AUSTRALASIAN CAVE & KARST MANAGEMENT ASSOCIATION JOURNAL

(Incorporating the ACKMA Newsletter)

No. 19

June, 1995

IN THIS EDITION: * Rehabilitation of the Ida Bay Quarry, Tasmania * ASF Minimal Impact Caving Code * 11th ACKMA Conference Reports * New N.S.W. Karst Conservation Act * Mt. Etna, Queensland * 12th ACKMA Conference at Waitomo.

EDITOR'S FOREWORD

Many ACKMA members attending at the recent *11th Conference on Cave and Karst Management* in Tasmania took the opportunity to visit and inspect the excellent rehabilitation work undertaken at the former Bender's Quarry at Ida Bay. This work is something of a benchmark for limestone quarry rehabilitation elsewhere and as such warrants careful attention.

The rehabilitation plan was developed by Mike Cooper (land rehabilitation officer), Helen Locher (scientific officer) and Ian Houshold (karst officer) of the Tasmanian Department of Environment and Land Management, assisted by karst consultants David Gillieson, Ken Grimes and David Shorthouse of the Commonwealth Department of the Environment.

On site work was supervised by Ian Houshold and Barry Batchelor (Ranger, Esperence District) with much of the revegetation work carried out by participants in a Commonwealth Government *Jobskills* program. One of the crew, Jason Hamill, is now employed by the Tasmanian Parks and Wildlife Service as the technical officer responsible for maintaining water quality monitoring equipment and records.

David Gillieson and Tony Veness (of the Australian Defence Force Academy) developed the water quality monitoring program, and Stefan Eberhard (presently a consultant with the NSW Parks and Wildlife Service) developed and is carrying out the ongoing fauna monitoring scheme.

My hope was to publish a major paper by Ian Houshold in this edition of the Journal, but unfortunately he has been so busy since the Conference that he has not had the time to contribute, despite his best intentions. Happily though, David Gillieson has been able to furnish the short paper which follows, and which gives a good overview of the work carried out.

REHABILITATION OF THE LUNE RIVER QUARRY, TASMANIAN WILDERNESS WORLD HERITAGE AREA, AUSTRALIA.

- David Gillieson

INTRODUCTION

Limestone has been quarried in Australia since 1798, but until very recently little or no treatment of the abandoned workings has occurred. Limestone and marble are used as high grade building stone, for agricultural lime, and for abrasives. Australia also produces about 6 million tonnes of cement annually, of which 5% is exported to Pacific countries. In Tasmania limestone from the Lune River quarry has been used as pH control in the electrolytic refining of zinc. Most resource conflict over limestone revolves around visual and water pollution, as well as loss of recreational amenity and conservation values. Most limestones in Australia are flat lying, have considerable overburden and often have the karst watertable close to the surface. Therefore limestone bodies with high relief are ideal for mining and are often the most cavernous. Most of these are found in the Eastern Highlands extending south into the island State of Tasmania.

Quarry rehabilitation is a rapidly growing field in Australia and at present three karst sites are being treated: Mount Etna in central Queensland, Wombeyan in southern New South Wales, and Lune River in the Tasmanian Wilderness World Heritage Area. The latter project is being funded by the Federal government under the World Heritage Properties Conservation Act 1983. The quarry overlies the Exit Cave system, and extensive and complex cave whose geomorphic and faunal values caused it to be inscribed on the World Heritage listing in 1989.

The Exit Cave system has 26km of mapped passages and has formed along three main genetic axes. Speleothems on high level sediments in Hammer Passage exceed the limits of U-series dating at c. 350,000 years B.P. The cave has been affected by glacial diversion of drainage waters on at least two occasions. (Goede, 1969), and it has captured part of both the D'Entrecasteaux and Lune River catchments in the past. There is extensive Devonian palaeokarst with sulphide mineralisation that has had a significant effect on karst processes. The cave is home to a rich terrestrial and aquatic fauna adapted to the continual dark and cold. In several places the walls are covered with awesome displays of glowworms which simulate the night sky. The cave fauna consists of more than 30 species, including 11 troglobites (Eberhard, 1990). There is a high degree of endemism in the fauna, and several species fall into the IUCN category of rare (Table 1).

A view over the former Bender's Quarry at Ida Bay, showing rehabilitation work.

