries of zones A-H delineated in red. Entrances 1 to 12 depicted by a number in red. Yellow shaded areas show the upper levels of the cave.

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.

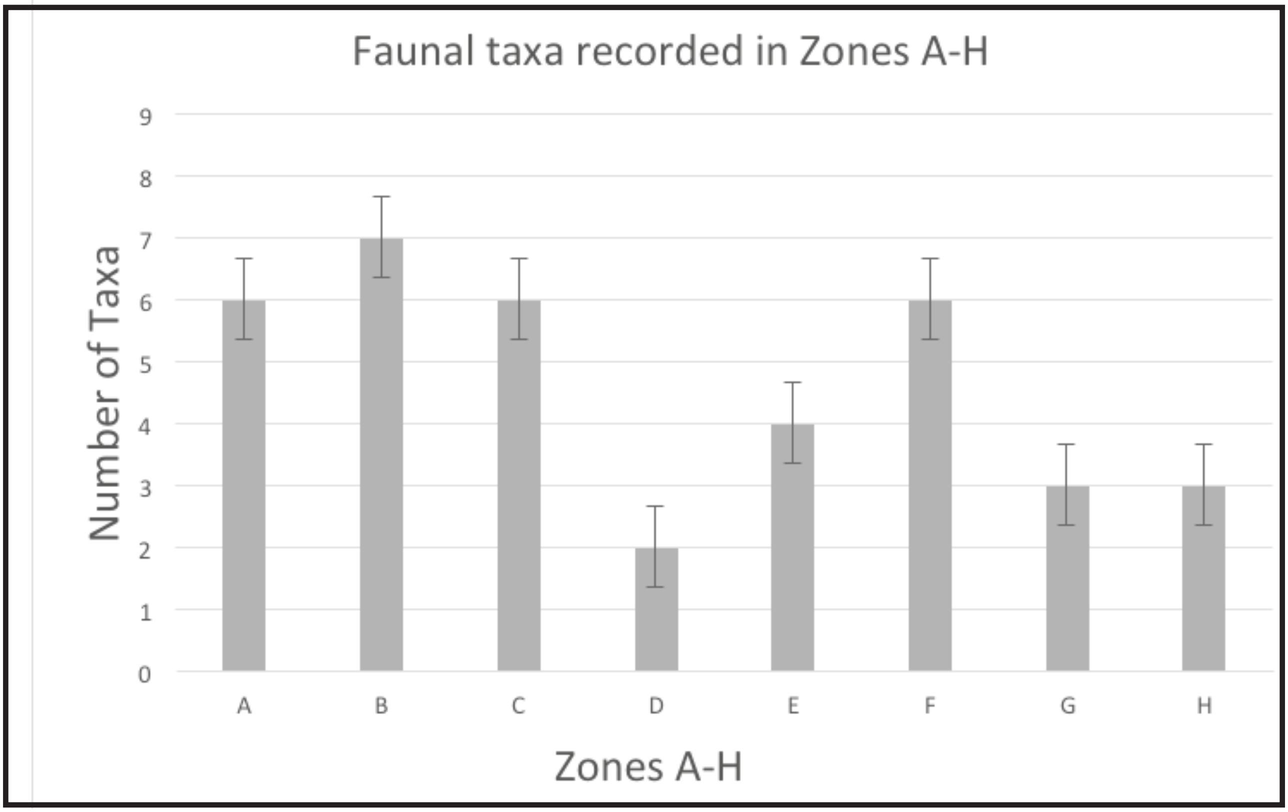

Figure 4. Number of taxa recorded in each zone of Britannia Creek Cave for the months of April, August and October combined. Total number of different taxa recorded was 15.

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.

