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FRONT COVER: Bottom of the 127m deep Fitch Pitch in Tham Pha Phueng, Thailand

Photo: Keith Batten

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IN THIS ISSUE

EDITORIAL

Steve Bourne

It is with relief, and some sadness that I write this last editorial after 7 years as Publications Officer. This journal is chock full of quality articles that embody what ACKMA is all about. This, plus the sense of achieving something worthwhile and some positive comments, had me thinking if I could possibly continue in the Publications Officer role. Unfortunately, the reality is I have to cease doing some things I currently do and this journal is one of them.

I acknowledge the contribution of Tony Culberg as proof reader, who has an excellent grasp of the English language. I have enjoyed quarterly discussions as he provides corrections over the phone, often with his wife Pat in the room. On more than one occasion, dictionaries have been consulted and debate over a word or grammar has been ensued. The journal has been much more professional for Tony's efforts. Errors have still remained of course, for which I am responsible. I trust that overall the journal has been a good read over the past 7 years.

In the December journal, I made mention that a manager had not been appointed at Naracoorte Caves after applicants were told the position had been withdrawn. Acting Manager Nick McIntyre has been appointed for a further 12 months, with the announcement made at his farewell function! I understand some knew prior to this, but the party was held anyway. Nick has established great relationships with staff and stakeholders and I have seen a few emails and heard some really positive comments about Nick staying on in this role. I understand the manager position is being reviewed and the Department is seeking private interest in parts of the business. This will sound familiar to the staff at Jenolan Caves. The Department is currently seeking expressions of interest for the operation of the Caves Café and adventure caving, an interesting mix if it was one business! Nick and the Executive Officer Chaka Chirozva are attending the ACKMA Margaret River conference and will no doubt update members on the work that has been going on at Naracoorte. A new grant has just been announced too, this time to assist with the management of weeds within the park.

The ACKMA conference at Margaret River is fast approaching and my understanding is registrations are quite healthy at this stage, although commitment to deliver papers is a little low. As I have said in this journal previously, too often we think that the work we are doing at our own site is not interesting enough to share with others, when in fact all work in caves should be shared as advances are most often in small increments, rather than quantum leaps. Write and talk about your work with pride!

Above. Revamped visitor centre at Naracoorte Caves
Below. New fossil display at Naracoorte Caves.
Photos: Steve Bourne

This journal is a great mix of articles including a great review of Camooweal caves and karst by David Gillieson and Keith McDonald. David now lives an enviable lifestyle between Queensland and Kangaroo Island and I hope to catch up with him "on the Rock" in the not too distant future. Terry Bolger and Martin Ellis provide an overview of caves in Thailand and I know I will see Terry in April in Laos!

ACKMA has been active in several consultations and our submissions and responses are printed for members to see the work executive has been doing with member support. This is a key part of ACKMA's work and we should remain active in this field without being political. To complete your reading for this journal is a commentary on signage at Borenore Caves by Kent Henderson and its effectiveness, an update from Tony Culberg on cave access management and news on Tim Moulds' appointment as Adjunct Secretary of the International Union of Speleology. Enjoy the journal and I look forward to seeing members soon.

PRESIDENT'S REPORT

Dale Calnin

I cannot believe as I write this repot there is less than two months to go until the much awaited ACKMA Conference in Margaret River, Western Australia.

I hope that there are many registrations and travel plans being finalised, and that we see a good turn-out of members for what promises to be another exciting and wonderful conference.

For me, this will my third conference in Margaret River Region during my time with ACKMA and I must say I am really looking forward to spending another delightful week in that beautiful part of the world with ACKMA members.

The upcoming AGM will also be a time to elect a new executive team to continue to move ACKMA forward as an active and relevant organisation and I strongly encourage you to consider nominating for a committee position or approaching a fellow member to stand. It is vital that we have new voices and new ideas on the committee. We are blessed with strong leaders but we cannot expect them to continue to carry the load year after year. Many of our members have different backgrounds and areas of expertise so it is important that there be a reflective and meritorious Committee.

I would like to take this opportunity to acknowledge the great work done by the committee and others over the past 12 months addressing some key elements of structural and operational reform, finalised review of membership, the development of PayPal Payment page for the ACKMA website and a review of the Honorary Life Members' Fund. Although at times this work has been quite stressful and frustrating these are significant achievements that will help carry the ACKMA organisation forward.

Other positive accomplishments include:

- The release of ACKMA Guide survey. I would encourage all those involved with cave guiding particularly to complete the survey and support this worthwhile initiative to help ensure guided tours in Australasia are kept to the highest quality in delivery and content.
- The Camooweal Caves National Park Submission drawing attention to the conservation significance and current management issues affecting the Camooweal Caves National Park in northwest Queensland – thank you Andy.
- Neil Collinson and others input into NZSS Te Waikoropupu Springs Golden Bay submission expressing concerns and highlighting the importance of protecting the existing aquifer.
- John Brush's submission to Help Save the Harman Valley Lava Flow, Byaduk, in Western Victoria
- Identifying the need to archive ACKMA's history.

I know these are just to name a few and I have no doubt there is an additional list of other great work being done by ACKMA members in the protection of cave and karst.

Unfortunately, over the past month or so we have all been truly tested again with some extremely sad and difficult times. The sad passing of ACKMA member Peter Wood and renowned ASF identity John Dunkley has left us with heavy hearts. Our sincere condolences and thoughts are with their families.

Finally, as flagged in my recent correspondence, I do expect this coming AGM to be my last as president. I feel that the time is now right for me to pass on the presidency baton and to provide the opportunity to another member. I can honestly say it has been a privilege to serve in this capacity and to work with people I truly admire for the great work they do in cave and karst management.

I am really looking forward to seeing you all at Margaret River in May. Until then, keep up the excellent work you all do in Cave and Karst Management.

Below is the ACKMA submission regarding the Camooweal Caves National Park and the Minister's response

Australasian Cave and Karst Management Association

Hon Leeanne Enoch
Minister for Environment and the Great Barrier Reef
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ACKMA
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Dear Minister Enoch

Re: Camooweal Caves National Park

The Australasian Cave and Karst Management Association (ACKMA) would like to draw your attention to the conservation significance and current management issues affecting the Camooweal Caves National Park in northwest Queensland.

ACKMA is an association of cave managers, rangers, scientists, cavers and other people interested in caring for Australasia's cave and karst. Although founded in Australia and New Zealand we have members world-wide – all devoted to caves and karst.

The Camooweal Caves National Park is the first protected area seen by visitors driving into Queensland along the Barkly Highway from the Northern Territory. They are directed to the Park by signage in the town.

It lies 15 km south of the town of Camooweal and facilities include a picnic table, signage and two short walking tracks. The park has a current grazing lease (expiring 2020) and stock have broken down fences as well as creating patch erosion and numerous tracks. During the wet season, soil and dung washes into the caves. Rubbish is also present around the parking area. There is little evidence of Ranger presence or interest in the park. This surely does not create a good impression of the management of the protected area. The groundwater is also used as the town water supply, so the introduction of pollutants (sediments, animal wastes, hydrocarbons) into this may have health implications for both residents and visitors alike.

The National Park was acquired as a representation of Regional Ecosystems (especially the Mitchell grass downs) and geomorphological formations (sink holes and caves formed in dolomite bedrock) not found on any other Queensland National Park. The National Park is currently administered from Boodjamulla National Park, some four hours to the north. Consequently, Ranger presence at Camooweal is therefore episodic at best.

Unfortunately a grazing lease was issued over the Park in 1988 for 30 years. The abuse of the park by this grazing enterprise, especially in the grasslands on clay soils, is nothing short of breathtaking with impacts far greater **on the park** than on the adjacent properties. The QPWS appears to have established a number of grazing exclosures in the Park but there is no evidence of monitoring taking place.

The following shocking photo shows cattle impacts along the southern boundary of the National Park. The National Park is on the right-hand side of the fence. (*Editor's note: please refer to the article by David Gillieson and Keith McDonald for this image)*

The attachment below, prepared by ACKMA members, provides further information on the Park.

Our Association would like:

- To have your support that cattle be removed in the near future?
- That amelioration programs be undertaken if cattle are removed, such as control of the limited areas of buffel grass and *Vachellia farnesiana*, together with erosion control especially around waterholes and along creeks?
- That the development of a cave and karst specific management plan be implemented to protect the caves and their significant aquatic fauna from impacts resulting from overgrazing? ACKMA members would be happy to provide support here.
- An appropriate fire management program be implemented?

We thank you for your help in conserving the significant Camooweal karst.

Yours sincerely

Australian Vice-President, ACKMA
International Affairs Officer, ACKMA
31 January 2017

Attachment

The Camooweal caves are extensive and are one of the few Australian karst areas developed in Precambrian dolomitic limestone. This is a relatively insoluble rock and caves are uncommon in this lithology on a global scale, other examples being found in Canada, South Africa and the Czech Republic. At Camooweal approximately 60 karst features (sinkholes, caves and springs) have been identified and speleologists have mapped 12 km of cave passages. Most of these caves descend in a series of steps to the groundwater table at 75m below the surface. In the last decade cave divers have explored and mapped 500 m of flooded tunnels in Great Nowranie Cave. These flooded levels are 22-30m below the watertable and it is likely that more will be found. Great Nowranie Cave and Little Nowranie Cave lie within the Camooweal Caves National Park and are not open to visitors without special permission. Many of the other caves, including Kalkadoon Cave (5400 m surveyed length) lie within remote, private pastoral properties and thus access is limited.

Eight of the caves at Camooweal contain populations of the Ghost bat *Macroderma gigas*, a species listed as Endangered in Queensland and Vulnerable at a Federal level. *Macroderma* is a large carnivorous bat that preys on smaller bats, birds, frogs and insects. In recent times population declines have been attributed to competition for prey with foxes and feral cats, and some prey species lost through habitat modification. Recent scientific surveys (White et al., 2016) of caves in both northwest Queensland and the adjoining Northern Territory (including Riversleigh, Boodjamulla NP and Pungalina) have shown that once more widespread populations of *Macroderma* have crashed, and that this may be due to these carnivorous bats consuming Cane Toads. The Camooweal population is now likely to be the largest extant. In addition, the Orange leaf-nosed bat *Rhinonicteris aurantius* is often found in association with *Macroderma*. This species is listed as Vulnerable in Queensland. Both species seem to prefer caves with high temperature and humidity. The known threats to Orange leaf-nosed bats are the destruction and disturbance of roosts from human visitation to caves, mining activities, and the collapse or flooding of ageing mine roosts.

Extensive freshwater pools and flooded tunnels in the Camooweal caves are listed by the Bureau of Meteorology as having known and high potential subterranean groundwater dependent ecosystems. Reconnaissance surveys by Dr Stefan Eberhard (2003), an aquatic biologist with cave diving skills, have shown that the waterfilled passages of some of the Camooweal caves contain a new, undescribed species of amphipod. This small crustacean of the genus *Chillagoe* is known only from karst drainage systems and its nearest relative (and the type species *Chillagoe thea*) is at Chillagoe, some 1400 km away. Freshwater amphipods are more common in cooler subterranean waters and the markedly disjunct distributions in northern Australia may reflect the fragmentation of past, more continuous populations isolated by the Cretaceous sea that flooded much of the Gulf country (Bradbury & Williams, 1997). There are also colonies of filamentous iron-metabolising bacteria in the cave waters. These groundwater dependent ecosystems are at present largely unknown and experience elsewhere in Australia has shown their extreme vulnerability to pollution and increased stream sedimentation.

In areas remote from waterpoints the black soil plains are uncompacted and act as sponges for wet season rainfall. Runoff into cave entrances is generated from exposed dolomite pavements surrounding them, plus shallow surface channels with a lag gravel of chert. Under grazing pressure there is soil compaction and incised cattle tracks channel water and sediment into cave entrances. Wet season rainfall can cause surface runoff and the caves flood rapidly. Increased flow down these channels also entrains fine gravel which enters the caves as an abrasive sediment load, along with organic flood debris. This can only have a detrimental effect on the cave biology. The karst groundwater is also used as the town water supply, so the introduction of pollutants (sediments, animal wastes, hydrocarbons) into this may have health implications for both residents and visitors.