A number of impacts have been observed in Exit Cave and its tributary caves as a result of the quarry operations (Houshold, 1992):

1. Removal of cave passages and their contents by quarrying.
2. Destruction of palaeokarstic fills by quarrying.
3. Increased sedimentation of fine clays in Little Grunt Cave (underlying the quarry) and the hydrologically connected Easter Passage of Exit Cave.
4. Recurrent turbidity in Eastern Passage and Exit Creek.
5. Changes in pH, conductivity and sulphate ion concentrations (to 150mg/L) in passages draining the quarry.
6. Re-solutions of speleothems by acidified drainage waters due to oxidation of sulphurs from palaeokarst fills.
7. Reduced densities of hydrobid molluscs (*Fluvidona* sp. nov.) in passages draining the quarry (Eberhard, 1992).

Because the continued operation of the quarry was producing these major geomorphic, water quality and biological impacts on the cave, the quarry was closed in August 1992 under World Heritage legislation. Following the preparation of a rehabilitation plan, a joint Commonwealth – Tasmanian team started active rehabilitation in April 1993 (DASETT – TasPWH, 1993). The challenge was then to rehabilitate the quarry and the affected parts of the cave without further impacting the karst values and ecosystems. Reshaping of the quarry by restoration blasting techniques was deemed inappropriate because of the sensitivity of both the geomorphology and the biology of the cave.

THE REHABILITATION PLAN

The primary objective of the rehabilitation has been to protect the World Heritage values of Exit Cave system by returning the ecosystem processes within the quarry area to as close as possible to their original state. The main issues for rehabilitation are the integrity of the underground drainage, its water quality and the cave invertebrate populations. A secondary objective has been to maintain a high degree of interconnected secondary porosity in the quarry for effective recharge and to simulate as much as possible the original polygonal karst drainage and its forest cover.

The key concept in the rehabilitation is the simulation of the high secondary porosity of a polygonal karst network at a range of spatial scales from that of the whole Exit Cave system down to the diffuse infiltration points within an area of $100m^2$. This hydrological approach is somewhat different to conventional quarry rehabilitation methods, which lay emphasis on the control of surface drainage, erosion control and aesthetics. Although these factors are also important at the Lune River Quarry, they are only a small part of the rehabilitation process. The maintenance of underground drainage, water quality and cave invertebrate populations are of paramount importance for the World Heritage values of Exit Cave.

To achieve these objectives the quarry was subdivided into a number of small closed drainage basins (0.1 to 0.2ha), each of which has a karst sink or infiltration zone (Figure 1). Each sink is protected by a filter structure, and areas under clay fans have additional structures to limit the movement of clay after rain.

Drainage control has been achieved by several methods. Impermeable bunds of clay and rubble have been constructed along the outer edge of the benches, about 500-1000mm high and 1000-1500mm wide. The height of these was based on analysis of the likely runoff from the 1 in 100 year rainfall event. These have been compressed with the excavator bucket to render them impermeable. Similar bund walls have been placed to subdivide the benches into 0.1-0.2ha internal drainage basins which simulate size of the depressions of polygonal karst (Figure 2) on adjoining Marble Hill. This simulation of natural karst drainage should be adequate to restore the dispersed nature of water flow into the Exit Cave hydrological system.