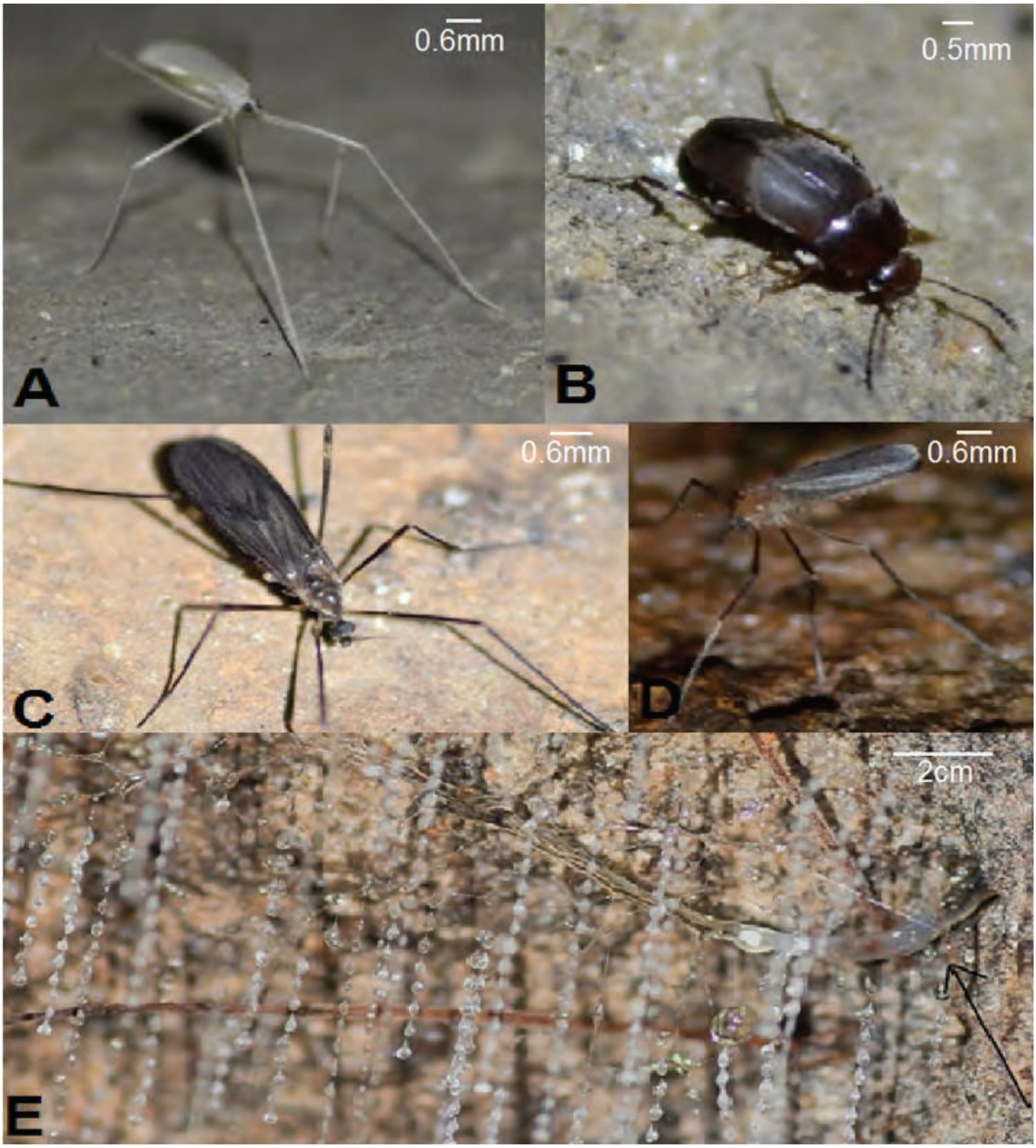

Figure 5. Photographs of live invertebrates taken in Britannia Creek Cave. A. Diptera gen. and sp. unknown; B. Coleoptera gen. and sp. unknown, Leiodidae (small carrion beetle or round fungus beetle); C. Keroplatidae, cf. Arachnacantha gippslandica *(glowworm); D. Diptera gen. and sp. unknown; E. Diptera,*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