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27 FEB 2018

Mr Andy Spate
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UTAS SANDY BAY TAS 7005

Dear Mr Spate

Thank you for your letter of 1 January 2018 to the Honourable Leeanne Enoch MP, Minister for Environment and the Great Barrier Reef, Minister for Science and Minister for the Arts regarding management of Camooweal Caves National Park (the national park). The Minister has asked me to respond on her behalf. I apologise for the delay in responding.

The national park was gazetted in 1988 to protect some of the unusual dolomite formations of the Barkly Tablelands bioregion including the Great Nowranie Cave and Little Nowranie Cave. As part of the gazettal negotiations at the time a grazing lease was put in place for 30 years.

As you have pointed out, the current grazing lease over the national park expires on 21 October 2020. Queensland Parks and Wildlife Service (QPWS) will commence negotiations this year with the lessee regarding the finalisation of their grazing interests in 2020 and a stock management plan is being developed to ensure the removal of all stock by this date.

QPWS has constructed a fence around Nowranie waterhole to control impacts to that area. QPWS will this year determine existing fencing conditions and requirements for the construction and maintenance of boundary fences that will be required to ensure cattle are excluded from the national park beyond 2020. These proposed actions will safeguard the values of the national park from the impacts of grazing.

Pest management activities on the national park have largely been undertaken by the Lake Eyre Basin Indigenous Land and Sea Rangers, and have focussed on the sensitive riparian areas of Nowranie Waterhole and Nowranie Creek consistent with the national park's management statement. The National Park management priorities will require reassessment following the removal of cattle from the park and your offer to assist with providing advice in regard to specifics around cave and karst management is truly appreciated.

In regard to fire management, we are working closely with the Indjalandji-Dhidhanu Traditional Owners, the Dugalungi Aboriginal Corporation and neighbours to implement the 2018 planned burn program. Much of the national park was impacted by severe successive wildfires in 2009 and 2011, and planned burning has been reduced in the intervening years to aid the park's recovery.

The national park has a current management statement, which was prepared in November 2013. The management statement recognises the importance of the caves and waterholes as a key conservation purpose for the park and prioritises them for management, and provides a number of management directions, actions and guidelines in relation to the cave system and groundwater (including the catchment) that directly relate to their protection under the desired outcomes for the landscape, natural values and pest management. As the national park has a current statement, QPWS are not intending to review the statement in the immediate future.

If you require any further information, please contact Ms Sarah Jess, Senior Ranger, Central Region, QPWS of the Department of Environment and Science on telephone (07) 4787 3388 or by email at sarah.jess@des.qld.gov.au.

Yours sincerely

Daniel Lato
Chief of Staff
Office of the Minister for Environment and the Great Barrier Reef, Minister for Science and Minister for the Arts

Harmans Lava Flow. A close view of the crushed area with a cave entrance (which was not damaged) and some of the rock heaps. Refer to John Brush's article for the Harmans Lava Flow story and ACKMA's involvement. Photo: John Brush

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Cliefden Caves Region

Proposal for listing on the NSW State Heritage Register

The Australasian Cave and Karst Management Association Inc (ACKMA) strongly urges the NSW Heritage Council to list the Cliefden Caves and associated features on the State Heritage Register.

ACKMA is an association bringing together karst and cave managers, cave guides, scientists, tour operators and cavers to better manage and interpret our karst resources in Australia and New Zealand in a professional manner. ACKMA members have provided professional expertise across the two countries and elsewhere across the Southern Hemisphere from South Africa to Tonga in the Pacific and in many Asian countries.

Cliefden Caves are the most significant karst areas in NSW outside the National Parks estate and the Wellington Caves. Indeed, Cliefden ranks highly when compared with the significant areas within the NPWS estate and Wellington[1,2].

Why do we say this? There are very many caves and other karst features, some with aspects not seen or are very uncommon elsewhere such as the rare polyhedral stalactites and blue calcite speleothems[3]. In contrast to many other areas in the Eastern Highlands of Australia, the caves do not appear to be stream-cut but rather by upwelling hydrothermal waters later modified by streams[4,5].

Natural warm springs are uncommon in NSW (as opposed to artificial artesian and sub-artesian waters). There seem to be only three – all associated with karst areas[2]. Other than the warm spring at Cliefden (which may be related to the upwelling waters mentioned above) the others are at Yarrangobilly and Wee Jasper. Little study has been done on any of these springs.

The tufa terraces along Davys Creek are the best developed in NSW and offer opportunities for climate change research[6,7] – as do the caves and their contents.

The cave biota is diverse and includes taxa not found elsewhere. The list, based on the literature and two short visits, reveals 38 taxa including at least six troglophiles, three troglobites and one stygobite[8]. Further investigations are very likely to reveal a far greater biospeleological diversity. The caves are home two, perhaps three, at least bat species[2]. If an Eastern Horseshoe Bat (*Rhinolophus megaphyllus*) maternity site exists here it will be at the far western end of the range for this species in NSW[2]. The three species are not necessarily threatened but are increasingly under threat through habitat change amongst other factors. There are perhaps 6-8 'forest' bat species that forage along the Belubula River at Cliefden.

Although there does not appear to be any Indigenous use of the caves, skeletal remnants were found in at least one cave[9,10,11]. These remnants, dated to 6250+/-430 years BP, provided useful information on the living environment of the individual. There are trees carved by Indigenous peoples at Cliefden.

From a European historical viewpoint Cliefden is the site of the first limestone discovered in NSW (1815); the site where Ordovician rocks were first identified; and a long history of effective conservative cave management to the present day by the Rothery family and descendants who first occupied the site in 1832.

Although outside the remit of ACKMA, mention must be made of the outstanding Late Ordovician fossil site at Cliefden (see, for example, Brocx[13] for a summary). The significance of the site led to its listing on the former Register of the National Estate. Many papers attest to the palaeontological values of the limestone at Cliefden.

As well as the National Estate listing for geological values the site has areas of the White Box-Yellow Box-Blakely's Red Gum Grassy Woodland – a critically endangered ecological community.

In summary, ACKMA believes that The Cliefden Caves region has a wide range of natural and cultural values that fully deserve listing on the New South Wales State Heritage Register.

Yours sincerely

Dale Calnin, President ACKMA

9 March 2017

[1]NSW NPWS, 2010, *Guide to New South Wales Karst and Caves,* NPWS Karst and Geodiversity Unit, Sydney

[2]Andy Spate, *pers. comm*. (Formerly 22 years as Senior Project Officer, Karst; NSW National Parks and Wildlife Service)

[3]Associate Professor Armstrong Osborne, University of Sydney, *pers. comm*.

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A TALE of WOE for the HARMANS VALLEY LAVA FLOW

John Brush
Canberra Speleological Society Inc

In early March, Marjorie Coggan and I attended a public hearing at Hamilton in Western Victoria into a land use planning issue concerning the nearby Harmans Valley lava flow. At the hearing I spoke on behalf of ACKMA and also the IUS Commission on Volcanic Caves of which I am Chairman.

The Harmans Valley lava flow, which came from the Mt Napier volcano, contains the Byaduk lava caves. The Mt Napier volcano and many lava caves are within the boundaries of the Mt Napier State Park and as such are protected. However, most of the flow is on private property where, until recently, it had not been afforded much protection at all.

Several caves are known to exist on private property but little is known about them.

As the lava flow is very young (around 40,000 years old), many surface features of the flow are still visible. It is regarded by experts as the best preserved flow in Australia and is very important for education and research purposes. It also has aboriginal and early-European cultural heritage significance as well as dramatic landscape values. When viewed from some vantage points, the flow can be seen at the bottom of a pre-existing valley with the volcanic source (Mt Napier) in the background (see photo). A public viewing point has been constructed beside the Hamilton-Port Fairy Road at one of these vantage points.

In recent years, some sections of the flow have been bulldozed, crushed and levelled to improve its farming potential. Unfortunately, this has obliterated some surface features and, as the most significant damage has been in areas that are visible from the public viewing point, the landscape significance has been diminished.

Prior to 2004, areas visible from the viewing point had been subject to small-scale quarrying and rock removal operations over a long period of time but these had not had a major impact on either important geological features of the flow or on the overall landscape vista. However the 2004 rock crushing operations flattened an estimated 15 hectares and 'surplus' rock was pushed into large heaps. At the time, a number of geologists, including the late Ken Grimes, agitated for action to prevent further damage and the local Council

Harmans Valley as it was in 1975
Photo: John Brush

2018 - also note the plantations in the background obscuring the base of Mount Napier
Photo: John Brush

apparently agreed to place an Environmentally Significant Overlay (ESO) over the flow area. A couple of months later, the Victorian Government produced maps of the proposed ESO area based on information that was provided by Ken. Unfortunately, the ESO was never implemented.

After a change of landowners, further rock crushing operations commenced in November 2015. The works were soon halted after a stop-work order was issued and the owner was asked to complete a Cultural Heritage Management Plan. The landowner recommenced work in mid-2016 to the east of (ie up-flow from) the 2004 work but from photos taken at the time, it is apparent that they also re-worked the areas crushed in 2004. In July 2016, another stop-work order was issued under the Aboriginal Heritage Act 2006. Then, in October 2016 following representations to the Minister for Planning, an interim Significant Landscape Overlay (SLO) was imposed over that area of the flow that was on private land within the Southern Grampians Shire. This basically meant that a permit was required to undertake any 'works'.

The Interim SLO will expire on 31 October 2018 and the purpose of the public hearing was to consider whether the SLO should be made permanent. As a first step in the process, last September a draft permanent SLO was released for public comment and submissions were invited by 20 October 2017. A total of 74 submissions was received, including one by ACKMA and two by individual members of ACKMA. Most of the submissions supported the SLO being made permanent.

At the Hamilton hearing, there were 18 presentations over two days, including several by landowners, the local Traditional Owners Corporation, academic institutions, naturalist groups and, as already noted, by ACKMA and the Commission on Volcanic Caves. A wide range of views was expressed in the hearing and during a field inspection. The hearing and outside discussions took place in a constructive and productive manner and a range of amendments proposed to the draft SLO addressed some of the concerns of landowners (most of whom were not keen on the SLO being made permanent) as well as those of the organisations seeking permanent protection of the flow.

The Planning Panel Chairman now has six weeks to finalise his report which will then go to Council for consideration, public comment and decision. If considered necessary, the Minister can intervene and override a decision of Council. Unless of course if a state election is called before the Council position is finalised. Even if a permanent SLO is implemented, Council will need to have the resources and inclination to ensure compliance.

At a later date I hope to be able to report on a good outcome on this issue and will provide an update at the ACKMA Conference in May.

NATURAL HERITAGE VALUES and MANAGEMENT of the CAMOOWEAL KARST and CAVES

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Abstract

The Camooweal caves and karst lie close to the Northern Territory border in northwest Queensland. The karst provides a good example of semi-arid dolomite karst, a style under-represented globally in protected areas. Although a great deal is known about the geology and geomorphology of the Camooweal karst, little is known about its biology, especially underground. Over fifty caves have been explored and mapped since the 1970s, with the longest being in excess of 5000 m. The caves descend in a series of steps to the regional water table about 75 m below the surface. The caves have populations of endangered or vulnerable bat species, specifically the Ghost Bat *Macroderma gigas* and the Orange Leaf-nosed Bat *Rhinonicteris aurantius.* A new species of amphipod of the genus *Chillagoe* has been collected from the Nowranie caves. An extensive karst groundwater body is fed by seasonal runoff and is subject to pollution from cattle grazing within the Camooweal Caves National Park. Weed invasion and fire management are ongoing issues for protected area management.

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Introduction

West of Mount Isa, close on the Northern Territory border, a gently undulating plateau of Cambrian dolomitic limestone is punctuated by steep side dolines. This is the Barkly karst (Matthews 1985) centred on the small town of Camooweal (Fig. 1). Surface outcrop is sparse and relief is low, less than 2 m. Extensive cracking clay plains surround the cave entrances and funnel runoff into the caves during the monsoonal wet season. The climate is semi-arid with long hot summers and short cool winters. Rainfall is strongly monsoon influenced and ranges from 400 to 600 mm annually. The dominant vegetation is Mitchell Grass *(Astrebla* spp.) plains with stands of Gidgee (*Acacia cambagei*) and Coolibah (*Eucalyptus coolabah*) along the ephemeral watercourses. There is also an extensive *Eucalyptus pruinosa, E. leucophloia, E. leucophylla* low open woodland on eroded Tertiary lateritic surfaces and calcareous red earths. The dominant land use in the area is extensive grazing for beef production, with low stock densities of 1 beast for 100 ha. Population density is correspondingly low, with one person to 200 km^2. This paper examines the natural heritage values and management of the Camooweal karst, as one of the disregarded arid and semiarid karsts of Australia.