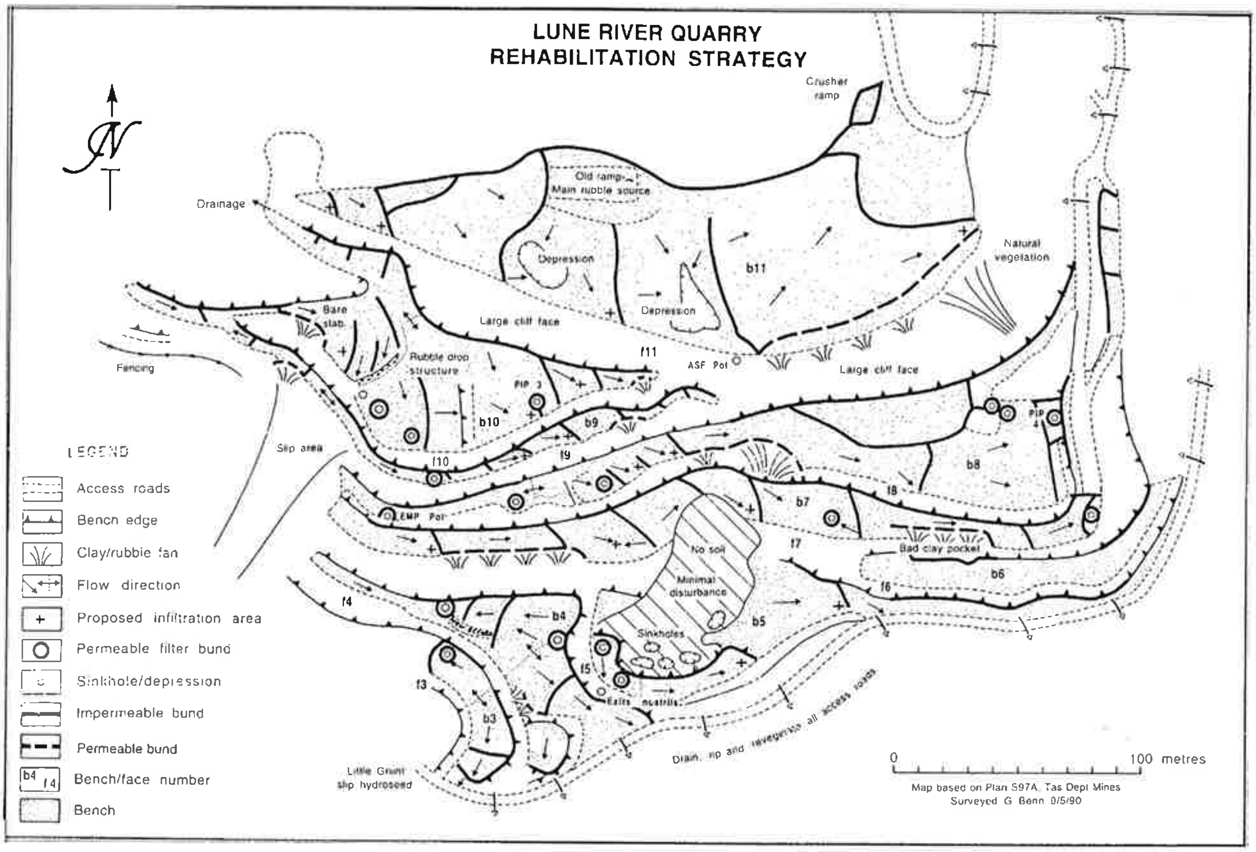
Following trials of different sink filter designs by I. Houshold and P. Bradley, the final design employed limestone blocks, a geotextile filter, crushed rock (20mm) and straw/mulch in order away from the sink point (Figure 3). Several additional water sink points became apparent when the highly compacted benches were ripped. On most benches open cavities were present up to 80m deep. These demonstrate the reality of open, direct hydrologic connections into the Exit Cave system over most of the quarry. Minor temporary turbidity in this water has been due to the localised leaching of silty fines from the gravel used in the permeable filter bunds.

The stabilisation of clay fans and cave fills on the benches has been achieved in several ways. First, the diversion of drainage from above by impermeable bunds has reduced gullying by overspillage. Where benches sloped steeply outwards, diffuse infiltration areas of mulch, gravel and straw bales have been constructed to slow water draining over the edge of a face into a gully. Secondly, hydromulching of steep clay fans has probably reduced the risk of rainsplash erosion liberating fine clays. This hydromulch is very thin (less than 5mm) but forms a stable, if not continuous, cover. Thirdly, the construction of permeable filter arcs below the clay fans has restricted the movement of fines on to the soil covered benches. Where some penetration of the filter arcs has occurred, hay bales have been emplaced as extra filters and appear to have been effective. Vegetative growth (especially of reeds and sedges) will replace these filters over time as the hay bales decompose.

The hydromulching was carried out using chopped ink-free newspaper, native seed and an appropriate low fertiliser level. Undyed wool fibre, normally a component of the hydromulch, was not available in time for the operation. Printer's ink, as used in newspapers, was found to contain significant concentrations of hydrocarbons which would pose a pollution problem if leached into the cave, and so unused newsprint roll ends were used.

ACKMA's new Executive Officer, Andy Spate, photographs an impermeable bund constructed in the restoration program.

Figure 1: Lune River Quarry rehabilitation strategy. From DASETT & TasPWH, 1993.



