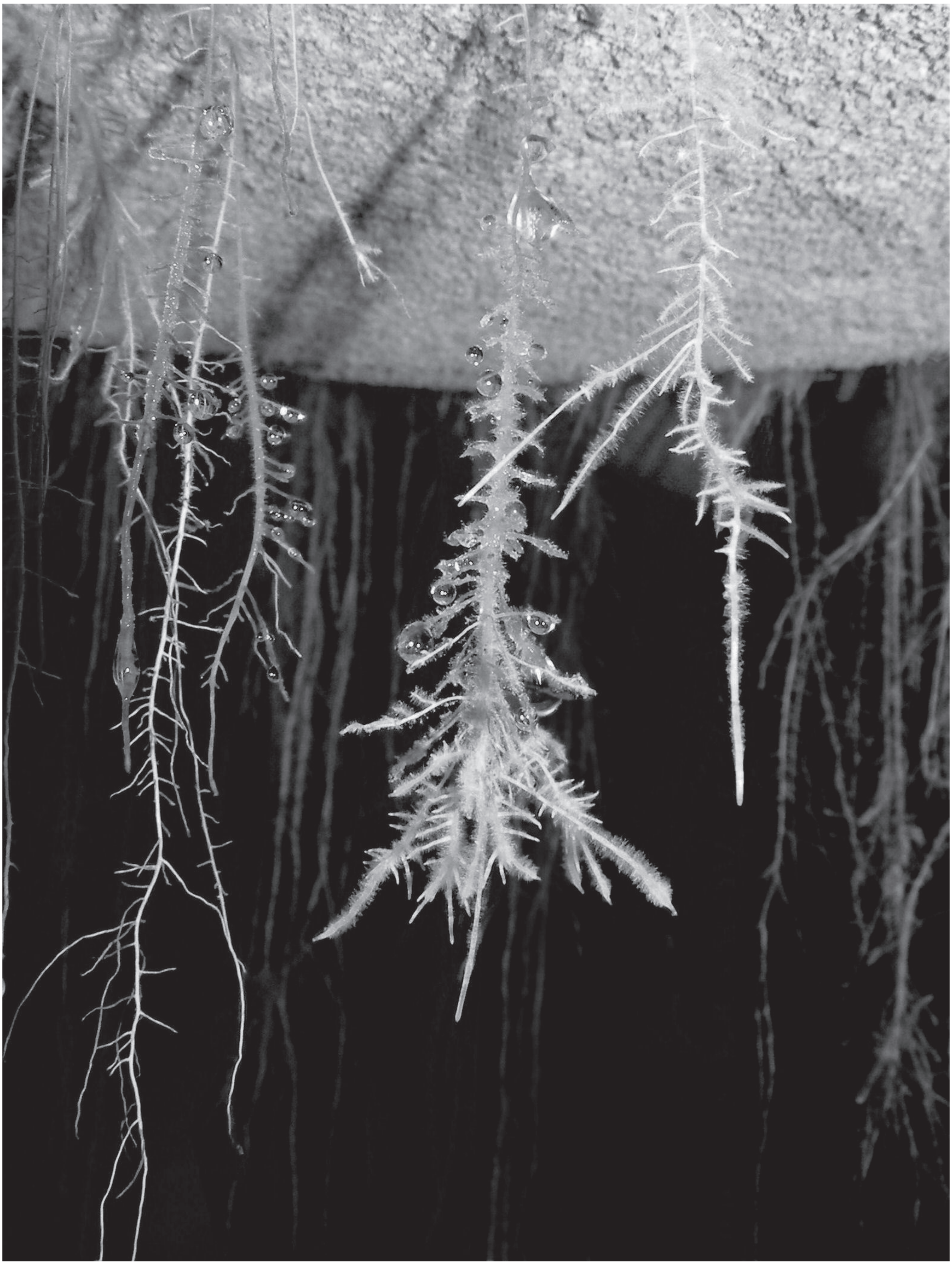
VOLUME 40 (2) 2011

Helictite

Journal of Australasian Speleological Research



Tree roots

Yvonne Ingeme

Helictite

Journal of Australasian Speleological Research

ISSN: 0017-9973

Helictite was established in 1962 by Edward A. Lane and Aola M. Richards, who were the foundation editors. It is intended to be wide ranging in scope from the scientific study of caves and their contents, to the history of caves and cave areas and the technical aspects of cave study and exploration. The territory covered is Australasia – Australia, New Zealand, the near Pacific Islands, Papua New Guinea and surrounding areas, Indonesia and Borneo.