Geomorphology and geoheritage values

The regional geology has been summarised by de Keyser (1974). The karst features are developed in Cambrian rocks, chiefly dolomites and limestones, of the Georgina Basin. The carbonates are generally flat lying, well bedded and jointed and are only gently folded 75 km to the north-east of Camooweal in the Undilla area. The carbonates are overlain by thin deposits of flat lying late Paleogene limestone and some thin Cretaceous marine sediments on the northern margins. Throughout the region black cracking clay soils (Vertosols) up to 2 m thick have developed on the carbonates and have developed gilgai microrelief. To the east of Camooweal thin, isolated Mesozoic sediments and ferruginous plains overly the carbonates forming a slightly elevated plateau (Grimes 1985). The partial stripping of this surface has exposed underlying clay soils formed from the carbonates. The ferruginous surface has lag gravels of chert which have been transported onto the karst and become entrained into the caves. There is little or no chert in the carbonates themselves.

Edgoose (2003) asserts that the black cracking clay soils have formed by the *in situ* alteration of kaolinitic clay minerals to smectites, a process defined by Veen (1973) on theoretical grounds of clay mineral equilibria. However, Viscarra-Rossel (2011) has shown that the mixed layer clays could form under the present climate with soil forming conditions favouring the retention of weathering products on an alkaline, poorly drained environment.

The surface drainage channels are reasonably well integrated and springs are present along the northern edge of the dolomite and to the west along the Georgina River, fed by regional groundwater flows in both directions. There are a very few blind valleys leading into sinkholes, the longest of which is about 3 km long. The heavy cracking clay soil limits infiltration into the underlying carbonates, except close to the sinkholes where surface stripping has exposed the bedrock (Fig. 2). There are more than 80 dolines and small depressions across the dolomite surface, and about half of these contain enterable caves (Grimes 1988).

At Camooweal approximately 40 caves have been identified and speleologists have mapped 12 km of passages. Details of the named and more significant caves are given in Table 1. Great Nowranie and Little Nowranie caves are in the Camooweal Caves National Park. Many of the other caves, including Kalkadoon

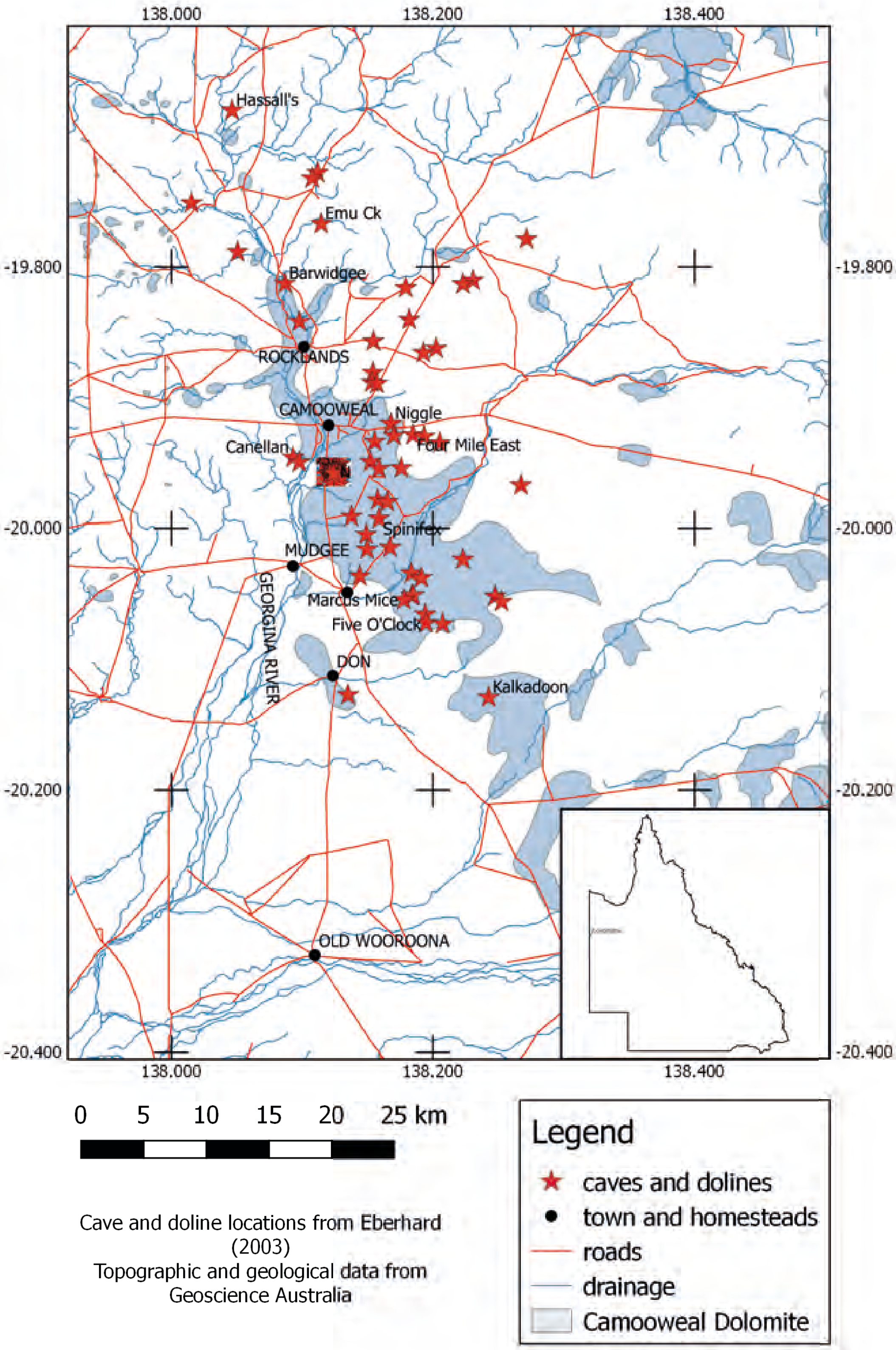

Figure 1. Location of caves and dolines at Camooweal

Figure 2: Entrance doline of 4C-1 Barwidgee Cave, Camooweal.
Photo David Gillieson.

Cave (Fig. 3; 5,400 m surveyed length) lie within remote, private pastoral properties and thus access is limited. Access to the caves is by permit and is restricted to experienced cavers who are members of the Australian Speleological Federation. Most caves are reasonably well explored and mapped, with few prospects for extensions. A number of caves were recorded by Daneš (1911) and some of these have not been found again. His observations on the geomorphology of the Chillagoe and Camooweal caves remain relevant (Jennings 1980) and well in advance of their time.

Most of the caves descend in a series of steps to the groundwater table at 75 m below the surface. Thus there is alternation between vertical shafts and horizontal passages, with the more soluble beds being dissolved to form low “flattener” passages. Collapse chambers have formed at major joint intersections. Maze passages and spongework suggest past solution by slowly moving groundwater, possibly by hypogene processes at depth in the bedrock when the land surface was higher and covered in a Tertiary lateritic profile. Calcite speleothems are rare and there appears to be a great deal of passage abrasion by floodwaters. It is difficult to discern whether horizontal passages are related to bedding or past groundwater levels as the bedding is near horizontal, but cave levels may relate to regional incision over a long timescale. In the last decade cave divers have explored and mapped 500 m of flooded tunnels in Great Nowranie Cave. These flooded levels are 22-30 m below the watertable (Fig. 4) and more have recently been found in Niggle Cave.

Table 1. Camooweal cave descriptions.
Based on Shannon (1970) and Australian Speleological Federation database (numbered karst features without descriptions are not included).

ASF code	Name	Length (m)	Depth (m)	Description
4C-1	Barwidgee	50	21	Inclined rockfall entrance leads to shaft and large chamber with daylight hole
4C-2	Theatre in the Round	100	17	Inclined entrance rockfall leads to large semi-daylight chamber with some short extensions
4C-3	Hassall's	75	108	Narrow vertical fissure leads to water-filled fissure, depth at least 20m
4C-4	Danes Four Cave	46	5	Rockfall entrance leads to spacious cave with short extensions
4C-5	Burketown Road	15	15	Single large daylight chamber, walk-in entrance
4C-6	Great Nowranie	290	62	Large canyon entrance leads to large tunnel with network maze extensions. Vertical shaft leads to meandering passage with terminal water-filled fissure, dived for 500m
4C-7	Karte Jopp's	-	-	Located 30km south of Camooweal, visited by Danes (1911)
4C-8	Cave on Bustard Ck	-	-	Visited by Danes (1911)
4C-9	Cave on Happy Ck	-	-	Visited by Danes (1911)
4C-10	Canellan Cave	262	73	Four entrances lead to dry network passages, vertical sections lead to low-level crawls and water-filled passage
4C-11	Little Nowranie Cave	120	73	Entrance shaft leads to horizontal and vertical sections and deep terminal passage at watertable
4C-12	Tar Drum Cave	55	-	Single chamber with short side passages
4C-13	Camooweal Four Mile East Cave	1070	73	Pothole entrance leads to high-level horizontal complex network. Canyon descent leads to water-filled hole and bifurcating crawls. Further shaft leads to large tunnel and water-filled shaft
4C-14	Whirlpool Cave	-	-	Pothole entrance
4C-15	Niggle Cave	2250	76	Tight entrance leads to vertical shaft and large horizontal passage with severeal drops, then several long low horizontal passage networks
4C-16	Python Cave near Rocklands Station	-	-	Shaft entrance leads to long steep rockfall

Table 1 continued from previous page

ASF code	Name	Length (m)	Depth (m)	Description
4C-17	Haunted	-	-	Extensive with bat guano, short distance off Urandangie Road
4C-18	Probably Kalkadoon			35km down Urandangie Road
4C-19	Cave 23 miles South			37km down Urandangie Road and 14km off road, between Owen's Bore and Old Wooroona
4C-20	Kalkadoon Cave	5400	75	Pothole (2 entrances) leads to a large high-level passage with branching leads to many complex low-level sections; some pools of water and large temperature and humidity variations; some short vertical pitches
4C-23	Spike Cave	6	-	Short crawl passage
4C-27	Koolairabah Cave	463	25	Tight rock-filled entrance leads to long low horizontal passage, mainly crawls with several tight sections
4C-32	Unknown name	10	10	Small joint-controlled shaft, no extensions
4C-33	Spinifex Cave	1000	70	Large cave with joint-controlled fissures, meandering passages and a large chamber, some vertical pitches
4C-34	Hornet Hole	-	3	Pothole entrance, short tight hole
4C-35	The Windtrap	17	8	Short vertical fissure leads to tight flat chamber and some small chambers
4C-36	Five O'Clock Cave	800	54	Inclined high-level section leads to vertical shaft and extensive horizontal passage network. Final flat chamber leads to long meandering low-level passage. Wide range of humidity, some vertical pitches
4C-37	Goanna Cave	12	14	Small chamber leads to tight shaft
4C-38	Marcus Mice Cave	60	82	Small entrance hole leads to large vertical water-filled fissure
4C-39	Unknown name	10	12	Narrow fissure entrance leads to small chamber
4C-40	Unknown name	15	6	Several small rockfall chambers
4C-1008	Barwidgee Sinkhole		10	Streamsink. Systematically explored, no obvious leads
4C-1039	Spiral Sink		8	Streamsink. Systematically explored, no obvious leads
4C-1056	Scrubby Creek Sink		1	Streamsink. Systematically explored, no obvious leads

Figure 3. Breakdown passage in 4C-3 Kalkadoon Cave, Camooweal. Photo: David Gillieson.