The final coating was between 2 and 5mm thick and effectively retarded erosion of the clays and loose rock faces over the wet Tasmanian winter. Mr. M. Cooper, the Land Rehabilitation Officer for the Parks & Wildlife Service chose to use a slow release fertiliser in the hydromulch at a level of application of 250kg/ha. This was applied to an estimated 0.9ha of steep faces and clay fans in the quarry where rapid vegetation establishment was seen as a high priority. According to a nitrate leaching model (Burns, 1975), this application would result in the following elemental concentrations in cave water.

Element:	N	P	K
Expected	0.90	1.24	0.55 mg/L
Maximum observed	0.60	0.013	1.20 mg/L

The observed concentrations were satisfactory and this rate of application was thus substantially less than the maximum value of 1.5ppm agreed to as the upper limit for nitrate-nitrogen concentrations in cave water without possibly impacting cave fauna. The high levels of potassium not preducted by the leaching model may relate to leaching of clays from the doleritic soils applied to the benches. In reality most, if not all, of the applied fertiliser should have been taken up by plants and immobilised by soil bacteria as the mulch breaks down.

On most benches a depth of between 200 and 300mm of sandy topsoil has been spread and mounded to give numerous small hollows and mounds for detention of rainwater. The clay content of this soil is less than 10% (from field texture) and it has a good humus content. Numerous roots are present in this material and is also a minor source of seed from branches of tea-tree (*Leptospermum* sp.) incorporated during clearance operations. The species used in the revegetation were as follows:

Acacia melanoxylon	*Acacia verticillata*
Bedfordia salicina	*Cassinia aculeata*
Eucalyptus nitida	*Eucalyptus obliqua*
Gahnia grandis	*Leptospermum scoparia*
Malaleuca squamea	

ACKMA members consider the rehabilitation work – Conference '95.

All these plants were collected in the vicinity of the quarry or came from the L18 biogeographic zone of the Tasmanian Forestry Commission, which includes the Lune River area (M. Cooper pers. comm. 3/5/93). The revegetation project will be reported elsewhere by Cooper and Houshold.

Safety is an important issue in any quarry. The rehabilitation plan indicated that the safety of rehabilitation workers would be ensured by the removal of loose or overhanging rocks from the edges of some benches. In general the decision about removal of rocks was guided by the following criteria:

a. blocks showing evidence of recent movement by block glide or toppling processes.

b. blocks on faces which were undercut to at least 50% of their depth and/or situated on steep clay slopes.

c. blocks showing major internal cracks at angles steeper than 30 degrees.

d. blocks on the edge of faces which were separated from the main rock mass by unloading joints and which had moved since January.

Wherever possible the mode of removal for small blocks was hand piking over the edge, and for large blocks clawing back onto the bench using an excavator. In some situations a narrow track was made to allow excavator access to unstable rock masses. An area of block gliding on unloading joints on the north extension of F8 was carefully evaluated and loose rocks removed. This area was about 10m long and overlooks PIP4 water sink. Monitoring of this area for further joint widening is being carried out routinely. Rocks gained from the cleaning of the bench edges were crushed for bund construction.

MONITORING WATER QUALITY

Only limited dye tracing experiments at the site has been carried out so far (Kiernan, 1993). All are low-flow traces using Rhodamine WT. IB47. National Gallery cave and PIP3 sink have fast positive connections to the Eastern Passage of Exit Cave. PIP4 sink has a fast positive connection to nearby Bradley Chesterman Cave. Flow directions at high flow are unknown and re-activation of fossil passages is quite possible, involving drainage capture in the upper parts of the quarry. Water quality monitoring in Exit Cave has been carried out in two ways, by spot water samples and automated sampling using dataloggers. Further Parks, Wildlife & Heritage staff were employed to assist with in-cave sampling at several sites at roughly three to four week intervals.

This has greatly enhanced the effectiveness of the monitoring programme. In addition to field measurements of discharge, temperature, pH and conductivity, samples are being taken for turbidity, total nitrate, total phosphate and major cations and anions. This will give a good set of data from which to evaluate the effectiveness of the rehabilitation programme. Recent sediment accumulations in the Eastern Passage of Exit Cave have been sampled and are being analysed for a 137 – Caesium profile which will provide an estimate of the rate of sedimentation.