In 1974 the Speleological Research Council agreed to support the Journal with financial assistance and in 1976 took over full responsibility for its production. From 1974 to 1997 the Journal was edited by Julia James assisted by other members of the Speleological Research Council Ltd. In 1998 Susan White and Ken Grimes took over as editors with Glenn Baddeley as Business Manager. Stefan Eberhard joined the editorial team in 2003.

In 2000 ownership was transferred to the Australian Speleological Federation, Inc. (ASF) and is administered by the Helictite Commission of the ASF.

The aim of the Helictite Commission of the Australian Speleological Federation is to publish the results of scientific studies in all fields of speleology in Helictite – Journal of Australasian Speleological Research, and other publications.

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Journal of Australasian Speleological Research
VOLUME 40 (2) 2011

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Cover: Tree roots in a South Australian dune limestone cave (5L-23). Photo by Yvonne Ingeme

Helictite, Volume 40, 2007-2011 consists of two issues. Price per volume is Aust. $27.00 post paid (Australia and New Zealand) and Aust $30.00 (rest of the world). "Helictite" is published by the Australian Speleological Federation Inc.

All correspondence to: 123 Manningham St., Parkville, Victoria, 3052, Australia.

This issue is published in March, 2011

Editorial

Ken Grimes & Susan White

After a long delay, for which we apologise, *Helictite* Volume 40 (2) contains papers on cave management at Jenolan, NSW, on Swiftlet colonies in lava caves of Samoa, a short note on cemented sand structures in a dune limestone cave, and two book reviews.

Looking to the future, *Helictite* volume 41 will be a special issue on the caves and karst of the Gregory-Judbarra Karst region. The dual name is a transitional one to facilitate web searches – the area is within the one-time Gregory National Park which is being renamed to Judbarra NP (pronounced jute-bra, and the spelling is still provisional) following its transfer back to its Traditional Owners. Papers are in preparation on the geology and geomorphology of the 120 km Bullita epikarst maze cave, the surface karrenfield, the cave biota, and the history of exploration and surveying.

Moving into the electronic age

Looking further into the future, we are considering a shift to purely online publishing. We already have the papers from Volume 36 onwards available as PDF files online at our website (details below). There is a proposal that we discontinue the printed volumes after Volume 41 and publish future papers individually on the web as they are completed, rather than waiting till we have enough to make a printed issue. This will reduce waiting time for authors and eliminate the major costs of printing and postage. The proposal is that the residual costs of editing, reviewing, layout, and maintenance of the website would be born by the Australian Speleological Federation. Print-on-demand copies would be made for a fee to those who request them, and existing subscription holders will be given the option of receiving such printed copies until their subscription runs out, or being given a refund. The published papers will be indexed by web search engines and would be freely available to all. Copyright would remain with the authors for the content, and with the ASF for the layout image.

The proposal will be discussed at the ASF council meeting at Chillagoe in April 2011. Comments from you, our readers, on this proposal would also be welcome. Email them to: ken.grimes@bigpond.com and susanqwhite@netspace.net.au

Helictite web page

The *Helictite* web site is part of the parent ASF site.

The URL is: http://www.caves.org.au/helictite/

The web site is maintained by our Business Manager, Glenn Baddeley. It provides subscription information, contact details, information for contributors, contents and abstracts for all issues of *Helictite* and complete PDF versions of all papers from Volume 36(1), 1998, through to the present

Helictite, (2011) 40(2): 27-34

Australia's crystalline heritage: issues in cave management at Jenolan Caves

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Abstract

This paper provides an environmental sustainability perspective on contemporary cave management issues in Australia through examination of Australia's most prominent tourist cave attraction, Jenolan Caves. Five key issues are discussed: the administration and funding of the Jenolan Caves Karst Conservation Reserve; the extent of baseline data available; long-term access and transport arrangements to the caves; visitor management; and the provision of interpretation facilities. Each of these illustrates the difficulty of balancing the competing values and interests represented by conservation, commercialisation and tourism. Cave management at Jenolan has improved in recent years but further changes in policy and management structures are required to ensure environmental sustainability.

Keywords: karst, tourist cave, management, Australia.