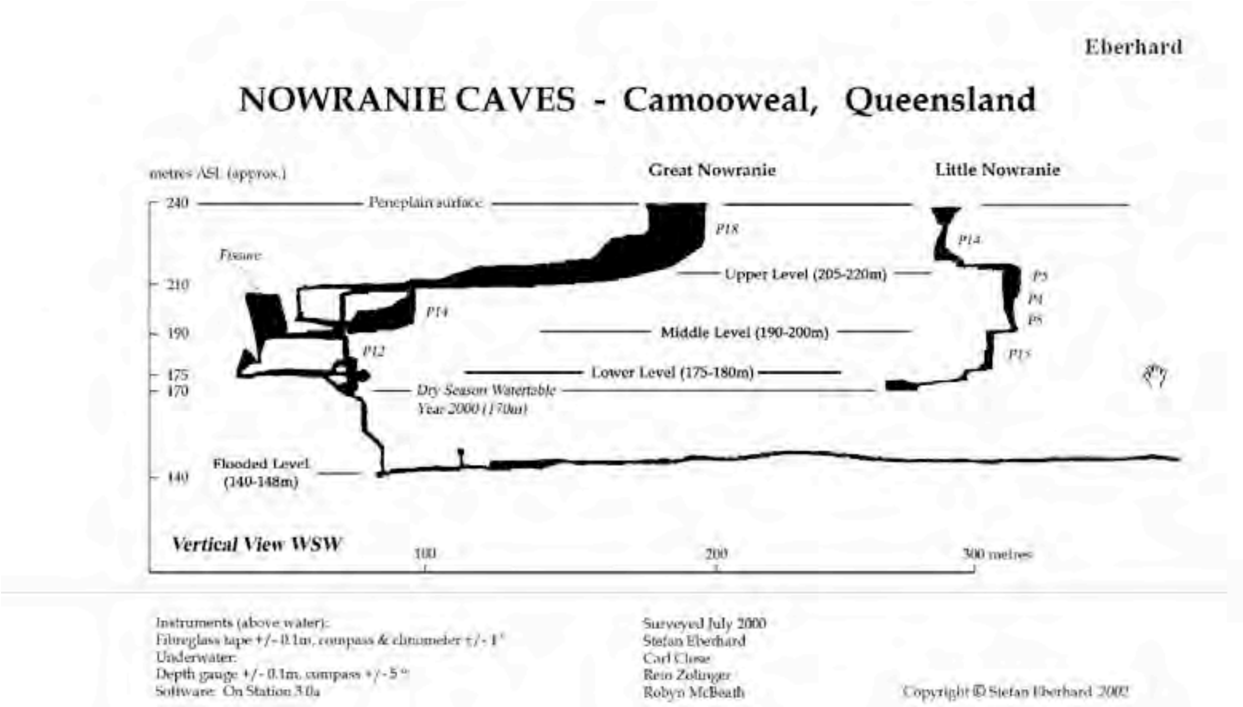

Figure 4: Cross-section of the 4C-4, 4C-11 Nowranie Caves, Camooweal (from Eberhard 2003).

Biological heritage values

The Camooweal Caves National Park (138 km^2) was declared in January 1988 to capture representation of cave systems and the poorly conserved Mitchell Grass downs.

The Camooweal Dolomite straddles two bioregions – the Mitchell Grass Downs (the Barkly Tableland sub-region) and the Northwest Highlands (Southwestern Plateaus and Floodouts sub-region). The small area of Mitchell Grass downs in the Camooweal Caves National Park is the only representation in a protected area in the northern sub-regions of the Mitchell Grass Downs bioregion.

The most widespread vegetation type on the Camooweal Dolomite is a Mitchell Grass community (*Astrebla pectinata* tussock grassland, commonly with *Eulalia aurea*, *Astrebla* spp., *Aristida latifolia*, *Iseilema* spp., annual grasses and forbs) which occupies over 20,000ha (Fig. 5, Table 2). Commonly this has brown and grey cracking clay soils with gilgai, with surface lag gravels of chert found close to cave entrances. About 19,000 ha is covered by *Astrebla pectinata* tussock grassland, commonly with *Aristida latifolia, Astrebla lappacea* and *Eulalia aurea*. Emergent *Atalaya hemiglauca*, *Ventilago viminalis* and *Vachellia sutherlandii* may also occur. This occurs on undulating plains of Cambrian limestone and dolomite. Soils are brown cracking clays with emergent limestone rocks. A low open woodland of *Corymbia terminalis*, with a scattered shrub layer of *Carissa lanceolata* and a tussock grass ground layer extends over 18,000 ha. *Eucalyptus pruinosa* is often present in the northern part of the area. This occurs along drainage lines and in areas of residual clay soils.

A further 15,000 ha is covered by *Eucalyptus pruinosa* low open woodland, often with *Eucalyptus leucophloia and E. leucophylla*. A shrub layer of *Acacia citriodora, A. lysiophloia* and *A. chisholmii* may be present. The ground layer is spinifex (*Triodia pungens*) and tussock grasses. This occurs on partially eroded remnant Tertiary surfaces with calcareous red-brown earths. Along the creeks and rivers, a Gidgee (*Acacia georginae* and/or *Acacia cambagei*) low open woodland occurs, occasionally with *Eucalyptus coolabah* and *E. camaldulensis*. This vegetation type occupies about 2500 ha and is not common in the area, nor is much of it in a protected area. The ground layer is heavily grazed patchy tussock grasses. The immediate area of the dolomite sinkholes and cave entrances (Fig. 6) has a low open forest of *Celtis strychnoides* and a second tree layer of *Ficus* spp., but this is very restricted in extent. It probably has high biodiversity value and may be subject to weed invasion and some trampling on the margins.

The following bird species are listed in Wildnet (2017) as being of Special Least Concern under the Queensland Nature Conservation Act 1992: Black-tailed Godwit (*Limosa limosa*), Wood Sandpiper (*Tringa glareola*), Glossy Ibis (*Plegadis falcinellus*). These appear to be migratory species which may be present in wetlands on a temporary basis and which are subject to migratory bird agreements.

The snail fauna has no endemic species around Camooweal although there are three restricted species on the Riversleigh limestone to the north (J. Stanisic pers. comm.). All snail species recorded to date from the Camooweal area have a widespread distribution. Collections have primarily come from around cave entrances and dolines and not from areas of limestone with towers, as is the case for Riversleigh where the habitat is not subject to flooding.

There are no plant species currently listed as near threatened or threatened in the Camooweal Dolomite area. Five significant weed species (*Vachellia farnesiana, V. nilotica, Parkinsonia aculeata, Cryptostegia grandiflora* and *Cenchrus ciliaris*) have been recorded. Additionally, there are a number of weeds associated with disturbed areas and heavy grazing pressure such as *Sida spinosa, Malvastrum americanum, Urochloa subquadri-paria, Echinochloa colona, Flaveria trinervia* and *Portulaca* spp.

Fires are infrequent in the landscape and rarely in Mitchell Grass downs. Since 2000 three fires only have been recorded in Camooweal Caves National Park woodlands, all during the later part of the year in November / December. Woodlands with *Triodia* have been significantly disturbed with recovery expected to take considerable time.

Eight of the caves at Camooweal contain populations of the Ghost Bat *Macroderma gigas*, a species listed as Endangered in Queensland and Vulnerable at a Federal level. *Macroderma* is a large carnivorous bat that preys on smaller bats, birds, frogs and insects. In recent times population declines have been attributed to human disturbance, competition for prey with foxes, feral cats, and prey lost through habitat modification by fire and livestock. There has also been a long-term reduction of the range of the species, contracting north, evidenced from fossil records in caves and mines (Molnar *et al.* 1984). Recent scientific surveys (White *et al.* 2016) of caves in both northwest Queensland and the adjoining Northern Territory (including Riversleigh, Boodjamulla NP and Pungalina) have shown that once more widespread populations of *Macroderma* have crashed, and that this may possibly be due to these carnivorous bats consuming Cane Toads (*Rhinella marina*). However this is unlikely as Cane Toads have been recorded in other locations with *M. gigas* where populations have not declined e.g. Kings Plains near Cooktown. In addition, the Orange Leaf-nosed Bat *Rhinonicteris aurantius* is often found in association with *Macroderma*. This species is listed as Vulnerable in Queensland. Both species seem to prefer caves with high temperature and humidity. The known threats to Orange Leaf-nosed Bats are the destruction and disturbance of roosts from human visitation to caves, mining activities, and the collapse or flooding of ageing mine roosts.

Extensive freshwater pools and seasonally flooded tunnels (Fig. 7) in the Camooweal caves are listed by the Bureau of Meteorology as having known and high potential as subterranean groundwater dependent ecosystems. Reconnaissance surveys by Eberhard (2003), an aquatic biologist with cave diving skills, have shown that the waterfilled passages of some of the

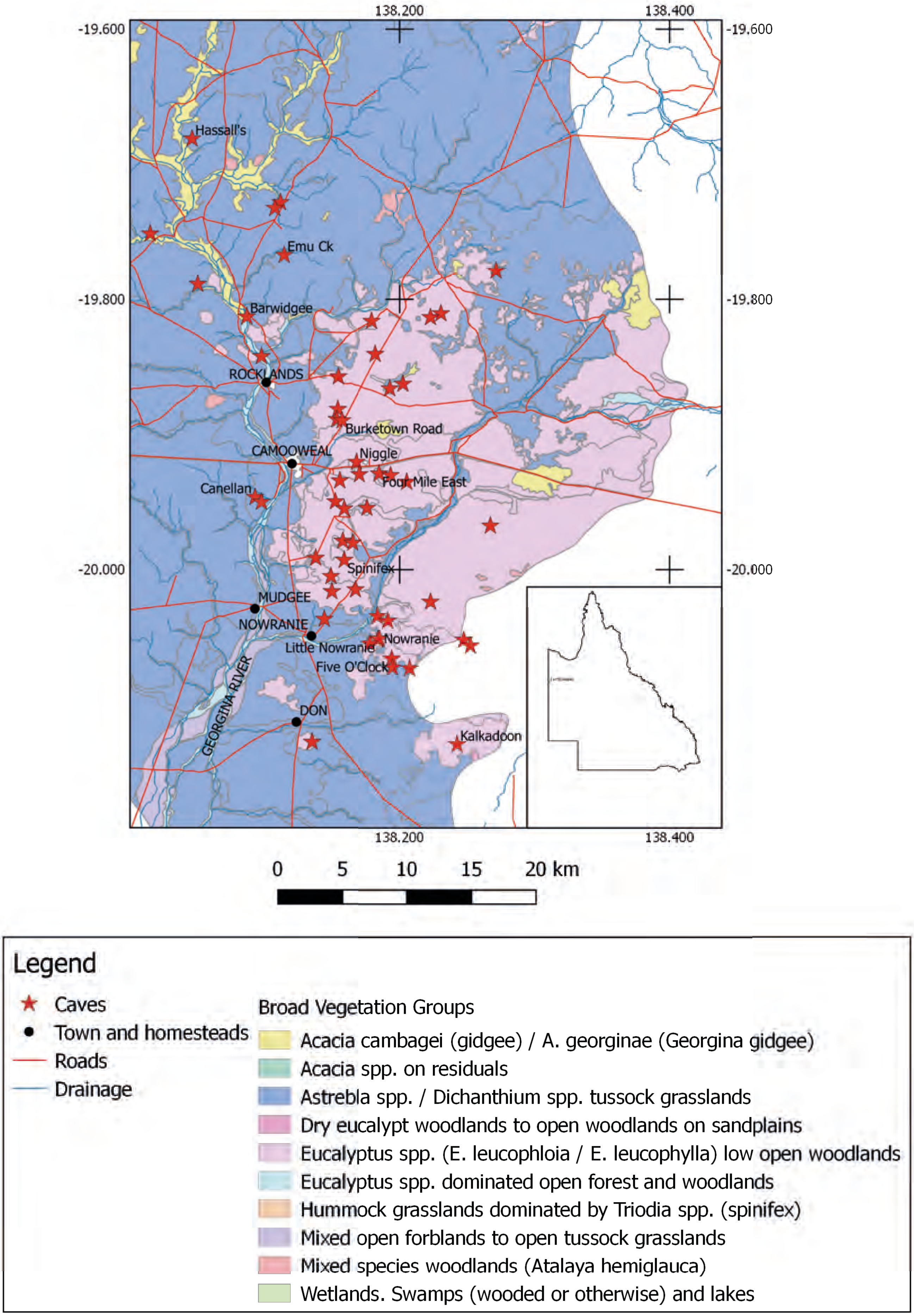

Figure 5. Distribution of Broad Vegetation Groups on the Camooweal Dolomite.