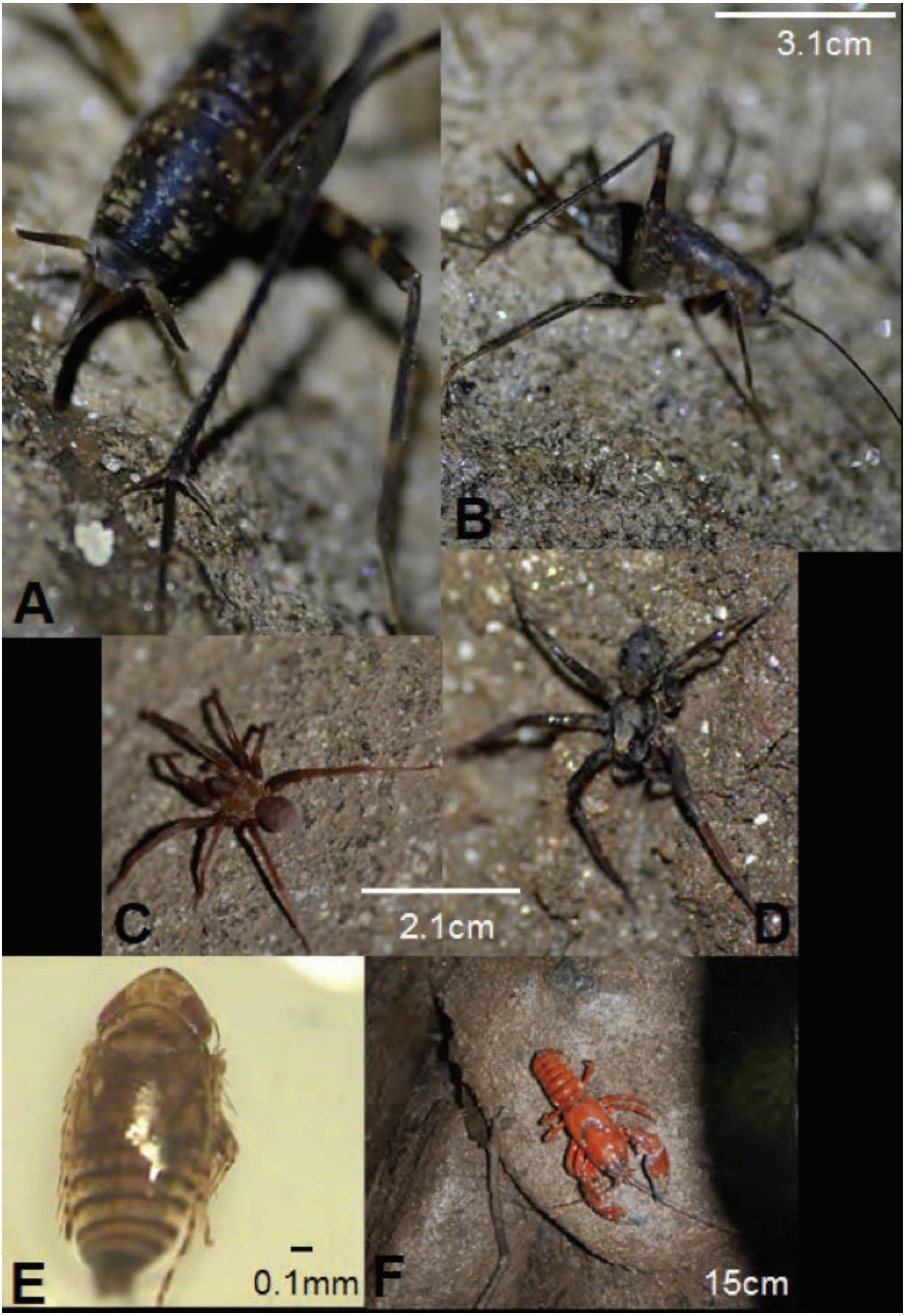

Figure 6. Photographs of live invertebrates taken in Britannia Creek Cave.
A. & B. Insecta, Orthoptera, Rhaphidophoridae, new species (cave cricket); C. & D. Araneae gen. and sp. unknown; E. Insecta, Hemiptera, Cicadellidae, Horouta *sp. (leaf hopper); F. Crustacea, Parastacidae,* Euastacus woiwuru *(freshwater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