Introduction

Despite the significant natural heritage values of caves and their vulnerability to human impact, caves are seldom given the attention in environmental management and planning that such fragile environments deserve. Caves provide particular management considerations and unique challenges for their preservation, many of which hinge on broader issues of environmental sustainability. This paper examines the context of environmentally sustainable cave management practice in Australia using Jenolan Caves, New South Wales (NSW), as a case study.

Jenolan Caves exist within Australia's largest cave reserve and are the world's oldest currently open caves (Osborne et al., 2006). Highly accessible, heavily visited and well known, Jenolan Caves has a long history of tourism and conservation extending back nearly 150 years (Horne, 1994). Close proximity to Sydney and location within the tourism region of the Blue Mountains; the scenic value of the reserve including the caves, grand arches and forested valleys; and their historical overlay, make the caves of unrivalled interest to tourists. While Jenolan was not the first show cave opened to tourists in Australia, it was from here that the Australian cave tourism industry emerged (Hamilton-Smith, 2003: 160).

Growing pressure from tourism and development at Jenolan Caves reveals unreconciled imperatives of conservation and tourism and raises the question of whether current management practices are environmentally sustainable. Five key issues have emerged at Jenolan: the administration and funding of the Jenolan Caves Karst Conservation Reserve (the Reserve); the data and knowledge informing management; long-term access and transport arrangements to the Caves; visitor management; and adequate interpretation facilities. Despite the aspirations of management at Jenolan Caves to provide a model of best practice in environmental sustainability (DEC NSW, 2006), realising these ambitions is a challenging project.

Environmental sustainability and caves

Over the last two decades, 'sustainability' has emerged as a key goal of environmental management. At its core, it recognises that current world development trends are unsustainable and exceeding the carrying capacity of natural systems, with limits to growth increasingly evident (Harding, 2006: 230-2). Defined by the 1987 Brundtland Report, sustainable development can be understood as "development that meets the needs of the present, without compromising the ability of future generations to meet their needs" (WCED, 1987: 43). In terms of cave management, environmental sustainability emphasises the interrelated nature of economic, social and environmental factors, and the need for an integrated approach that recognises their interconnection and interdependency.

A number of policy and management issues identified in environmental sustainability (Dovers, 2005:44-51) are relevant to caves. Firstly, environmentally sustainable management may involve long temporal scales. This is apparent in cave management, where the development of caves occurs on geological timescales, essentially making them a non-renewable resource. Secondly, the land tenure system overlaying the natural environment has often not reflected the spatial extent of cave systems and this has hindered their appropriate management. Thirdly, cave management, like other areas of environmental sustainability, requires policy that is long-term in scope and inter-jurisdictional.

In addition there is the issue of shared responsibility for environmental resources. Where cave systems extend across different systems of tenure, there is potential for conflicts over who benefits from a resource and who pays the cost of any resulting environmental degradation. Threats to the natural values of caves can also be traced back to deeply rooted systemic causes, such as the failure of the market to correctly value the economic advantage of environmental goods and services, or allocate property rights for trading purposes (Dovers, 2005: 46). In addition, environmental sustainability often poses a difficult challenge for management, as change is often impeded by high associated costs (Dovers, 2005: 47, Howes, 2005: 176) and conflicting long versus short term goals.

Central to environmental sustainability is the notion of ecological thresholds, where human-induced changes can push a natural system beyond the point of recovery. Even where the explicit goal is environmental sustainability, cave management is often characterised by a degree of uncertainty. This can arise from a lack of basic information of natural systems, or of appropriate management responses to issues, and this uncertainty contributes to the potential for cumulative or irreversible environmental degradation to occur. This is evident at Jenolan Caves where there is insufficient baseline information to determine the visitor capacities of cave systems. This, in turn, presents a challenge for management. In the face of scientific uncertainty, policy responses need to minimise risk and be proactive rather than reactive (Harding, 2006: 235).

Environmental sustainability issues are also multidimensional. Environmental problems cannot be effectively treated in isolation from their wider economic and social context. Community involvement in environmental management is important to ensure land-use and resource decisions reflect the diverse range of actors, interests and values involved in managing caves (Hall, 1999: 280).