Table 2. Regional ecosystems on Camooweal dolomite and related surficial deposits (total area 87,150 hectares), Camooweal region. Data modified from Regional Ecosystem Description Database (REDD) Version 10.0 (Queensland Herbarium 2016).

RE code	Short Description	Area (ha)	Fire season recommendations	Comments
4.4.1d	*Astrebla pectinata* ± *Aristida latifolia* +/- *Eulalia aurea* grassland on Tertiary sediments overlying limestone	20360	Do not burn deliberately and exclude wildlfires	
4.9.4x1a	*Astrebla pectinata* and herbs ± *Astrebla* spp. grassland on Cretaceous sediments	19943	Do not burn deliberately and exclude wildlfires	
1.5.4a	*Eucalyptus leucophylla* low open woodland on red earths in valleys	18568	Storm season to early dry season	*Cenchrus ciliaris* (Buffel Grass) is invading the ecosystem
1.7.2a	*Eucalyptus pruinosa* ± *Eucalyptus leucophloia* low open woodland on eroded Tertiary surfaces	15937	Storm season to early dry season	High total grazing pressure and spread of *Cenchrus ciliaris*
4.3.8f	*Acacia cambagei* low woodland on braided channels or alluvial plains	2524	Wet to early dry season when soil is moist	Subject to clearing in some flatter alluvial areas. Ground layer substantially modified by total grazing pressure
4.3.17a	*Astrebla pectinata* ± *Astrebla* spp. ± *Aristida latifolia* grassland on alluvium	2353	Do not burn deliberately and exclude wildlfires	
4.3.5b	*Eucalyptus coolabah* ± *E. camaldulensis* ± *Acacia georginae* open woodland on drainage lines and/or plains	2136	Wet to early dry season when soil is moist	
1.7.1a	*Eucalyptus leucophloia* low open woodland on silcrete and lateritic surfaces	1760	Storm season to early dry season	
1.5.13	*Eucalyptus pruinosa* low open woodland	641	Storm season to very early dry season	
1.5.3	*Eucalyptus leucophloia* low open woodland on sandy and gravelly red soils	494	Storm season to early dry season	
4.9.14x41	*Acacia georginae* or *A. cambagei* low open woodland with *Astrebla* spp. on limestone	317	Wet to early dry season when soil is moist	
4.3.16a	*Astrebla elymoides* ± *A. squarrosa* ± *Aristida latifolia* grassland on alluvium	310	Do not burn deliberately and exclude wildlfires	Being invaded by exotic weed species eg. *Vachellia farnesiana*

Table 2 continued from previous page

RE code	Short Description	Area (ha)	Fire season recommendations	Comments
1.3.15	*Eucalyptus pruinosa* low woodland	274	Storm season to very early dry season	
4.3.20x1	*Atriplex* spp. and *Sclerolaena* spp. ± *Astrebla* spp. ± short grasses ± forbs, open herbland on braided or flat alluvial plains	272	Do not burn deliberately and exclude wildlfires	Highly modified floristic composition due to total grazing pressure
4.9.14x40a	*Acacia georginae* or *A. cambagei* low open woodland with *Astrebla* spp. on limestone	217	Wet to early dry season when soil is moist	
4.4.1c	*Astrebla pectinata* ± *Aristida latifolia* ± *Eulalia aurea* grassland on Tertiary sediments overlying limestone	147	Do not burn deliberately and exclude wildlfires	
1.5.16	*Acacia cambagei* low woodlands on red soils	144	Storm season to early dry season	
1.5.17	*Corymbia terminalis* low open woodland on sandy red earth plains	119	Storm season to early dry season	
4.3.18x1a	*Eulalia aurea*, *Astrebla squarrosa* ± *Astrebla* spp. grassland on alluvial plains	102	Do not burn deliberately and exclude wildlfires	
4.5.8x1	*Triodia pungens* hummock grassland wooded with *Acacia* spp. ± *Eucalyptus* spp. on Quaternary sand sheets	71	During the wet season to early dry season while soil retains moisture	Fire frequency can affect density of woody species and *Triodia pungens*
1.9.9	Low woodland of *Acacia cambagei*	34	Storm season to early dry season	
4.9.12x4a	*Corymbia terminalis* low open woodland with *Astrebla pectinata* ± *Eulalia aurea* on plains and low lying areas	32	During the wet season to early dry season while soil retains moisture	Little regeneration or coppicing of *Corymbia terminalis* is occurring, possibly due to high total grazing pressure
4.5.6x5	*Acacia cambagei*, *Senna* spp., *Sida platycalyx* tall open shrubland on Quaternary sand sheets	16	Wet to early dry season when soil is moist	
1.5.6d	*Atalaya hemiglauca*, *Ventilago viminalis*, *Grevillea striata* low open woodland on red earth plains	15	Storm season to very early dry season	
1.9.10	Sink holes with low open forest of *Celtis strychnoides* and *Ficus* spp.	14	Do not burn deliberately and exclude wildlfires	

Figure 6. Entrance sinkhole of 4C-6 Great Nowranie cave. Photo by Keith McDonald.

Camooweal caves contain a new, undescribed species of amphipod. This small crustacean of the genus *Chillagoe* is known only from karst drainage systems and its nearest relative (and the type species *Chillagoe thea*) is at Chillagoe, some 1400 km away. Freshwater amphipods are more common in cooler subterranean waters and the markedly disjunct distributions in northern Australia may reflect the fragmentation of past, more continuous populations isolated by the Cretaceous sea that flooded much of the Gulf country (Bradbury & Williams 1997). There are also colonies of filamentous iron-metabolising bacteria in the cave waters. These groundwater dependent ecosystems are at present largely unknown and experience elsewhere in Australia has shown their extreme vulnerability to pollution and increased stream sedimentation.

Comparative heritage analysis

The arid and semi-arid karsts of Australia have significant conservation values in a continent not well endowed with limestone landscapes (Jennings 1983). There are, however, many resource issues connected with development for mining, pastoralism and tourism. These impact on groundwater resources, on native vegetation and on the caves and their fauna (Gillieson 1993).

Williams (2008:6) indicates that there is poor representation of arid and semi-arid tropical karsts in the current list of World Heritage Properties. This karst style is widespread in the Middle East, Central Asia and in parts of Australia and Brazil. There are outstanding semi-arid examples in the Kimberley karst (seasonally arid karst) and from subtropical Brazil (Canyon du Rio Peruaçu). At the extreme arid end of the scale are the Nullarbor Plain in southern Australia (subject of a World Heritage values study in the 1990s) and limestone terrains from Yemen to Afghanistan. However "less is known about karst in deserts and semideserts than anywhere else except beneath glaciers and permafrost. Even the limits are uncertain" (Jennings 1983:61).

The Camooweal caves and the Barkly karst (including the nearby Riversleigh dolomite areas) can be compared with several other dolomite karsts globally. In Tasmania the well decorated Hastings caves are formed in Precambrian dolomite, as are caves and karst at Mount Anne and Weld River in the Tasmanian Wilderness WHA. The Tasmanian dolomites exhibit interactions between karst landforms and glaciation, as well as diverse

Figure 7. Upper section of 4C- 15 Niggle Cave, Camooweal. This cave is very close to the Barkly Highway and is affected by road runoff in the wet season, with the passage pictured flooding to the roof. Photo: David Gillieson.

endemic cave fauna. Subfossil deposits in the caves, including megafauna, are regionally significant and cave sites also have archaeological significance (Sharples 2003). Long palaeoclimatic histories have been gained from speleothems in the caves. Humic acids derived from blanket peats may be significant in Tasmanian karst development and may account for the significant karst development in the less-soluble Precambrian dolomite carbonate rocks.

In South Africa there are extensive Proterozoic dolomite karsts in the Transvaal, with important hominid sites in the Sterkfontein, Swartkrans and Kromdraai areas, and tourist caves at Cango near Oudtshoorn in the south. The area contains outstanding examples of cave sediments with fossils deposited over an interval of several million years into very ancient karst systems. Sinkhole development in the dolomite poses significant engineering problems, with dewatering following gold mining leading to accelerated collapses (Martini & Kavalieris 1976).

Canada has approximately 600,000 km^2 of dolomite (Ford 2004) but the legacy of multiple glaciations has meant that karst features are not well exposed in many areas due to glacial outwash and till deposits overlying the karst. In Ontario dolomites are associated with Niagara Falls and the Bruce Peninsula on Lake Huron. There are karst pavements, coastal karren and short caves. Doline karst on dolomite is found in Manitoba, between Lakes Winnipeg and Winnipegosis. In the United States the Carlsbad Caverns National Park WHA is developed in Permian dolomites and limestones. There are extensive well decorated caves which provide the world's foremost example of cave evolution by sulphuric acid dissolution of the bedrock. The semi-arid terrain is dominated by ridges and dry valleys. There is very high biodiversity, including significant bat populations.

In Botswana the Gewihaba area (a tentative World Heritage site) contains cavernous dolomite hills rising above an arid sand plain. The caves contain wind-blown sand and are rich in fossils and speleothems indicating humid conditions in the past.

The Camooweal karst and caves has comparable geomorphological values to the North American sites, while its biological significance is barely researched but has considerable potential. The clear integration of surface and underground drainage into a regional groundwater system, with several levels of cavern development, suggests a great antiquity for the karst. The palaeontological and archaeological potential of the caves is unknown, though the proximity to the Riversleigh WHA suggest that important assemblages might be found in the northern caves.

Ongoing conservation and management issues

The *Eucalyptus pruinosa* / *Eucalyptus leucophloia* low open woodland on eroded lateritic surfaces is subject to high total grazing pressure and inevitable spread of Buffel Grass *Cenchrus ciliaris.* This species is also invading the *Eucalyptus leucophylla* low open-woodlands along valleys and, as in many areas of the adjoining Northern Territory, will eventually have dramatic effects by changing the understorey composition and significantly increasing fuel loads. The Gidgee (*Acacia cambagei*) and River Redgum (*Eucalyptus camaldulensis*) low woodland along drainage lines is being modified in its understorey by high grazing pressure, while small areas of *Atriplex* spp. / *Sclerolaena* spp. / *Astrebla* spp.

Figure 8. Fenceline contrast along southern boundary of Camooweal Caves National Park, showing high density of cattle dung and overgrazing within park, compared to lightly grazed paddock outside the park. Photo: Keith McDonald.

open herbland are being highly modified due to grazing pressure. The extensive Mitchell grassland (*Astrebla elymoides* / *A. squarrosa* / *Aristida latifolia*) is being invaded by exotic weed species eg. *Vachellia farnesiana* as well as being subject to high grazing pressure. This is most noticeable in and around the Camooweal Caves National Park.

The Camooweal Caves National Park is the first protected area seen by visitors driving into Queensland along the Barkly Highway from the Northern Territory. It lies 15 km south of the town of Camooweal and facilities include a picnic table, signage and two short walking tracks. The park has a current grazing lease (until 2020) and stock have broken down fences as well as creating patch erosion and numerous tracks. During the wet season soil and dung washes into the caves. Rubbish is also present around the parking area. There is little evidence of Ranger presence or interest in the park. This surely does not create a good impression of the management of protected areas in Queensland.

The stated cardinal principle for the management of National Parks in Queensland is “to provide, to the greatest possible extent, for the permanent preservation of the area's natural condition” (QDNPRSR 2013) and the protection of the area's cultural resources and values. Another stated management principle for national parks is “to ensure that park use is nature-based and ecologically sustainable”. This is clearly not being achieved at Camooweal Caves National Park (Fig. 8).

Wildfires in November 2011 burnt approximately 50% of the Camooweal Caves National Park (Table 3), including Mitchell Grass plains which in total are 8% of the park area. These natural grasslands on cracking clay soils should never be deliberately burnt nor should fires be allowed to spread into them. Although rainfall in 2013 was in the severe rainfall deficit category (Table 4), subsequent years have received average or above average rainfall. Thus claims by the management authority that drought was the underlying cause of poor vegetation recovery are not borne out by the data. The recovery of these grasslands has been impeded by continued heavy grazing by the lessee and an absence of effective monitoring by the management authority (Fig. 8).