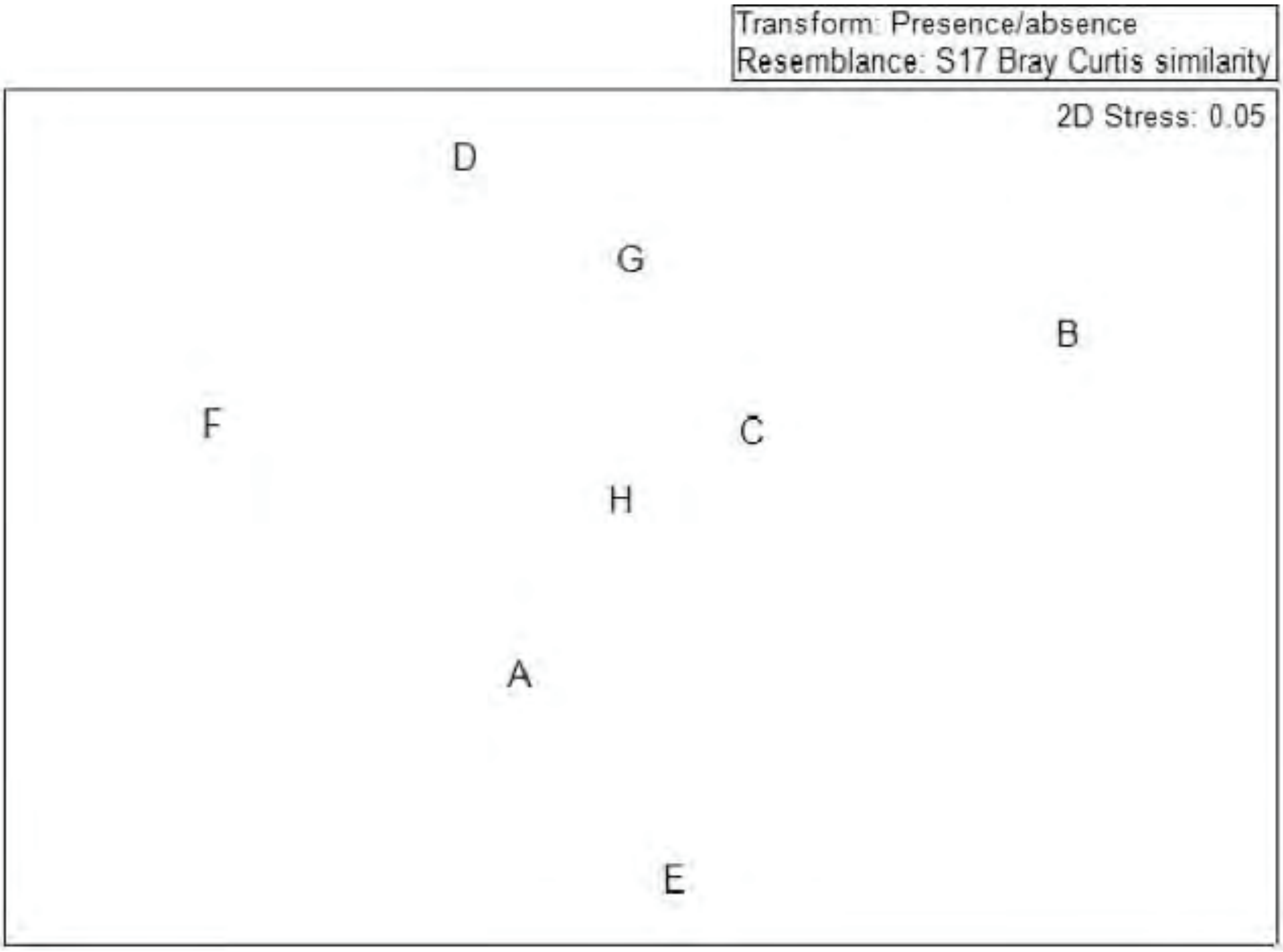

Figure 7. MDS analysis of the community composition of invertebrates recorded in zones A to H combined, at three sample times (April, August and October) in Britannia Creek Cave.

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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ABSTRACT

Hit or miss could mean life or death for juvenile Southern Bent-wing Bats

YVONNE INGEME[1,2], AMANDA BUSH[3], LINDY LUMSDEN[3], EMMI VAN HARTEN[4], STEVE BOURNE[5], TERRY REARDON[6]

The Southern Bent-wing Bat (*Miniopterus orianae bassanii*) is a critically endangered obligate cave-dwelling bat that is restricted to South Australia and Victoria and has undergone significant population decline in recent decades. Only three maternity colonies are known, the largest at Bat Cave in Naracoorte Caves National Park, SA. Anthropogenic factors at maternity caves may adversely impact survival rates, especially juvenile survival. Fencing is often installed around cave entrances to restrict human access, but this can create a collision risk for bats, especially for juveniles learning to fly. Infrastructure around Bat Cave includes a fence and a large metal panel. Trapping was undertaken at the cave entrance as part of a separate research project in January 2016–2018, at the time when young commence flying, which enabled opportunistic observations on collisions rates with this infrastructure.

In 2016, four of the 387 (1.03%) juveniles caught over one weekend had broken limbs from colliding with infrastructure, and required euthanasia. Many other bats were heard to collide with the metal structures although the fate of those individuals was unknown. In 2017, the fence was covered with shade cloth in an attempt to reduce the rate of injuries. No injured bats were caught; however, 90 bat strikes on metal were heard over two nights of monitoring. In 2018, the fence and metal panel were both padded and covered with shade cloth. No injured juveniles were found, and no bat strikes were heard during four nights of trapping. Covering the metallic smooth surfaces with shade cloth may have improved the ability of the young bats' echolocation to detect it, with the padding reducing injury if any did collide.

This study highlights the need for careful fence design and placement, especially around the entrances of bat maternity colonies, and the importance of monitoring new, and even existing, bat cave fences for bat collisions.

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Hit or miss could mean life or death for juvenile Southern Bent-wing Bats

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Introduction

The Southern Bent-wing Bat (*Miniopterus orianae bassanii)* is an obligate cave-dwelling bat with a restricted range in southeastern South Australia and southwestern Victoria. It has undergone significant population declines in recent decades, resulting in it being listed as critically endangered. Only three maternity colonies are known, the largest at Bat Cave in Naracoorte Caves National Park, World Heritage Area, South Australia. Bat Cave has a vertical window entrance (7 x 4 m) leading to a 10 m drop to the cave floor. The rim of the entrance is thin and undercut, making it hazardous for staff, researchers and tourists. The entrance is fenced to prevent 1) people from falling into the cave, 2) unauthorised access, and 3) disturbance to the bats and fossils within the Bat Cave.