The automated monitoring stations for Exit Cave are based on Datataker model 600 loggers and were installed in each of the Eastern and Western Passages. Each datalogger was connected to sensors or probes for flow stage, water temperature, conductivity, pH, and turbidity. At each site a Partech turbidity unit was used and set to record at hourly intervals on the rising stage of a storm event. There is a very good relationship between Partech turbidity readings (in NTU) and total suspended solids (Finlayson, 1985). Each datalogger has been downloaded at three to four week intervals, discharge measured and spot samples taken at that time for major cations and anions. The Western Passage site serves as a control as its unaltered catchment lies under primary cool temperate rainforest to the west of Marble Hill which overlies the cave. An additional YSI-6000 sealed datalogger with attached sensors for flow stage, water temperature, conductivity, pH, and dissolved oxygen has been placed in Exit Creek downstream of the Eastern Passage confluence. The sites in Exit Cave will be maintained for at least two years. The data will allow evaluation of the success of the rehabilitation programme in reducing the inflow of suspended sediments and excess anions (especially sulphates) into the Exit Cave system, as well as the restoration of natural percolation rates into the karst drainage system through analysis of recession hydrographs.

KARST REHABILITATION OBJECTIVES

Some objectives for karst quarry rehabilitation learnt from the Lune River project can be summarised below:

1. Restore the hydrology of the site by simulating as much as possible the drainage characteristics of the unimpacted karst. Reducing peak runoff by the creation of small internal drainage basins which simulate dolines in polygonal karst is an effective way of restoring near-natural infiltration rates and their spatially diverse patterning to allow soil and subcutaneous zone recharge.
2. Control sediment movement at the source by the use of control structures and filters, and construct adequate filters at streamsinks to prevent entry of sediment into the karst hydrological system.
3. Control active soil erosion and sediment entry to the karst system by stabilising the soil surface (using hydromulching on steep areas) and encouraging cryptogam growth which is the soil's first defence against erosion.
4. Establish a stable vegetation cover, preferably of perennial plants. A diverse vegetative cover with viable seed and the right structure to maintain geomorphic and biotic processes is not only aesthetically pleasing but in the long term will effectively moderate karst processes.
5. Get the soil biology working again. Allowing the colonisation of the site by soil biota, especially the colonial insects necessary for litter breakdown, will enhance the recovery of nutrient cycling and produce a good soil structure for plant seedling establishment and water infiltration.
6. Monitor progress above and below ground. The success or failure of the rehabilitation can only be assessed with meaningful data, preferably collected on an event basis so as to allow calculation of loads of solutes and sediments entering the karst drainage system.
7. Leave the site alone unless things go wrong. It is tempting to keep a very close watch, but each visit to the site has an impact, and vegetation growth is best assessed after a minimum of one complete growing season, preferably two.

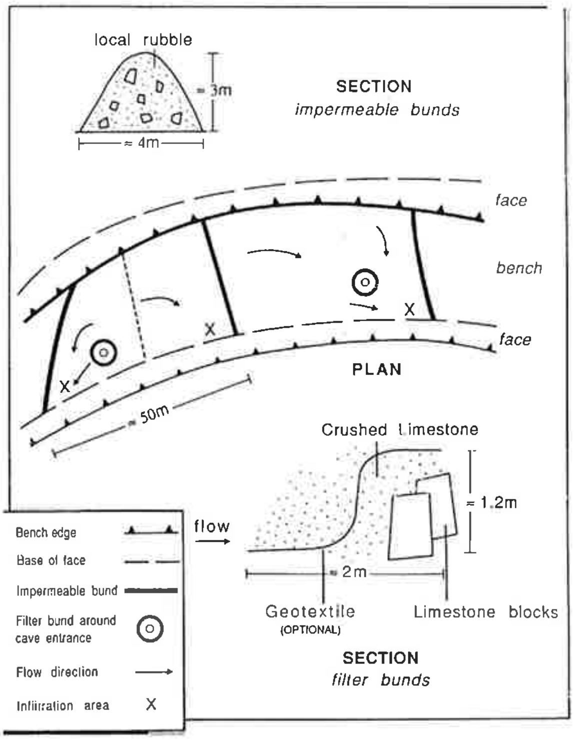


Figure 2: Layout and construction details of small catchment areas or bunds, Lune River Quarry Rehabilitation. From DASETT & TasPWH, 1993.

