NATURAL HERITAGE VALUES and MANAGEMENT of the CAMOOWEAL KARST and CAVES

David Gillieson[A] and Keith McDonald[B]

[A]School of Geography, University of Melbourne, Carlton Vic 3053, Australia. Email: dsgillieson@gmail.com
[B]PO Box 1026, Atherton Qld 4883, Australia

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.

This article was originally published in the *North Queensland Naturalist* and is reproduced here with their permission.

Citation: Gillieson & McDonald. 2018. Natural heritage values and management of the Camooweal karst and caves. *North Queensland Naturalist* 48: 1-17.

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

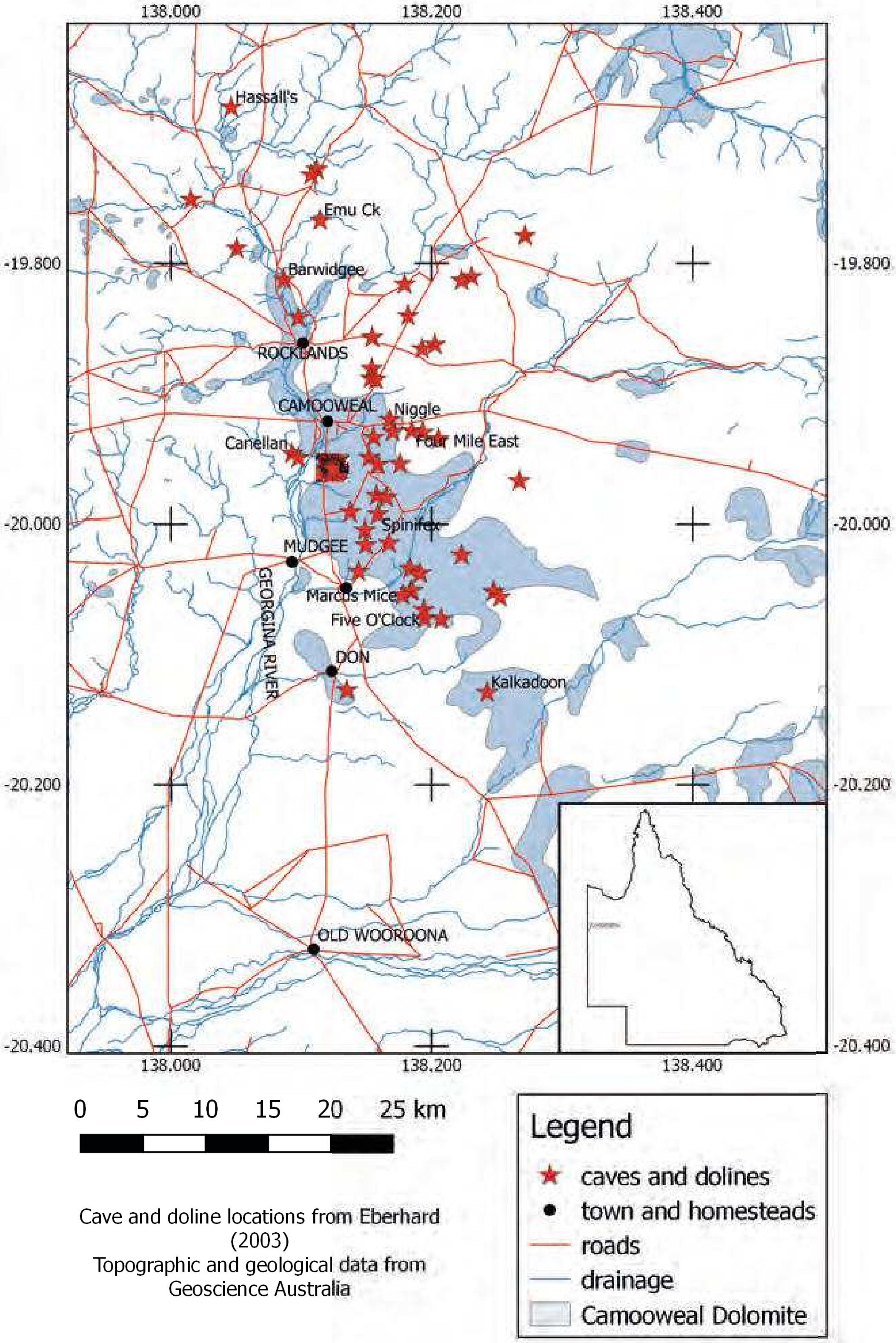

Figure 1. Location of caves and dolines at Camooweal

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.

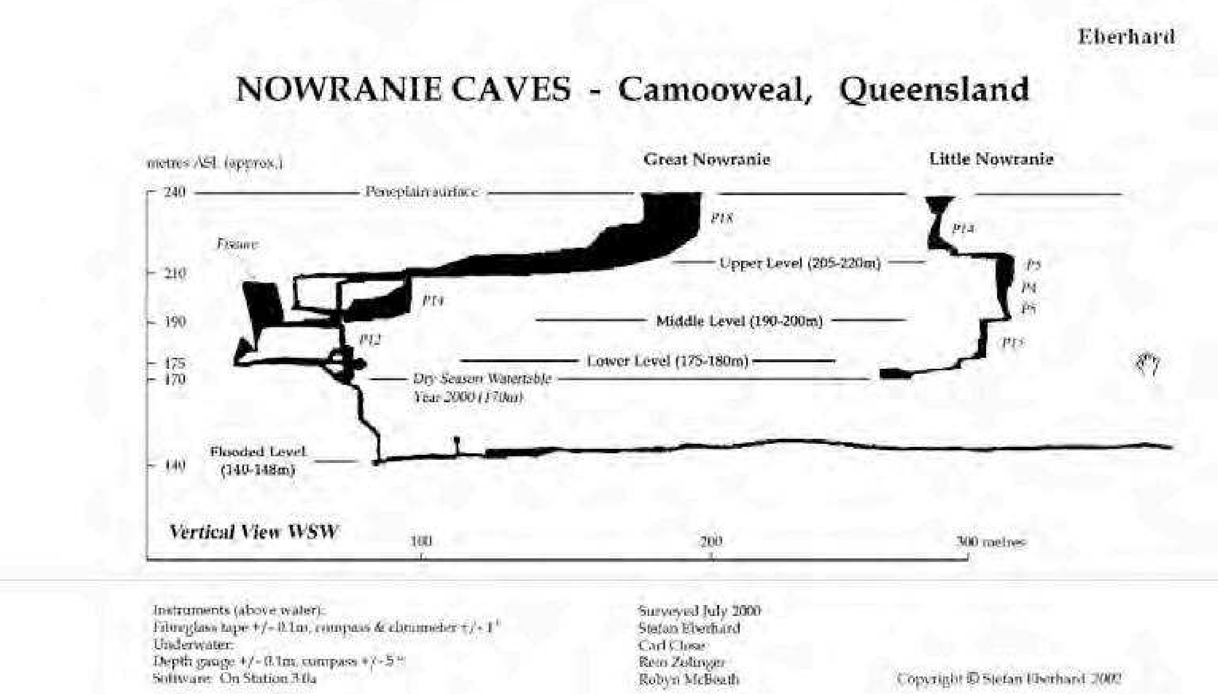

Figure 4: Cross-section of the 4C-4, 4C-11 Nowranie Caves, Camooweal (from Eberhard 2003).