In areas remote from waterpoints the black soil plains are uncompacted and act as sponges for wet season rainfall. Runoff into cave entrances is generated from exposed dolomite pavements surrounding them, plus shallow surface channels with a lag gravel of chert.

Table 3. Regional ecosystems on Camooweal Caves National Park burnt in November 2011 fires. Data modified from REDD Version 10.0 (Queensland Herbarium 2016).

Regional Ecosystem	**Short Description**	**Area burnt (ha)**
1.3.15	*Eucalyptus pruinosa* low woodland	51.5
1.5.17	*Corymbia terminalis* low open woodland on sandy red earth plains	33.1
1.5.3	*Eucalyptus leucophloia* low open woodland on sandy and gravelly red soils	278.2
1.5.4a	*Eucalyptus leucophylla* low open woodland on red earths in valleys	1,577.2
1.7.1a	*Eucalyptus leucophloia* low open woodland on silcrete and lateritic surfaces	1,406.9
1.7.2a	*Eucalyptus pruinosa* ± *Eucalyptus leucophloia* low open woodland on eroded Tertiary surfaces	1,735.0
1.9.10	Sink holes with low open forest of *Celtis strychnoides* and *Ficus* spp.	4.3
4.3.17a	*Astrebla pectinata* ± *Astrebla* spp. ± *Aristida latifolia* grassland on alluvium	296.3
4.3.5b	*Eucalyptus coolabah* ± *E. camaldulensis* ± *Acacia georginae* open woodland on drainage lines and/or plains	11.8
4.4.1c	*Astrebla pectinata* ± *Aristida latifolia* ± *Eulalia aurea* grassland on Tertiary sediments overlying limestone	199.8
4.4.1d	*Astrebla pectinata* ± *Aristida latifolia* ± *Eulalia aurea* grassland on Tertiary sediments overlying limestone	298.3
4.5.6x5	*Acacia cambagei*, *Senna* spp., *Sida platycalyx* tall open shrubland on Quaternary sand sheets	74.4
4.5.8x1	*Triodia pungens* hummock grassland wooded with *Acacia* spp. ± *Eucalyptus* spp. on Quaternary sand sheets	17.4
4.9.4x1a	*Astrebla pectinata* and herbs ± *Astrebla* spp. grassland on Cretaceous sediments	348.1
	Total burnt	6,332.0

Under grazing pressure there is soil compaction and incised cattle tracks channel water and sediment into cave entrances. Wet season rainfall can cause surface runoff and the caves flood rapidly. Increased flow down these channels also entrains fine gravel which enters the caves as an abrasive sediment load, along with organic flood debris. This can only have a detrimental effect on the cave biology. In addition the Camooweal town water supply is drawn from the karst aquifer, which is continuous and fed by this surface runoff. Thus there is the possibility of polluted water being ingested by residents and visitors.

Any consideration of the management of park integrity must take account of the unusual characteristics of karst landscapes (Watson *et al.* 1997). First, karst is notable as it comprises both surface and subterranean features and values and integrates surface and subterranean processes, both biological and physical. Cave deposits can record stages in the evolution of the karst and of the surface environment over a very long timescale. Secondly, karst ecosystems are fragile because they are periodically arid at the surface whilst being dark and remote from food sources underground. The cave ecosystem is particularly fragile as it is dependent on energy flows transmitted by water, the quality of which is critically important for survival of the biota. Thirdly, the water passing through the karst is introduced by sinking streams, often fed by large and poorly defined catchments draining impervious rocks. The transit time for water passing through the karst after rainfall may vary with the duration and intensity of the events, with different flow paths becoming active at varying levels in the karst. Thus the reappearance of water at a spring can vary from days to years depending on the size and nature of the groundwater system.

There is a strong imperative to develop and implement a cave and karst specific management plan to protect the caves and their aquatic fauna from impacts resulting from overgrazing. Coupled with this would be control of the limited areas of Buffel Grass (*Cenchrus ciliaris*) and Prickly Acacia (*Vachellia farnesiana*), together with erosion control especially around waterholes, along creeks and roads. An appropriate fire management program should also be implemented and monitoring sites established.

Table 4. Rainfall records for Camooweal township (BOM station 037010) for 2007-2017, with classification by deciles and interpretation of drought classes.
Data from Bureau of Meteorology.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Decile	Drought class
2007	190	3.6	61	0	18	0.2	0	7.8	0	6	40.4	71	398.2	6	**Average**
2008	3.2	87.6	1.4	0	0	0.2	0	0	6.4	4.8	29.4	73.2	206.2	2	**Below average**
2009	498	270	2.2	10.8	0	0	0	0	0	0.2	16.8	168	965.6	10	**Very much above average**
2010	152	110	27.8	46.2	12.6	0	9	0	12.4	21.4	43.6	93.8	528.2	9	**Above average**
2011	193	303	168	12.2	0	25.8	0	0	0	6.6	74.8	148	931	10	**Very much above average**
2012	39.8	39	70	23.6	10.4	0.6	5.8	0	1.2	13.8	47.2	124	375.4	6	**Average**
2013	26.4	14.8	25.6	0.4	14.2	0	0.2	0	0	0	13	70.4	165	1	**Severe**
2014	23.6	154	62.8	9	0	1.2	0	12	0.2	0.4	50	51.4	364.8	5	**Average**
2015	192	27.2	20.2	0	0	3.8	0	0.8	0.8	0	22.2	204	471	8	**Above average**
2016	49.4	73.8	157	0.8	20.8	43.2	21	22.6	92.8	7.8	34.6	145	668.2	10	**Very much above average**
2017	148	31	25.6	0	0	0	3.4	0	0	9.6	7.8				

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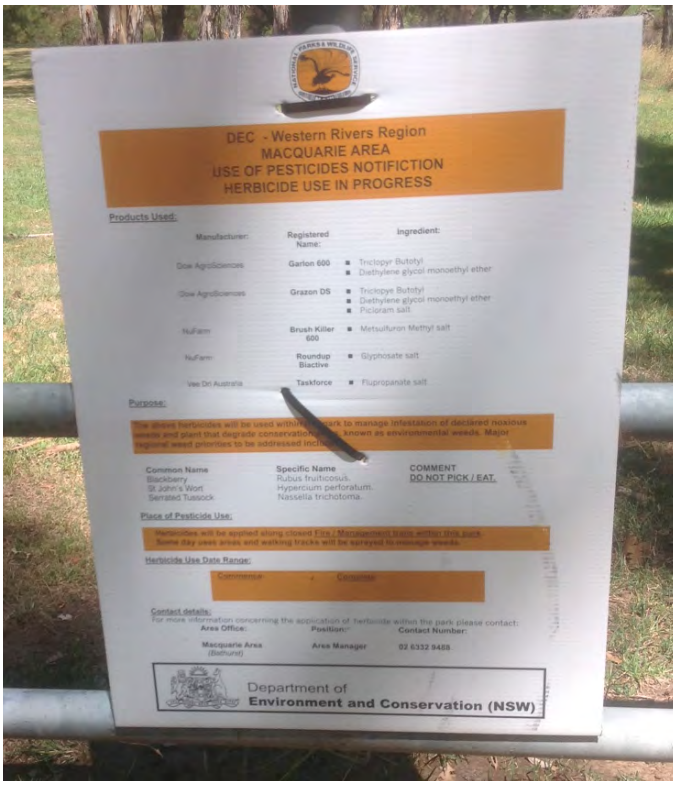
BORENORE CAVES:
A CASE STUDY of MANAGEMENT by SIGNAGE

Kent Henderson

In January 2018, I found myself in Orange, New South Wales, for a few days on business, and thus I paid a visit to the nearby Borenore Karst Reserve (as you do!). I have been there "more than a few times" over the last 30 years; I think the first time was with Ernie Holland, then Manager at Jenolan, and Mick Chalker, then Manager at Wombeyan - so that is almost Precambrian!

Back in those days, as I recall, the management of Borenore was not good. One of the main problems was that the Reserve was to a substantial extent overrun with blackberries. That matter has long since been resolved by what is by now an ongoing spraying program over many years. Certainly, not a blackberry to found at Borenore today.



The first thing to appreciate is that Borenore is totally unmanned and is open until 7.00pm daily. And obviously while rangers of the managing agency, the New South Wales National Parks & Wildlife Service, regularly attend the Reserve, the lack of a 'visible presence' creates ongoing management challenges in many ways different from a show cave location.

This has been addressed by what I consider to be the best example of 'Management by Signage' I have seen.

On the highway is the following:

Aside from the obvious function of the sign, it immediately introduces the word 'karst' to the visitor, and the concept of conservation....

Upon driving onto the short road into Borenore, one next sees a series of three signs:

These signs are all self-explanatory; but clearly set out the management parameters to be observed by visitors. The management instructions continue:

Once you reach the car park, prior to the path to Arch Cave, an excellent three panel interpretative sign awaits the visitor:

It is one the best of its type I have seen, covering all relevant areas of cave and karst conservation, and imparting quite thorough karst education.

Thereafter follows excellent directional signage:

And well maintained tracking:

The 'self guided' cave experience involves passing through the (dark) section of Arch Cave (a short traverse), ascending to the front of the river section, and a final cave traverse up the stream. The entirety is really is a very pleasant cave and karst experience.

There are two other caves described to the public; Verandah Cave and Tunnel Cave. From a management perspective both are a long walk from the car park and thus much less visited than the convenient Arch Cave. Tunnel Cave is a long, dark passage, about 110 metres long, which emerges from the base of a large hill. It is closed from May to October each year so that its colony of Eastern Bentwing Bats *Miniopterus shreibersii*, which hibernate there, is left undisturbed.

Overall, Borenore is wonderful example of excellent 'sign driven' management that could usefully be emulated in more than a few other locations, even at some show cave sites, it could be suggested.

Above. The entrance to Arch Cave, Borenore
Below. Inside the River Section of Arch Cave, Borenore

AN OVERVIEW OF CAVES AND CAVING IN THAILAND

Terry Bolger[1] and Martin Ellis[2]

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Abstract

Karst is widespread in Thailand and covers 18% of the land area, formed on limestones deposited from the Ordovician to Jurassic periods with Permian limestones occurring most extensively. Also, the Khorat Plateau in northeast Thailand contains some sandstone pseudokarst. The exploration and documentation of Thai caves has been particularly active since the early 1980s. These exploration activities have resulted in rapid increases in speleological knowledge during this period. Currently 5200 sites have been recorded in a database of Thai caves. In total there are 19 caves longer than 3km and 28 caves with a vertical range greater than 120m. The longest surveyed cave in Thailand is Tham Phra Wang Daeng at 13.75km and the cave with the largest vertical range is Tham Pha Phueng at 476m. Cave exploration is still active in a number of karst areas around Thailand, while other karst areas remain virtually unexplored with regard to speleology. Surveys of the cave biodiversity have resulted in over 450 species being recorded, of which 200 were discoveries new to science. Significant archeological discoveries in caves include human remains in southern Thailand dated to 25,000 BP, and log coffin burials in northern and western Thailand dated to 1700 BP. Surely, many more exciting discoveries await intrepid cave explorers in Thailand.

Keywords: Caves, exploration, karst, speleology, Thailand

Introduction

Karst is widespread in Thailand (Figure 1), except in the northeastern region, and covers 18% of the land area (93,000 km2), formed on limestones deposited from the Ordovician to Jurassic periods with Permian limestones occurring most extensively. Also, the Mesozoic sandstones of the Khorat Plateau in northeast Thailand contain some pseudokarst. The exploration and documentation of Thai caves has been particularly active since the early 1980s, with the majority of the exploration (to date) being done by European, Australian and American cavers on small scale expeditions and by Western expatriates living in Thailand. While caving is not organized as a sport or pastime in the country, Thai academics are conducting ongoing speleological research in the fields of biology, archeology, paleontology and hydrology. More recently the Department of Mineral Resources has begun exploring and documenting caves, starting in the south of Thailand. These exploration and research activities have resulted in rapid increases in speleological knowledge during this period. Currently 5200 sites have been recorded in a database of Thai caves.