The fence around the entrance to Bat Cave is a standard 1.5 m high galvanised iron fence with vertical rungs (typically used to fence swimming pools). It is positioned 2–5.5 m from the entrance (Figure 1). In addition, there is a smooth metal panel 12 m long and 1.5 m wide, located between the fence and cave entrance (about 1.5 m from the cave entrance). The metal panel is fixed on a 45 degree angle sloping away from the entrance. It was installed in 2012/13 to assist with undertaking population estimates by recording bats emerging from the cave using thermal imagery, but is now rarely used.

Figure 1. Left: Infrastructure surrounding Bat Cave, including the metal fence and smooth metal panel, and temporary set up of padded harp traps. Right: Harp traps set up to trap bats during January 2016-18 field sampling. Photos: Yvonne Ingeme

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Methods

Between 2016 and 2018, the field work component of Emmi van Harten's PhD research project 'Population dynamics of the critically endangered Southern Bent-wing Bat' was undertaken. The aim was to PIT-tag 1000 Southern Bent-wing Bats per breeding season with approximately half to be juveniles. This involved placing a large number of harp traps around the cave entrance. Harp traps comprise a large aluminium frame with two banks of vertical, fine fishing line with a canvas bag underneath. To reduce the risk of bats injuring themselves if they hit the metal uprights or cross bar, these poles were covered with foam. The traps were positioned immediately outside the fence and with the top of the bag below the height of the fence. Trapping was conducted in January and February to coincide with the period when juvenile Southern Bent-wing Bats commence flying.

Trapping commenced on dusk and continued into the early hours of the morning as it was found that the juveniles tended to emerge later in the night than the adults. The traps were under constant surveillance during the night, to enable bats to be removed as they were caught. Noise and lights were kept to a minimum, with red filters on the lights when they were used. The observers spent most of the time in the dark quietly listening, and this provided the opportunity to make observations on collision rates with the infrastructure around Bat Cave.

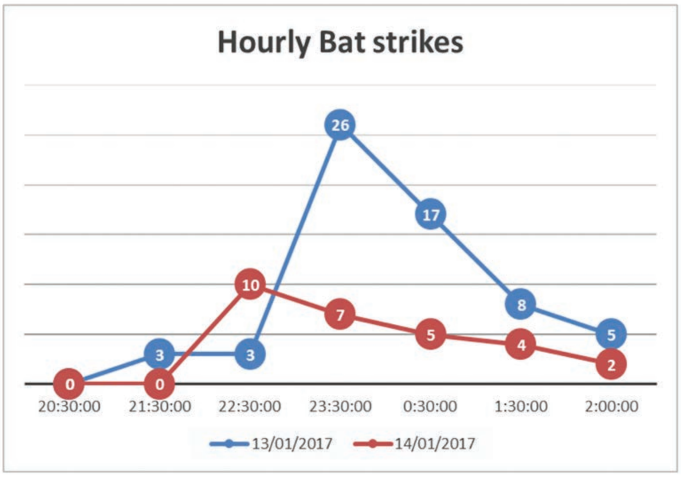
Results

In 2016, the first weekend of trapping (8 and 9 January) was prior to the majority of juveniles commencing flying, and we only caught a few juveniles. By the second weekend of trapping (15 and 16 January), the juveniles had started to fly. During this trip we discovered some significant issues. On the first night, two bats caught in the harp traps were found to have recently broken limbs. Initially it was unclear if the injuries were caused by collisions with the harp trap frames or with the fence immediately in front of the traps. Therefore, on the second night, mist nets were used instead of harp traps, which covered a larger area with fewer vertical poles. However, a further two bats were caught with broken bones, well away from the mist net poles, but immediately behind the fence. This suggested that the injuries were a result of bats hitting the fence or metal panel rather than the harp trap frames, and that the momentum of their flight had just carried them into the traps. In total, four of the 387 (1.03%) juveniles caught that weekend suffered life threatening injuries in the form of broken limbs and required euthanasia. Many other bats were heard to collide with the metal structures during the night, although the fate of those individuals was unknown.

The Naracoorte Caves park staff were provided with an incident report following this trapping weekend. Park staff then installed temporary measures to reduce potential bat collisions, covering both the fence and the metal panel with shade cloth (Figure 2). No collision injuries were recorded during the trapping on the weekend of 19 and 20 February 2016, however by this time the young had been flying for over a month and may have been more adept in avoiding obstacles.

Figure 2. Temporary protection measures installed in 2016 with the infrastructure covered with shade cloth. Photo: Y. Ingeme

Figure 3. The number of times bats were heard to hit metal infrastructure around the cave during two nights of trapping in January 2017, between sunset and 2 am.



The following year on 13 and 14 January 2017, the fence had been covered with shade cloth in an attempt to reduce injuries, but no protection had been placed over the long smooth metal panel. The shade cloth was flush with the fence. No injured bats were caught in the harp traps, however, bats were heard striking the metal 90 times over two nights of monitoring (Figure 3). Most of the bat strikes were loud and sounded like they were hitting the smooth metal panel.