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

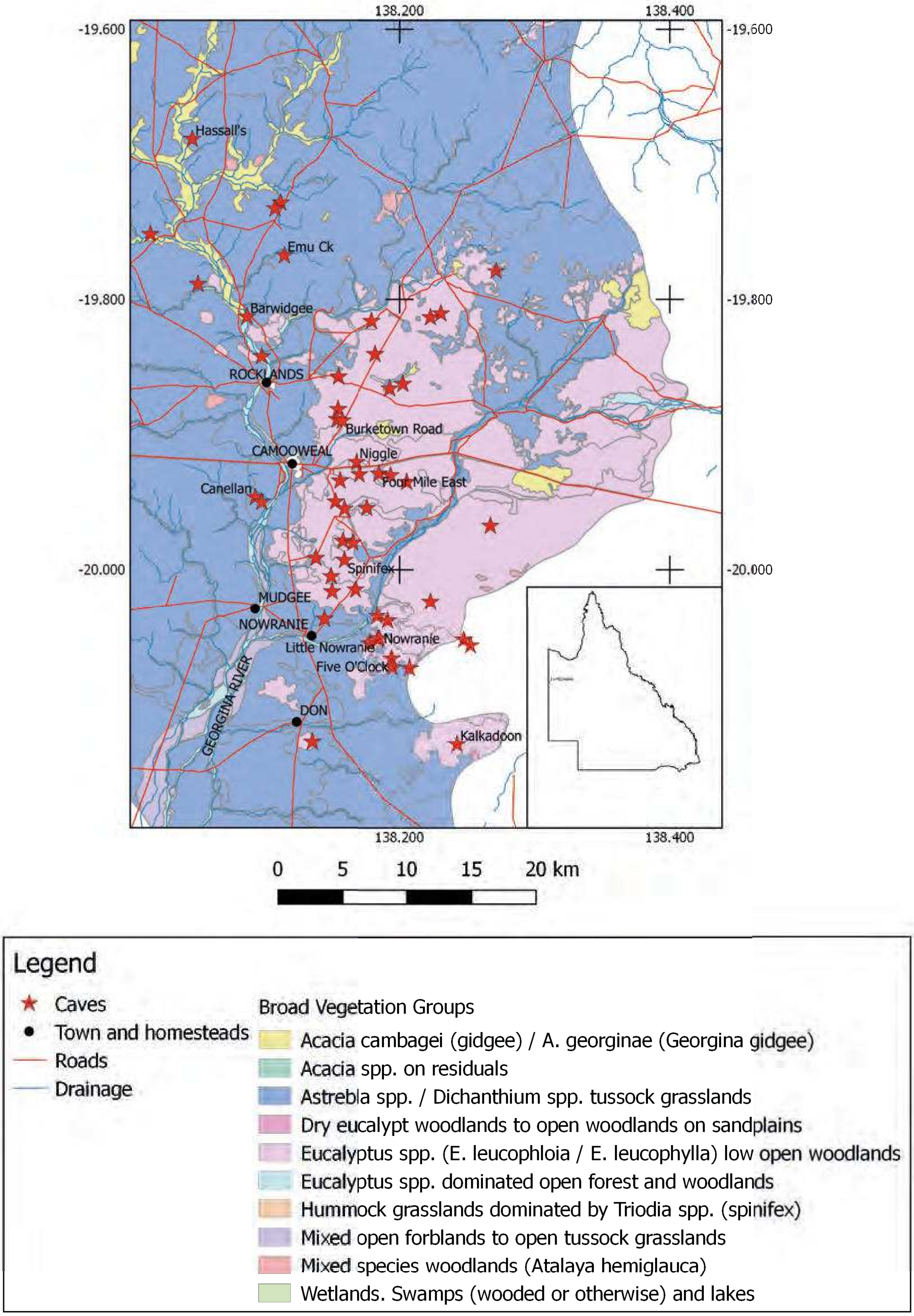

Figure 5. Distribution of Broad Vegetation Groups on the Camooweal Dolomite.

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				

References

Bradbury JH, Williams WD. 1997. The amphipod (Crustacea) stygofauna of Australia: description of new taxa (Melitidae, Neoniphargidae, Paramelitidae), and a synopsis of known species. *Records of the Australian Museum* 49: 249-341.

Daneš JV. 1911. Physiography of some limestone areas in Queensland. *Proceedings Royal Society Queensland* 23: 73-86.