With environmental sustainability in mind, a range of practical measures are implemented in caves to rejuvenate cave systems, slow degradation, improve presentation and enhance visitor participation. At Jenolan, such measures have included high-pressure water cleaning, low-heat lighting, and tracks designed to contain and channel water run-off. The need for collaborative partnerships between stakeholders, to adequately protect the cave system and the wider water catchment and environmental system of which it is a part, has also been recognised. Forums for each of the scientific, speleological, historical and staff interests at Jenolan are well established.

The unique challenges of caves

Caves have some unique management considerations that make them a particularly important case study for environmental management (Gillieson, 1996). Firstly, due to their subterranean nature and complex three-dimensional structure, caves are often difficult to see and conceptualise. Secondly, caves are subject to direct impacts from sub-surface human activity, and vulnerable to surface impact and activity in the wider catchment and surrounding land (Watson et al., 1997). Thirdly, cave management is about protecting both non-living and living elements of a cave system.

Current approaches to conservation are mainly based on protecting biodiversity, with geological natural heritage, like caves, traditionally protected under legislation primarily for their value as habitat for species (Osborne, 1989). Tourism in protected areas often includes some appreciation of wildlife (Burns, 2006, 2009); however, the focus of cave tourism is very rarely inclusive of cave fauna. Opportunities for viewing some of the more specialised cave fauna, such as troglobites, is probably reduced by their retreat from show caves, and the less sensitive fauna of caves, such as bats, spiders and crickets have only limited appeal to tourists. The non-living elements of the cave, their chambers and speleothems, are the main attractions for cave tourism (Gillieson, 1996).

Management issues at Jenolan Caves

Early records indicate that the Jenolan Caves were first known to Europeans around the 1840s and by the 1860s improved access and increased information about the Caves saw a substantial increase in visitors (Horne, 1994: 8-25). The Fish River Caves (as the Jenolan Caves were then known) became a public reserve in 1866 when increasing land alienation was recognised as a potential threat to public access to the caves. Access was considered important because of the caves' scenic and potential scientific value (Horne, 2005: 245-7). The gazetting of the caves as a reserve marked an early move towards nature conservation, occurring six years before the world's first national park was proclaimed. It also made Jenolan Caves the first government-owned tourist attraction in Australia (Environment Australia, 1998: 156). The caves became a model for other developing tourist caves and management still aspires to provide a best-practice model of cave tourism and development (DEC NSW, 2006: 20; Horne, 2005: 250). Increasing tourism and development has placed growing pressure on the show caves at Jenolan that currently operate within a rapidly changing management environment. Five key management issues that have emerged are discussed below.

Management Issue One: Administration and Funding

One of the most crucial issues at Jenolan Caves is the administration and funding model for the Reserve. The Reserve, like other public-owned protected areas, has been subject to persistent under-resourcing and under-funding. A number of administrative arrangements have been implemented since the establishment of the Reserve in 1866 in an ongoing search for a model that is financially self-sustaining and profitable, but also environmentally sustainable; protecting the resource upon which tourism to the Reserve is dependent and for which the area was initially protected. These models can be divided into four main time periods: (a) prior to 1989, (b) during the 1990s, (c) during the 2000s, and (d) the current model.

(a) Models prior to 1989

A traditional public service model dominated prior to 1989 when the Jenolan Caves were managed by a succession of NSW Government departments (Austen and Griffin, 2007: 37). This changed in 1989 when the Greiner government established the Jenolan Caves Reserve Trust (JCRT), a statutory government authority, to manage Jenolan Caves as well as the Abercrombie and Wombeyan cave systems. The Reserve's first management plan was released in the same year (Cameron McNamara Consultants, 1989) and the last of various increases to the area of the Reserve was made. This alteration to the reserve boundary was determined by the need to protect the catchment area of the Jenolan Underground River.

(b) Models in the 1990s

In 1990 Silkbard Pty Ltd (an entity of the Peppers Group) took up a 99 year lease of the hospitality services, including Caves House and other accommodation, food outlets, and the souvenir shop (Clennell, 2006; DEC NSW, 2006: 26) Responsibility for administration of the lease was shifted to the NSW Government and separated from that of cave operations managed by the Trust (Austen and Griffin, 2007: 36). Silkbard Pty Ltd was purchased by the Field family in 1995, and the administration of the lease and cave tourism operations were brought back together to be managed centrally by the Trust.