When the juveniles began emerging from Bat Cave on 13 January at approximately 22:30-23:30 hours (as determined by the age of trapped individuals), there was a distinct increase in the number of strikes heard on the metal infrastructure (Figure 3). The number of strikes heard on the second night was considerably lower than the first night. By the second weekend of trapping (3 and 4 of February 2017), no bat strikes were heard. We reasoned that the juveniles had gained more flying experience by this time and had learnt to navigate the fencing and metal panel.

In January 2018, further padding was added. The shade cloth was angled away from the fence to provide more 'give' and the top rung of the fence was padded with lengths of pool noodle foam (Figure 4). The metal panel was padded with inflated air mattresses and covered in shade cloth. No injured bats were found and no bat strikes were heard during four nights of trapping over two weekends, including in early January when the young had just commenced flying.

Discussion

Recently published work by Greif *et al.* (2017) found that bats may collide with objects with smooth surfaces, because the bat's echolocation calls are deflected away from the surface and not back to the bat until they are almost upon the smooth surface. Covering the smooth metallic surface of the metal panel with shade cloth changed the texture and may have improved the ability of the young bats' echolocation to detect it, with the padding reducing injury if any did collide. In addition, the shade cloth was cream in colour, which may have made it more visible to the bats.

When there was no fence covering in place, the number of bat collisions appeared to decline as juvenile Southern Bent-wing Bats became more experienced flyers. However, our observations indicate that there is a potentially significant percentage of the juvenile bats suffering life threatening injury per night during the first few weeks of juvenile bats emerging from the maternity cave. Continuing actions to mitigate these impacts are therefore critical.

So how long have these injuries been happening and what has been the likely impact on the bat population?

Figure 4. Additional padding on the smooth metal panel in the form of (colourful) inflated air mattresses and pool noodles on the top of fence. Photo: Yvonne Ingeme

Figure 5. Left: Photo of a fence around Bat Cave taken in 1977 (Photo: Jim Cundy, source Lewis 1977). Centre: The entrance of Bat Cave from within, showing how close the fence was to the cave entrance prior to 1986 (Photo: supplied by Steve Bourne). Right: A Southern Bent-wing Bat caught in a barbed wire fence that used to surround Sand Cave, Naracoorte (Photo: Steve Bourne).

Historical fencing at Bat Cave at Naracoorte

The fence at Bat Cave has potentially been posing an adverse risk to bats for a very long time. In the 1960s the fence was only 1-2 m from the edge of the cave entrance and was made of barbed wire (Figure 5). Barbed wire fences are known to be an entanglement risk to bats (*van der Ree 1999*).

The fence was upgraded in about 1986 by Brian Clark (previous manager of the reserve), with a standard pool fence design that was located close to the cave entrance (Figure 6). Based on our current observations it is likely that this would have impacted the survival of some juvenile bats each year, however it is unknown how many.

During the summer of 2012, regular flyout counts of the bats at Bat Cave were undertaken using thermal cameras (*Lear* 2012). During that study, it was noticed that when the juveniles began flying, the number of bats hitting the fence increased dramatically. Several juveniles were observed to fall to the ground. One had a broken wing and had to be euthanased. In response, Lear (2012) covered the fence with tarps and observed that number of bats hitting the fence then dramatically decreased.

The fence was moved further away from the entrance later in 2012 for a number of reasons: Firstly, this improved the ability to undertake the flyout counts by extending the fence past the filming position and enabling the installation of the metal panel. Secondly, it improved the tourist interpretation and kept people further away from the entrance, and thirdly, it provided a safer buffer between the edge of the cave and the fence to reduce the risk for staff walking inside the fenced area. The construction of the new fence was staged, i.e. the second fence was built first and then the first fence removed (Figure 7). To reduce impacts on the bats, the fencing was undertaken once they had dispersed to other caves for the winter. When bats returned to Bat Cave later that year in spring they appeared to acclimatise to the new position of the fence over several nights (*Lear* 2012). However

Figure 6. Fence upgrade dating back to 1986 located close to Bat Cave entrance. Photo: Steve Bourne.

Figure 7. Construction of the new fence several metres further away from Bat Cave entrance. Photo: Steve Bourne.

we are unaware of any detailed follow up monitoring to determine if the fence relocation reduced the number of bat strikes.

Observations made by Steve Bourne while manager of the reserve suggest that the adult Southern Bent-wing Bats fly up and out of the cave to clear the fence and then quickly swoop down low, potentially to avoid predation. He therefore questioned if moving the fence further from the cave exit may actually increase collision risk when the bats fly low as they disperse from the cave. Without further data, we do not know how different off-set distances might influence bat behaviour and the number of collisions with fences at cave entrances, however this warrants further investigation.