Note: this article is based on a chapter written by Ian Houshold and David Gillieson for the International Association for Hydrogeology publication *Karst Hydrogeology and Human Activities: Impacts, Consequences and Implications.*

REFERENCES

Burns, I.G. 1975. An equation to predict the leaching of surface-applied nitrate, *J. Agric. Sci.*, Cambridge, 85: 443-454.

Commonwealth Dept. of Arts, Sport, Environment and Territories (DASETT) & Tasmanian Department of Parks, Wildlife & Heritage (TasPWH), 1993. *Rehabilitation Plan, The Lune River Quarry, Southern Tasmania.* Joint report to World Heritage Planning Team, Department of Parks, Wildlife & Heritage, Tasmania, 26pp.

Eberhard, S. 1990. *Ida Bay karst study: the cave fauna at Ida Bay in Tasmania and the effect of quarry operations*, Report to World Heritage Planning Team, Department of Parks, Wildlife & Heritage, Tasmania, 25pp.

Eberhard, S., 1992. *The effect of stream sedimentation on population densities of Hydrobid molluscs in caves.* Report to World Heritage Planning Team. Department of Parks, Wildlife & Heritage, Tasmania, 8pp.

Finlayson, B.L. 1985. Field calibration of a recording turbidity meter. *Catena*, 12: 141-147.

Goede, A. 1969. Underground stream capture at Ida Bay. Tasmania, and the relevance of cold climate conditions. *Aust. Geogr. Stud.*, 7; 41-48.

Houshold, I. 1992. *Geomorphology, water quality and cave sediments in the Eastern Passage of Exit Cave and its tributaries,* Report to World Heritage Planning Team, Department of Parks, Wildlife & Heritage, Tasmania, 18pp.

Kiernan, K. 1993. The Exit Cave Quarry; tracing waterflows and resource policy evaluation, *Helictite*, 31; 3-12.

Author's Address: – David Gillieson, Department of Geography & Oceanography, University College, University of New South Wales, Canberra, A.C.T. 2601.

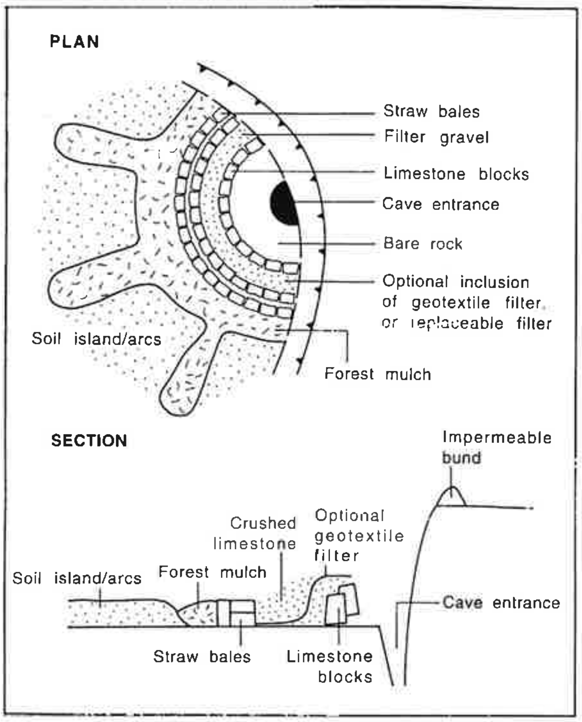


Figure 3: Layout and construction details of treatment of stream sinks and infiltration areas, Lune River Quarry rehabilitation. From DASETT & TasPWH, 1993.

Table 1: Some notable species of the Exit Cave fauna (from Eberhard, 1992).

Species	Life form	Endemic to karst	IUCN status
Arachnocampa tasmaniensis	glow-worm	No	vulnerable
Anaspides tasmaniae	syncarid shrimp	No	vulnerable
Eucrenonaspides sp.	syncarid shrimp	Yes	rare
Hickmania troglodytes	cave spider	No	rare
Olgania sp.	cave spider	Yes	rare
Hickmanoxyomma cavaticum	harvestman	Yes	rare
Idacarabus troglodytes	beetle	Yes	rare
Goedetrechus mendumae	beetle	Yes	rare
Pseudotyrannochthonius sp.	pseudoscorpion	Yes	rare
Micropathus tasmaniensis	cave cricket	Yes	rare
Styloniscus sp. nov.	isopod	Yes	rare