The Trust's responsibilities were expanded in 1997. A fourth cave system, Borenore, was added to the management responsibilities of the JCRT without additional funding from the State Government. Consequently the limited revenue from visitor charges and lease payments at Jenolan Caves subsidised management of Abercrombie and Borenore and, to a lesser extent, Wombeyan Reserve (Austen and Griffin, 2007: 37; Jenkins (MLC) in NSW LC, 2005). As a result, the Trust had difficulty recovering enough financial resources to fund conservation initiatives and infrastructure development and improvements needed at Jenolan Caves. Additionally, a regional decline in tourism in the Blue Mountains, amongst other factors, placed further financial strain on the Trust. Visitor numbers dropped significantly over a ten-year period, from over 250 000 in 1994 to 214 000 in the 2002 to 2003 financial year (DEC NSW, 2006: 55; JCRT, 2003: 3).

(c) Models in the 2000s

A review by the Council on the Cost and Quality of Government was commissioned in January 2004 (Austen and Griffin, 2007: 38; Beeby, 2006: 4) after the Trust experienced a financial loss of approximately $380 000 (AUD). This led to a series of changes to administration of the Reserve. In October 2005, an amendment to the National Parks and Wildlife Act 1974 was passed that included provision for the transfer of Abercrombie, Borenore and Wombeyan to the National Parks and Wildlife Service (under the New South Wales Department of Environment and Conservation (DEC)), with the intention that the Jenolan Caves Reserve would follow. The Act also established a specialised State Karst Advisory Unit, located within DEC, to provide expert guidance on management of NSW's significant karst areas.

In December 2005, the 99-year lease for Caves House was placed in receivership. This followed conflict between the lessee of Caves House and the Government over provision and responsibility for infrastructure upgrades in the Reserve (Frew, 2007; Harwin (MLC) in NSW LC, 2005; Trute, 2005). Caves House returned to government control in 2006, but not before the number of guests staying at Caves House dropped significantly reflecting visitor dissatisfaction, as evidenced by over thirty letters of complaint sent to the Minister, and the hotel business being likened by the media to the notorious 'Fawlty Towers' (Cohen (MLC) in NSW LC, 2005; Gibbs, 2006; Silmalis, 2005).

The NSW Government once again reconsidered the management model for the Reserve and its assets, deciding that an administrative model based on a public-private partnership (PPP) would be most appropriate. The main problem with the PPP model in place until 2006 was the tensions arising from the Trust being both a commercial operator (of the caves) and a regulator (of the Caves House lease), and from its inability (as a self-funding model) to directly access Treasury funding for capital improvements.

In August 2006, the Jenolan Karst Conservation Reserve Draft Plan of Management was released for public comment. Shortly afterwards, a tender was released, calling for expressions of interest for private sector participation in the management and operation of activities within the Visitor Use and Service Zone (VU&SZ) of the Reserve. Specifically, it called for private sector "operation, management, protection, maintenance and marketing" of Caves House (under a much shorter lease of 21 years), and also the show caves and adventure caves (under a 7-year license) (JCRT, 2006: 5-10). It was hoped that these changes would see reduced cost and increased efficiency with the integration of services under one operator, with the government in a regulatory role (Austen and Griffin, 2007: 38). The tender received a poor response from the private sector and, as a result, the Caves remained managed by the Trust with input from the Karst Management Advisory Committee while long-term arrangements were finalised (Grant Commins, Manager of Cave Operations at Jenolan Caves, pers comm., 15 July 2007). The conflict between the government and the ex-lessee of Caves House was played out in the Industrial Court of NSW in 2007 (Frew, 2007), and a final version of the management plan is yet to be released.

(d) The current model

The changes of administration at Jenolan Caves raise a number of important issues. Concerns were raised that the outsourcing and commercialisation of operations at Jenolan Caves would see the caves' natural and heritage values compromised in the pursuit of profit. This reflects tensions between values of stewardship and commodification in cave management (Davidson, 2004: 170). However, significant effort was made in both the current management plan and the tender to outline the environmental standards required, as well as performance indicators and monitoring requirements for the lease and license arrangement. The second reading of the National Parks and Wildlife Amendment Bill shows that the proposed changes in administration at Jenolan Caves were intended to provide an opportunity "to get commercial operations right", as a new model of best practice PPP in the management of protected areas (Cohen (MLC) in NSW LC, 2005).