Recent fencing designs at Naracoorte Caves

Naracoorte Caves management has recently installed new fencing around other caves in the park (Figure 8), some of which have also resulted in fatalities. A juvenile Southern Bent-wing Bat was found dead at the fence junction at Wet/Stick Tomato Cave (Figure 8), nine days after being PIT-tagged. This individual may have had less than three weeks flying experience. A necropsy by Dr Peter Holz found that the bat was in excellent condition, with a stomach full of invertebrates, but had brain trauma, likely due to collision with the fence.

Some of the authors of this paper were approached by cave management in 2017 to provide feedback about proposed fence designs for Bat Cave, including a large glass viewing panel through which tourists could view the bats emerging from Bat Cave. The glass panel was not recommended because it was considered to have a similar effect to the smooth metal panel and hence would have likely resulted in further bat collisions.

Lear (2012) indicates that discussions were being held back in 2012 regarding improvements to the fence around Bat Cave stating that ‘retractable shade covers may be installed along the top fence edge so they can be pulled out during times when the population is at its peak,

Figure 8. Fences at other caves within the Naracoorte Caves National Park. Left: Wet/Stick Tomato Cave. Photos: Emmi van Harten.

which will hopefully reduce the number of collisions on the fence' (p14). Discussions are again underway to install a more bat friendly fence around Bat Cave, however little to no information is available as to what a bat-friendly fence might look like. A *Scopus* and *Science Direct* search did not find any suitable references on the topic.

Designing a bat-friendly fence at Bat Cave needs to consider the behaviour and abilities of the juvenile Southern Bent-wing bats. The fence also needs to serve as a secure barrier to discourage unapproved access to the cave (for human safety and for protection of the roosting bats). The study undertaken by Greif *et al.* (2017) suggests that a fence should have a textured surface that can be easily detected by bat echolocation. From the recent observations of juveniles exiting Bat Cave, their flying skills can be very poor, with some individuals either not detecting the pool fence or not being agile enough to avoid it even if they did detect it. Therefore, a textured, padded, light coloured, sloping fence that was not too high may be best. A vegetated fence consisting of soft foliage may be an option, especially if far enough away from the entrance so that bats would not get tangled in the vegetation. This may look more aesthetically pleasing in a national park setting, although the vegetation would need maintenance to ensure the entrance does not become overgrown. This fencing option would restrict visibility for tourists, although an alternative viewing area has already been built up-hill looking down on the entrance to Bat Cave.

As we have discovered from these opportunistic observations, the impact of fence design and infrastructure can be critical to the survival of individual bats. Therefore, any new designs need to be tested first (e.g. filming using thermal cameras) to determine how the bats, particularly juvenile bats, interact with the infrastructure before final design, placement and installation occurs.

Conclusion

This study revealed that infrastructure at maternity caves can impact bat survival, especially for juvenile bats. These observations have implications for fence designs used to protect cave entrances world-wide. We suggest that greater consideration is given to the understanding of the natural functions of the cave when designing fences and seeking designs that protect these, while providing the necessary safety and prevention of access. In the case of Bat Cave, an analysis of bat behaviour and flight paths when exiting the cave should guide fence placement and materials used. We highlight the need for careful fence design and importantly this study suggests that new and even existing bat cave fences should be monitored for bat collisions, especially for maternity colonies, where inexperienced bats will be flying, because 'hit or miss' could mean life or death for juvenile cave-dwelling bats.

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ABSTRACT: POSTER

Monitoring a bat maternity cave in south-eastern Australia using remote technology

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The Critically Endangered Southern Bent-wing Bat (SBWB) *Miniopterus orianae bassanii* is restricted to south-eastern Australia, where its numbers have declined significantly in recent decades. It is an obligate cave-dwelling bat with two known key maternity caves, one in south-western Victoria and the other in south-eastern South Australia. Little is known about what makes these caves suitable as maternity sites or how microclimate, seasonal conditions and environmental triggers influence the SBWB breeding cycle. This information is critical to effectively manage the bats and their cave environment. In addition to monitoring the bat population using bat detectors, which sample relative activity every night, more detailed data is now being collected using three remote, covert, infrared, time-lapse cameras in one of the birthing chambers, taking a photograph every hour, and two temperature and humidity dataloggers (Hydrochron ibuttons) collecting hourly microclimatic data. The bat detector, infrared camera and dataloggers can remain in place for up to four months between battery changes, enabling long term sampling.

The Victorian maternity cave has several entrances that allow air to circulate. One of the birthing chambers is within a bell hole approximately two metres above the cave floor. The infrared cameras reveal highly synchronised birthing patterns. In 2015, the first pups were born on 2 December, the main birthing commenced in the early hours of 3 December with the majority of pups born by 4 December. Females then transferred their pups to another bell hole within a larger (40-metre high) more open chamber by 8 December 2015.