De Keyser F. 1974. A review of the middle Cambrian stratigraphy in the Queensland portion of the Georgina Basin. *Bureau of Mineral Resources Australia, Bulletin* 139: 13-27.

Eberhard S. 2003. Nowranie caves and the Camooweal karst area, Queensland. *Helictite* 38(2): 27-38.

Edgoose C. 2003. *Barkly Tablelands Region, Northern Territory.* CRC Landscape Evolution and Mineral Exploration: Canberra.

Ford DC. 2004. Canada, In *The Encyclopedia of Caves and Karst Science*, ed. J Gunn, pp. 175-178. Taylor and Francis – Routledge, New York.

Gillieson D. 1993. Environmental Change and Human Impact on Arid and Semi-arid Karsts of Australia. In *Karst Terrains: Environmental Changes and Human Impact*, ed. P Williams, pp. 127-146. *Catena Supplement* 25: Cremlingen, Germany.

Grimes KG. 1985. Phanerozoic mapping in Northwest Queensland, 1983-1984. *Geological Survey Queensland Record* 1985: 41.

Grimes KG. 1988. The Barkly Karst Region, north-west Queensland. In *Proceedings 17th Biennial Conference of the Australian Speleological Federation (Tropicon), Cairns*, pp. 16-24. Australian Speleological Federation, Sydney.

Jennings JN. 1980. 'Spoil of the Old World's Farthest End' Does Distance Tyrannise Science? In *Of Time and Place: Essays in honour of OHK Spate,* ed. JN Jennings & G Linge, pp 72-94. ANU Press: Canberra.

Jennings JN. 1983. The disregarded karst of the arid and semiarid domain. *Karstologia* 1: 61-73.

Martini J, Kavalieris I. 1976. The karst of the Transvaal. *International Journal of Speleology* 8: 229-251.

Matthews PB. 1985. *Australian Karst Index*. Australian Speleological Federation: Melbourne.

Molnar RE, Hall LS, Mahoney JH. 1984. New fossil localities for *Macroderma* Miller, 1906 (Chiroptera: Megadermatidae) in New South Wales and its past and present distribution in Australia. *Australian Mammalogy* 7: 63-73.

QDNPRSR. 2013. *Camooweal Caves National Park Management Statement*. Queensland Department of National Parks, Recreation, Sport and Racing.

Queensland Herbarium 2016. *Regional Ecosystem Description Database (REDD). Version 10.0 (December 2016).* Queensland Department of Science, Information Technology and Innovation: Brisbane.

Shannon CHC. 1970. Revised cave list, Camooweal caves, 'Barkly Tableland'. *Down Under* 9(2): 37-44.

Sharples C. 2003. *A Review of the Geoconservation Values of the Tasmanian Wilderness World Heritage Area*. Nature Conservation Report 03/06, Department of Primary Industries, Water and Environment, Tasmania: Hobart.

Veen AWL. 1973. Evaluation of clay mineral equilibria in some clay soils (Usterts) of the Brigalow lands, *Australian Journal of Soil Research* 11: 167-184.

Viscarra-Rossel RA. 2011. Fine–resolution multiscale mapping of clay minerals in Australian soils measured with near infrared spectra. *Journal of Geophysical Research* 116: F04023.

Watson J, Hamilton-Smith E, Gillieson D, Kiernan K. 1997. *Guidelines for Cave and Karst Protection.* World Conservation Union (IUCN): Gland, Switzerland.

White AW, Morris I, Madani G, Archer M. 2016. Are Cane Toads *Rhinella marina* impacting Ghost Bats *Macroderma gigas* in Northern Australia? *Australian Zoologist* 38: 183-191.

WildNet 2017. *Plant and Animal Species Lists for Camooweal Caves National Park*. https://environment.ehp.qld.gov.au/report-request/species-list/, accessed 7 August 2017.

Williams PW. 2008. *World Heritage Caves and Karst.* Gland, Switzerland, IUCN.