Management of the caves under a private operator would be subject to the same environmental, heritage and planning legislation that protects the caves at present. However, there was concern from speleologists that existing legislation did not provide enough protection to the caves in the face of commercial over-exploitation (Osborne quoted in Beeby, 2006: 5). On the other hand, the lack of private sector response to the tender may reflect the extent of environmental conditions imposed on the lease and license that was offered. While the environmental conditions were important for environmentally sustainable management of the caves as a tourist destination, a highly regulated scenario may have been less attractive for private enterprise due to the additional complexity imposed on the operator. This raises the question of the relevance of a PPP in management of the caves, when the regulations required to protect them potentially deter the private sector, with fewer regulations being more attractive for private interest.

The model currently in place sees government control reasserted. Caves House and the caves have been retained by the Trust while the Department of Environment, Climate Change and Water (DECCW, formerly DEC) has taken responsibility for the non-karst areas of the Reserve (Austen, 2009:4).

The question of who is best placed to manage the caves – the government or the private sector – is both political and ideological. Public authorities have traditionally managed protected areas (Worboys, et al., 2005). However, increasing pressure on government resources and perceived efficiency of the private sector has seen a growing role of private sector involvement in protected area management (Fowke, 2005: 120-123). Jenolan Caves offers an ideal case study for an on-going inquiry into the implications of public and private management models of protected areas. Speleologist Andy Spate commented on the recent events at Jenolan Caves, saying: "You'd be surprised how political the Jenolan Caves, and caves in general, can be…There's a doctoral thesis in there somewhere, but mind you, whoever tried to write it would probably be lynched" (Spate quoted in Beeby, 2006: 4). Austen and Griffin (2007, 2009) provide insights into the recent events at Jenolan, but so far there has been little other scholarly analysis.

Management Issue Two: Insufficient baseline and applied data

Management of the Jenolan Caves is hindered by a lack of baseline data on environmental conditions of the caves, as well as applied data on the impact of tourism on the Caves or their carrying capacity. In part, this may reflect a management policy that actively discouraged scientific investigations in the show caves (Kiernan, 1988: 7). The management model in place for over 50 years, prior to the first management plan in 1989, operated during a period when innovation was not embraced, and scientific research and evidence-based policy development was not encouraged. Lack of baseline data also reflects inadequate funding of the Reserve. Without this essential information it is difficult to manage for environmental sustainability.

Changes post-1989 go some way toward addressing this problem. For example, a Scientific and Environmental Advisory Committee was established in 1990, and in its 1993/1994 Annual Report the Trust noted concern "about the lack of coordinated monitoring of the increasing visitation". An $80 000 grant was obtained toward a consultant report, and a survey of fauna and human impacts was undertaken in 1993. In 1995 a resource data bank was established to assist management decisions, the same year a Visitor Impact Monitoring (VIM) process was implemented (Hill and Pickering, 2008). A Social and Environmental Monitoring (SEM) committee was established in 1996 and replaced by the DECCW Karst Management Advisory Committee in 2006. In 1998 a consultant report was commissioned on in-service and other training needs for guides. More recently, with funding from the NSW state government, the JCRT has embarked on an Environmental Monitoring Program that focuses on air and water quality in the show caves (Meehan, 2009).

Despite an increase in involvement of universities, publication of site-specific research papers and theses (for example, Michie, 1997; Campbell, 1998; McArthur, 2000 and Davidson, 2004), as well as extended professional education of staff (Cove, 2009), more research is required. The current draft management plan identifies many research and management gaps. It also discusses prospects for establishing institutional research partnerships with universities to increase research on the caves (DEC NSW, 2006: 112). Whether future research at the caves will be tourism focused or directed towards conservation of the caves, in terms of understanding these karst environments and the upper limits on tourism, remains to be seen.

Management Issue Three: Access and transport

Access and transport arrangements to Jenolan Caves present another set of environmental issues. Most people visit the caves as part of a coach tour of the Blue Mountains, or by private vehicle travelling along the Two-Mile Road from Oberon, or the more commonly used Five-Mile road from Hampton. Following safety concerns and closure of the 5-Mile Road, the NSW Roads and Traffic Authority spent a considerable sum of money on its upgrade (DEC NSW, 2006: 62). However, the road passes through the Grand Arch, in which several entrances to show caves are located, raising concerns of the effects of vehicle emissions on the Caves and their inhabitants (Manidis Roberts Consultants, 1995: 8). A study by Hose, et al. (2002) indicated that a recorded decline in a species of spider common to the Grand Arch was likely a result of increased dust from the passing vehicles. Despite indicators that the road and the increasing number of vehicles may be compromising the environment of the caves, management has not as yet responded with mitigating action. This raises questions about their ability to effectively apply the ‘precautionary principle’ stated as a key commitment in the caves’ management philosophy and which is fundamental to environmentally sustainable management (DEC NSW, 2006: 2).