The temperature and humidity dataloggers revealed how and when the bats modified their microclimatic environment, while the cameras provided detailed corresponding information on the number of bats in this bell hole. Data collected over a four-month period indicate that while adult bats are clustering within the birthing chamber, they increase the temperature around the pups by up to 17.0˚C above ambient cave temperature, to a maximum of 33.1˚C. They also influence humidity by lowering RH from 99.6 within the cave to a minimum of 72.8 around the pups. The remote cameras and dataloggers show great promise as non-invasive techniques enabling detailed, hourly monitoring of bat numbers and their behaviour, as well as the microclimatic conditions within their roosts, with minimal disturbance to the bats.

Presented at the 17th International Congress of Speleology — Speleo 2017

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ABSTRACT: POSTER

Disturbance caused to cave-roosting bats during ecological monitoring: implications for researchers and cavers

AMANDA BUSH[1], LINDY LUMSDEN[1] PhD, YVONNE INGEME[2,3], CHRISTA BECKMANN[4] PhD, and PETER BIRO[4] PhD

Cave roosting bats are highly susceptible to human disturbance with the potential for significant impacts on population numbers and viability. Ecological monitoring is essential to determine status and population trends. However, it is critical that this monitoring does not have unintended negative impacts. Short-term disturbance to roosting bats can be readily apparent; however, long-term impacts from people entering caves is more difficult to assess.

The Critically Endangered Southern Bent-wing Bat *(Miniopterus orianae bassanii)* is an obligate cave roosting bat in south-eastern Australia whose population has significantly declined over recent decades. Regular monitoring is undertaken at two key maternity caves, but little is known of the use of key non-breeding caves. This study aimed to determine the relative numbers and seasonal patterns of bats using non-breeding caves. Daily estimates of relative activity were recorded in six caves over a two-year period, with the efficacy and potential risk of disturbance of this monitoring investigated.

Bat call recorders were set within or at the exit of caves to record relative levels of activity each night. The number of bat call pulses were tallied to obtain an index of nightly activity. Caves were entered once a month to change the batteries on the recorder, with one or two flash photographs quickly taken of the roosting bats to estimate numbers and help interpret the recorder results. Other light, noise and time spent in the cave were kept to a minimum. The bat call data revealed variation in activity reflecting weather and seasonal patterns. In addition, substantial activity spikes were observed following visits where flash photography was used. While some immediate increase in activity due to bats taking flight was expected, what was unexpected was that activity levels remained elevated for several weeks after the visit. As a result, flash photography has now ceased, resulting in reduced activity spikes after battery changes.

In an attempt to obtain accurate population estimates with minimal disturbance, remote, time-lapse, infrared cameras are now being used. These cameras are completely covert, producing no visible light or sound. They are set opposite roosting bat colonies and take a photograph once an hour for three to four months, between battery replacements. This reveals population estimates, activity patterns and roosting behaviour. These findings have implications for bat researchers, cavers and members of the general public entering bat caves, with disturbance potentially having an impact long after people have left the cave.

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ABSTRACT: POSTER

Caves of the Nullarbor — their nature and setting

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The more famous deep caves of the Nullarbor are actually uncommon. The typical Nullarbor cave is short, shallow and present in thousands. Examples for this paper are from South Australia only, near the coast but beyond timbered ground. The plain appears little modified from its inferred state at the finish of Nullarbor Limestone deposition; an idea supported by the survival of fossil shorelines at the inland margin of the plain, notably the Ooldea Range. Their presence constrains what can be allowed for later erosional lowering of the plain. The donga areas, which are closed depressions, are incised some five metres below the net of rises surrounding them. They are usually aligned features some, and possibly all, following structural trends.

Extra general lowering is indicated by breccia clasts in fossil cave fills that are not Nullarbor Limestone and come from strata that no longer exist. At present there is build-up of a windblown dust and calcrete cover studded with float blocks. Enterable caves develop from breaching of a cupola topping an aven made up of ellipsoidal swellings. The smooth form indicates development under phreatic conditions with a water table above the present surface, so the caves are fossil features. Once the breach is made there is space to put the cover materials away and a doline develops through stripping of cover down to limestone pavement. The cave then tends to fill up with sediment; it does not to grow in response to modern water input. If a suitable seal develops a cave converts to a rockhole and holds water.

Where a cave is small but more than just a shaft entry, passages with smoothly rounded phreatic-style forms can be followed a short distance before degenerating into spongework or anastamosing tubes. It is common to have remnants of earlier episodes of cave development such as wall pockets with miniature cave scenes and breccia-filled former caves truncated by the solution-style or break surface of the present cave.

In the case of larger caves more broken rock is present tending to the form of the deep caves; arch sections with an up-and-down central hump of broken rock. But in these caves, there is evidence for solutional attack on the actual fallen blocks and of a crystal crust shed prior to the water table dropping away.