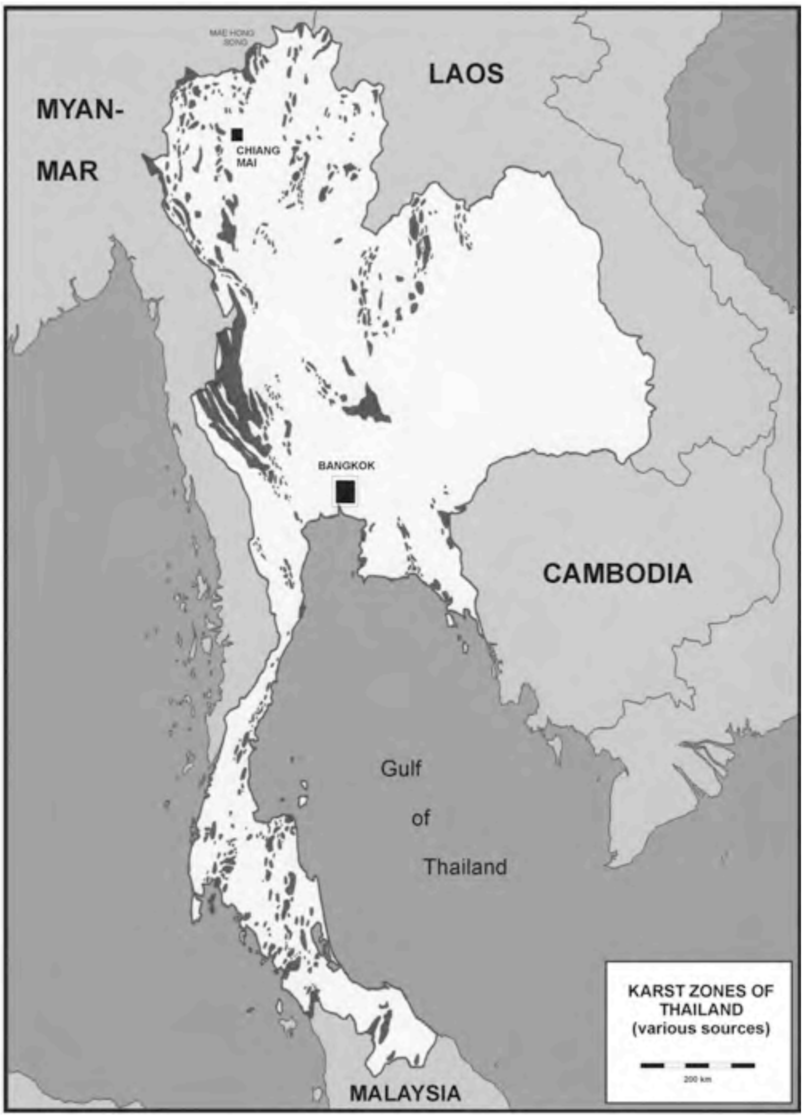

Figure 1. Karst map of Thailand (according to Pèpe et al 1997 and SGGES World Karst Map)

Longest caves

The 10 longest surveyed caves in Thailand are listed in Table 1. The table shows that long caves occur from the north to the south of the country. Seven of the 10 longest caves have been surveyed or had their survey extended since the beginning of this century. Tham Phra Wang Daeng is currently the longest cave in Thailand at 13.75km. A line plot of Tham Phra Wang Daeng overlaid on a topographic map is presented in Figure 2. Consisting mainly of a 10km long, large streamway passage, it makes for a magnificent caving trip. Detailed descriptions of the twenty longest caves in Thailand are given in Ellis (2015).

Table 1. *The 10 longest caves in Thailand*

No.	Cave Name	Region	Length (m)	Explored
1	Tham Phra Wang Daeng	North Central	13,789	1997-2004
2	Tham Mae Lana	North	12,720	1986-1992
3	Tham Yai Nam Nao	North Central	10,631	2004-2014
4	Tham Luang	North	10,316	1986-2016
5	Tham Lom system	North	9,277	2015-2017
6	Tham Nam Lang	North	8,550	1986
7	Tham Takobi	North Central	7,346	2000-2003
8	Tham Krachaeng	South	5,633	1993-2000
9	Tham Nam Wang Si Thamma Sokarat	South	5,200	2011-2014
10	Tham Chiang Dao	North	5,170	1985

Figure 2. The large stream passage of Tham Phra Wang Daeng
Photo: Andy Goddard

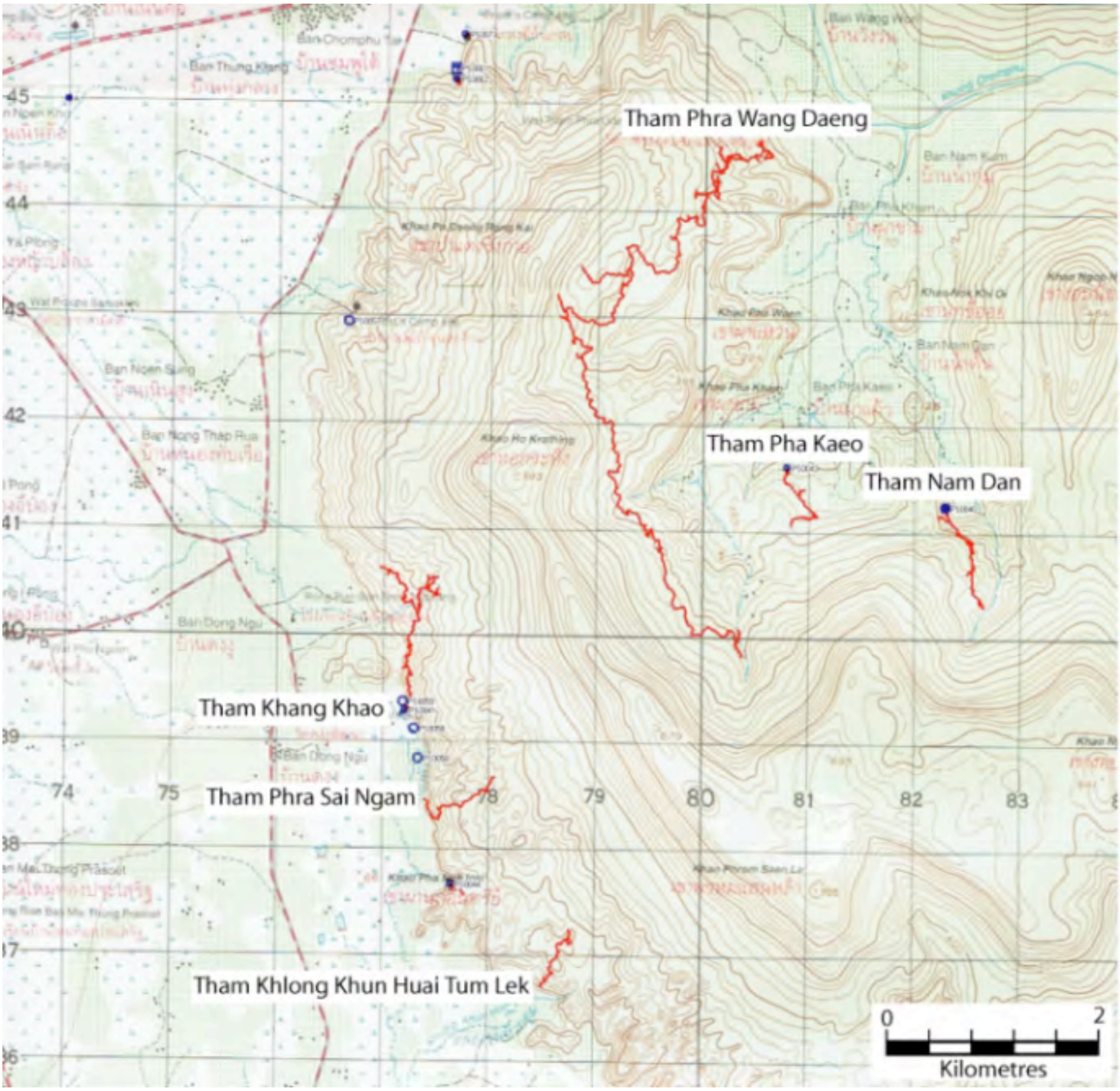

Figure 3. Topographic map with a line plot of Tham Phra Wang Daeng and other nearby caves

Deepest caves

The five deepest surveyed caves in Thailand are listed in Table 2. Thailand is not known for deep caves, with only three caves having a vertical range greater than 200m. Most of the deepest caves are found in the north of Thailand, with several deep water-filled springs such as Tham Sra Kaeo occurring in the southern region.

Tham Pha Phueng is currently the deepest cave in Thailand with a vertical range of 476m. A vertical section map of Tham Pha Phueng is presented (Figure 4). The cave initially descends at 12° to 20° for about 700m in mostly large passage, leading to the top of a very deep pit. At this point the cave becomes more sporting with the 127m deep Fitch Pitch being the biggest descended pitch in Thailand. Detailed descriptions of the twenty deepest caves in Thailand are given in Ellis (2015)

***Table 2**. The five deepest caves in Thailand*

No.	Cave Name	Region	Depth (m)	Explored
1	Tham Pha Phueng	North	476	2005-2014
2	Tham Pha Daeng	North	246	2005-2013
3	Tham Sra Kaeo	South	240	1993-2007
4	Tham Ban Luang	North	199	1984
5	Tham Ya Wua Yai/Tham Phet	South	190	1987-2016

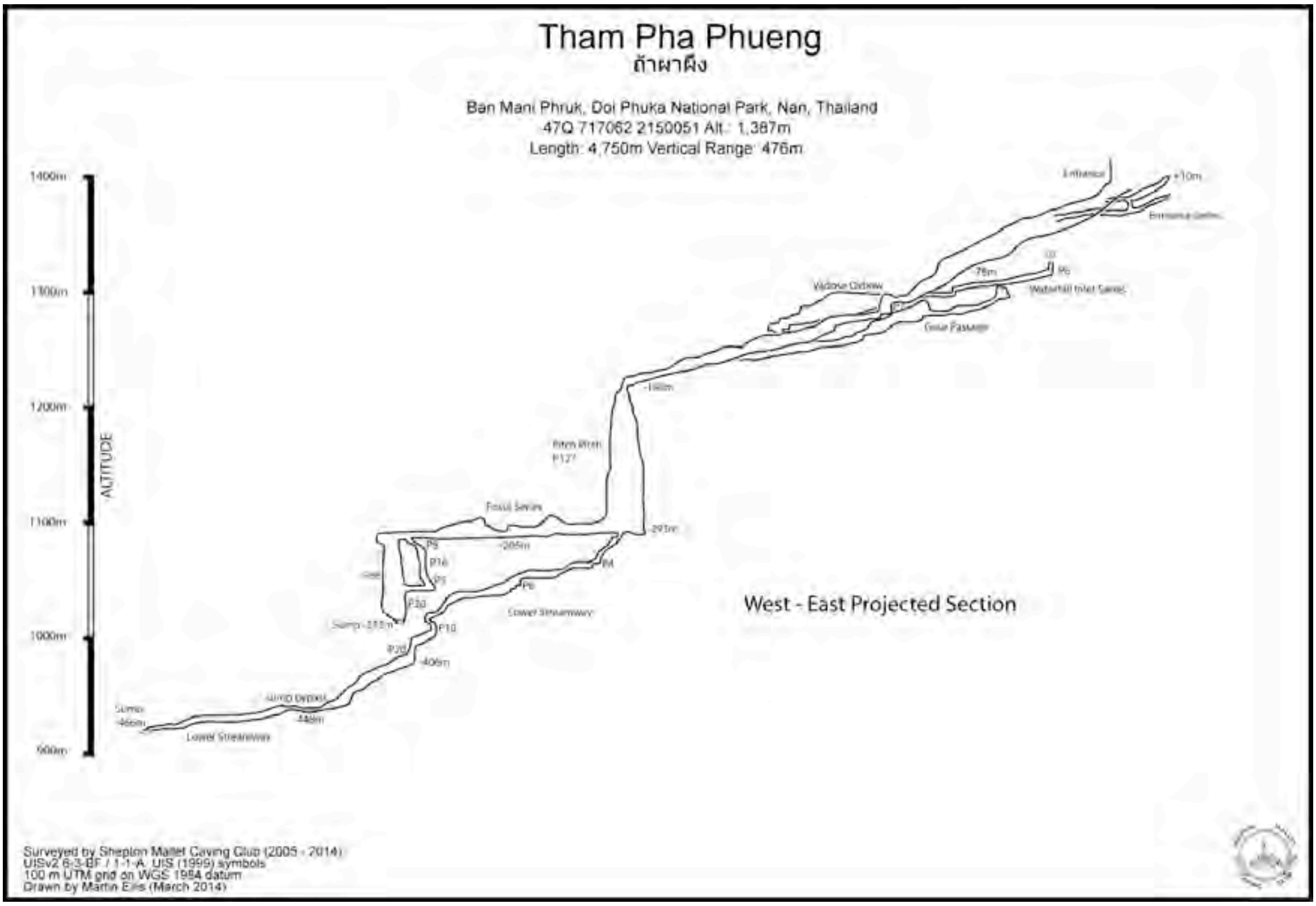

Figure 4. Vertical section map of Tham Pha Phueng

Cave biodiversity

Surveys of cave biodiversity have recorded 466 species in Thailand (Table 3), with 43% of the species being described as new taxa. These new taxa include 5 species of bat, 13 species of scaled reptiles (lizards and snakes), 8 species of cave-adapted fish, and a wide range of invertebrate species.