Increased vehicle traffic has also placed considerable strain on the Reserve’s existing infrastructure. As a result of traffic congestion in peak season, the 5-Mile Road has been made one-way at certain times of the day. At present, the number of car park spaces limits the number of visitors to the Reserve, and there is little prospect of easily increasing parking spaces given the location of the caves in a narrow valley surrounded by steep sides (Manidis Roberts Consultants, 1995:18). Management has attempted to accommodate more vehicles by placing additional parking bays further up the hill, and running shuttle buses to transfer people to the caves. This has the flow-on effect of dispersing human impact and development in the Reserve. Multiple car parks are also visually intrusive and detract from the scenic amenity of the Reserve, a key listed management value. The development of car parks alters natural drainage patterns in the valley, affecting karst landforms in the Reserve. Given the physical limitations of space in the valley, it seems inappropriate to give such priority to car parking when space is crucial for the development of a visitor interpretation centre. In some ways, this places revenue above education. Provision of public transport access (of which there is currently none) would address some of these issues and is critical to the long-term sustainability of the caves as a tourist destination.

A study was commissioned in 1994 by the Trust to examine future transport options for the Reserve (Colston, Budd, Hunt & Twiney Pty Ltd, 1994). Options explored included road upgrades, and the provision of shuttle-buses, a light rail system, or a novelty aerial cable-car transport system (which attracted considerable media attention). A tender was released for the cable-car option, but it was not developed due to concerns about its initial environmental impact, and significant development and user costs. Some of the transport issues discussed above can be identified in the literature as far back as 1988 (Cameron McNamara Consultants, 1989: 25-35; Kiernan, 1989), indicating the scale of the challenge for resolving transport arrangements for Jenolan Caves. Sustainable transport is currently listed in the 2006 draft management plan as a high priority management issue (DEC NSW, 2006: 95).

Management Issue Four: Visitor management

The presence of visitors, and the infrastructure provided for them, both have potentially negative impacts on the cave environment. However, tourists also provide much-needed revenue to manage the caves for their long-term conservation, as well as justifying their protection in the face of competing interests in limestone landscapes (such as mining, agriculture and forestry, water exploitation, and urban development). In the light of this competition, visitor numbers to the caves need to be delicately balanced with the conservation values of the Reserve to avoid short term over-use of the caves and degradation of the environmental resource on which the cave tourism industry is financially dependent.

In addition to degrading or destroying the caves, tourism has the potential to cause other unintended environmental, social, and economic problems. Recent marketing initiatives have seen visitor numbers increase by 1.45%, from 221 864 people in 2007/2008 to 225 076 in 2008/2009 (Austen, 2009:3). The tension between conservation and tourism interests at Jenolan Caves has been described as the ‘paradox of conservation’ (McArthur, 2000: 12; O’Brien and Watson, 1977). While varying visitor management models have been developed in an attempt to institutionalise environmentally sustainable tourism in show caves, the practical application of any model is difficult to put in place because of competing financial and environmental tension.

Management Issue Five: Interpretation

Interpretation is important for promoting, understanding and appreciating a protected area, as well as enhancing visitor experience (Worboys et al., 2005: 484-492). Site interpretation can significantly influence behaviour through increased awareness of the conservation values of caves, and the threats to them (Davidson and Black, 2007). As stated in the 2006 Draft Management Plan (DEC NSW, 2006), the caves are recognised as a significant educational asset for the community and their interpretation is essential for promoting values of environmentally sustainable tourism.

Several layers of interpretation, both on-site and off-site, are needed to cater for potentially diverse audiences.

At Jenolan Caves, these include the use of print and broadcast media, a newly upgraded website, the use of signage within the VU&SZ and guided tours of the caves. Building on the initiatives between 1989 and 2006 and on a consultant report in 1998, the current management has improved the calibre of guides employed and improved their morale and professional development opportunities. On-site interpretation of the caves, however, is heavily reliant on the guides who, although providing a quality service, do not replace the need for an upgraded visitor centre and improvements to signage within the Reserve.