Table 3. Biodiversity recorded from caves in Thailand

Taxonomic Group	**Species**	**New Taxa**
Mammals	93	5
Birds	12	0
Reptiles	35	13
Amphibians	7	1
Fish	18	8
Invertebrates	312	173
Total	**466**	**200**

Figure 5. A cave gecko, Cyrtidactylus auribalteatus, from Tham Phra Wang Daeng. Photo: Phil Collett

Figure 6. Log coffin burial site in a cave in northwestern Thailand
Photo: Terry Bolger

Cave archeology

Significant archeological discoveries in caves include human remains from Tham Moh Khiew in southern Thailand dated to 25,000 BP, the oldest remains of modern humans from Thailand. In northern and western Thailand log coffin burials dated to 1700 BP are found in a number of caves and rock shelters, often in very inaccessible places. The culture related to the log coffin cave burials is still a mystery.

Concluding Remarks

While the speleological knowledge of Thailand's caves has increased rapidly over the last 35 years, surely many more exciting discoveries await intrepid cave explorers in Thailand. For those wanting to know more about Thailand's cave heritage, a wealth of information is available in the reading list below, and on the Caves & Caving in Thailand website: www.thailandcaves.shepton.org.uk

Reading List

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ACKMA EXTENDS its REACH!

Andy Spate and Tim Moulds

Dr Tim Moulds is now an Adjunct Secretary of the International Union of Speleology.

At 2017 at the UIS conference in Sydney, Tim was encouraged by several people including Dr Julia James and ASF President John Cugley to stand for the UIS Bureau. Tim was elected as Adjunct Secretary at the UIS General Assembly and now represents all Australian cavers, karst scientists and speleologists at the UIS. He maintains a strong interest in the biology and management of Australasian caves and karst.

Tim was born in the suburbs of northern Sydney in the late 1970s. His parents had a strong interest in the outdoors and Tim was fortunate to travel Australia widely during most summers camping and collecting insects for the Australian Museum as a child. His father Max had been interested in caves as a young man and was a founding member of Kempsey Speleological Society. This interest in caves was passed onto Tim at a young age and his first caving trip was into Weebubbie Cave on the Nullarbor at the age of five.

It was not until Tim started university studies that his interest in caving was reignited when he joined the Macquarie University Caving Group (MUCG) in 1996 as he started his undergraduate studies in geology. He caved variously in 1996 and 1997 with a keen cohort of other cavers and geology students all over NSW and into Buchan Caves in Victoria.

At the end of 1997 Tim joined the MUCG trip to Waitomo NZ and the world of international caving was awakened in him. He loved the caving in NZ for the high adrenaline and the cave rivers compared with what he had experienced previously in NSW. He went on to visit NZ caves many times over the past 20 years notching up some 17 trips across the ditch.

Following the completion of his undergraduate studies Tim spent several months caving in western Canada, on both Vancouver Island and the Rockies, exploring and mapping alpine caves with the Alberta Speleological Society. After working at the Australian Museum as a research assistant he was then able to combine his love of caves, entomology and geology to apply for a PhD scholarship at the University of Adelaide to study the guano invertebrates in Bat Cave at Naracoorte. Moving to Adelaide in 2002 he immersed himself in his PhD studies for the next three years whilst also attending his first ASF and ACKMA conferences in 2003. The guidance of then Naracoorte Cave manager Steve Bourne was invaluable in his appreciation of cave management standards.

Tim moved to Perth, Western Australia, in 2006 following the completion of his PhD studies to work as a mine geologist. While an interesting change from caves and entomology he quickly reverted back to working as an environmental consultant, specialising in subterranean fauna. For the past 12 years Tim has combined karst science, cave management and subterranean biology to become an expert in Australian cave fauna, its management and the management of cave and karst. He has undertaken consultancies in Christmas Island, the World Heritage listed Phong Nha-Ke Bang karst in Vietnam and in the Mulu Caves in Malaysia. He was also accepted as a member of the IUCN World Commission on Protected Area (WCPA) Cave and Karst Protection working group in 2013, a position that he still holds. He currently runs his own environmental consultancy *Invertebrate Solutions* specialising in the diversity and management of subterranean invertebrates in Australasia.

Tim regularly participates in international caving expeditions and has caved in every major karst area in Australia as well as New Zealand, Papua New Guinea, China, Thailand, Laos, Malaysia, Madagascar, Slovenia, Italy, Czech Republic, UK and Canada. He is currently the President of the Western Australian Speleological Group.

Tim Moulds
Photo: Supplied

CAVE ACCESS MANAGEMENT

Tony Culberg

Tasmania is blessed with some magnificent caving areas – Mole Creek for pretty caves, Ida Bay for long caves and the Junee-Florentine for deep and technically challenging caves. Other areas like Mt Cripps have a wide assortment of caves – over 240 at Mt Cripps – and face similar issues.

With a biennial ASF Conference due in northern Tasmania just after Christmas 2018, Southern Tasmanian Caverneers (STC) has addressed the issue of ensuring that visiting cavers have an enjoyable visit to caves in the south of the state. While STC is not directly responsible for the conference itself, it recognises that many visitors will want to challenge themselves in 'our' caves.

One of the problems is that, in the Junee-Florentine (JF) particularly, the access tracks to caves are overgrown quite quickly. Over the years, STC members have been so busy exploring new caves that in many cases a cave might have been discovered, numbered, explored, surveyed, mapped and documented and then not looked at again. JF does have a surplus of caves yet to be fully documented. Some 40+ items of interest were reported by the Book End Trust in the area between the Little Florentine River and the Florentine River, a little over 2 years ago. Some of these are yet to be explored, surveyed, mapped and documented.

Starting in early 2017, STC has embarked on a program of tidying up the access tracks. Broad policy is not to make the start of any track too obvious, lest casual visitors be tempted to "see where this track goes". At one stage a local Visitor Centre in Maydena was handing out photocopies of notes on how to get to Growling Swallet. At least one party had an accident on that straightforward walk.

Generally, a party which includes a qualified and licensed chainsaw operator, will tackle one track. There will be several support workers, whose task is to throw the cuttings into the bush and clean up any small material, using secateurs. Pink plastic tape is tied around trees to show the way. Experience is that one man with a chainsaw can get ahead of 6 or 7 follow up workers! Tracks are generally widened to make it feasible to manhandle a stretcher. Helicopter access in rainforest with trees taller than 70 m is unlikely. Most casualties will need to be removed to a road or a clearing.

Recently STC has also started marking the track from the cave back to the road with reflective tags. STC will almost always be providing one of its members as a guide for visiting parties, the issue then is how visitors would find their way back if the STC member is the one injured. GPS will tell you where you are, and where you need to reach. It does not show you the track.

An interstate party visiting Ida Bay in March 2017 relied on GPS and spent some considerable time thrashing around in the bush looking for the cave entrance. Its entire timetable for the day's caving was disrupted.

The reflective markers are made from discarded corflute road signs. These are available at Tip Shops all over Tasmania. On occasions metal signs are obtained – these are a little more challenging to use. The signs are cut down to about 22 mm squares. Corflute will cut with a Stanley knife in one direction, and a paper guillotine in the other direction. Metal signs need an industrial guillotine, a hacksaw or tinsnips. Fortunately, one member has good contacts at the local TAFE College Metal Fabrication facility.

Some care is required to discard parts of the signs which are not reflective – the sign showing a worker leaning on a shovel has lots of black. Others like speed limit signs have a range of colours, black, red and white. Really good signs are the large green ones used for places of sightseeing interest. These have almost no waste sections!

Corflute squares are then fitted with a nail – 50 mm flathead is sufficient – and taken by the bucketful to the cave entrance, with a hammer. On the return trip markers are installed so they are visible from the last marker. At night, assuming that a flat battery is not the issue, it is then easy to find one's way back to the road/carpark.

Metal squares, from some older signs, need a drill press to drill a 3 mm hole through each tag. That is a time consuming task! Fortunately, most TAFE colleges also have that kind of gear as well.

So far STC has spent very little money on this project – the running total is $10.00 for a 25kg box of nails! All the corflute has been rescued from some form of waste disposal, like a tip shop. It ought to be possible to obtain scrap from sign-making businesses, and your local council works depot may have signs which have been damaged.

Visitors to the southern Tasmanian caves can be confident of being able to find their way back to their cars!!

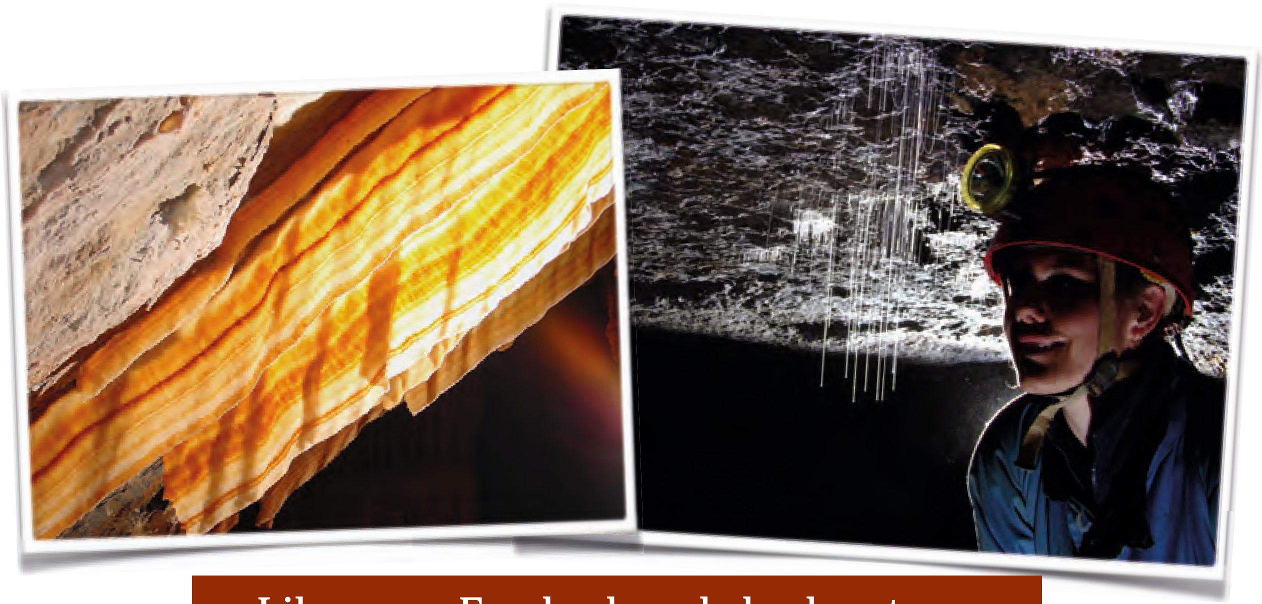
Upcoming event
Sunday 30 December 2018 - Friday 4 January 2019

31st ASF Conference

Devonport, Tasmania

31ST 2018–2019
ASF
The Darkness Beneath

Discover The Darkness Beneath this summer at the 31st Australian Speleological Federation conference.



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