Despite the high visitor numbers to the Reserve and its World Heritage status, the existing visitor centre and museum is arguably well below the standard expected. Figure 1 illustrates some of the information displays provided in the visitor centre. Refurbishment of the existing visitor centre and museum facilities, described as a "dowdy old-fashioned tourist attraction that had seen better days" (Beeby, 2006: 4), may assist rejuvenation of the caves as a tourist destination. Such rejuvenation occurred at the Naracoorte Cave system in South Australia where an impressive interpretation centre was developed that included, for example, animatronic life-size models of the prehistoric megafauna found as fossils in these Caves. At Naracoorte, the new facilities prompted visitor numbers to increase by eighty percent in the year of its opening. Some of the unrealised potential at Jenolan is evident here: despite having much better facilities, Naracoorte receives substantially fewer visitors than Jenolan (DEH SA, 2001: 15).

Interpretive signage could easily be improved at Jenolan Caves. Many visitors congregate in the same area while waiting for tours to commence, where facilities include a paved and covered area with picnic tables (Figure 2). While signage exists (Figures 3 and 4), the opportunity to provide basic interpretive material about the caves and karst features of the Reserve has been missed. Such simple measures may see the information of the natural values of caves and karst landscapes communicated to more people, and add to the visitor experience of the Reserve.

Figure 2: Main waiting area for cave tours

Figure 3: Cave tour timetabling board for visitors

Figure 1 (above): Information display in the Jenolan Caves Visitor Centre in 2007

Figure 4 (right): Signs displayed for visitors indicating appropriate behaviour on cave tours

Conclusion

Management at Jenolan Caves has a complex history, and in 1989 Kiernan wrote that the scope of management initiatives needed for the caves was "daunting" (Kiernan, 1989: 130). Over the past 20 years many management issues have been addressed, but many more still remain. Encouragingly, Austen and Griffin (2009) recently claimed that "extensive work examining management options to best ensure the commercial and environmental sustainability at Jenolan has been undertaken". The current management model is in its infancy; its ability to deliver best practice in environmental sustainability has not yet been demonstrated but it has the potential to offer a positive way forward.

This overview of management issues in one of Australia's largest tourist cave systems can inform decision making for the management of less complex sites both within and outside Australia. The long-standing nature of the issues discussed above at Jenolan Caves reflects their complexity, and the practical difficulty of managing the competing values and interests represented by conservation, commercialisation and tourism. It is hoped that the new direction of management outlined by recent events will see some of these issues resolved, and the caves better managed for environmental sustainability as a model for other cave systems, and more generally, other protected areas.

Acknowledgements

This study was originally completed as part of an honours project supported within the Griffith School of Environment. The authors acknowledge the assistance provided by the Environmental Futures Centre at Griffith University, as well as support from Dr M.A Smith. Thanks also to Dr Richard Hindmarsh and Mr Casey Fulton for their time and advice on early drafts, and Dr Ian Bytheway for later stage editing. Photographs in Figs 1-4 are by M. J. Smith, July 2007.

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White-rumped Swiftlet Breeding Colony Size and Colony Locations in Samoa

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Abstract

This paper describes the breeding and roosting caves used by the White-rumped Swiftlet (*Aerodramus spodiopygius*) on Upolu and Savai'i, Samoa. Because these sites tend to be permanent and often difficult to locate, their locations and other information to help find them are provided as a guide for future workers. This study lasted four years and followed close after two devastating cyclones (Val & Ofa) so the data can form the basis for further study once the populations have fully recovered and equilibria for the populations is reached.

Keywords: Aerodramus spodiopygius, Swiftlet colony, Lava caves, Samoa

Introduction

Swiftlets are smaller members of the Swift family [Apodidae] and like the larger members they fly all day without landing except to incubate eggs and feed young when breeding. Although they do not migrate like many of the swifts, swiftlets in the genus *Aerodramus* can echolocate accurately enough (albeit using audible frequencies) to build nests in totally dark portions of caves. The best-known swiftlets are probably the two species that produce edible nests in South-east Asia and are of great economic importance (Lim and Cranbrook, 2002). They both nest in large caves such as Niah Cave in Borneo: one (*A. fuciphagus*) producing a white nest from pure saliva and the other (*A. maxima*) adding breast feathers to the saliva to produce a "black" nest.).

The White-rumped Swiftlet (*Aerodramus spodiopygius)* is the most widespread swiftlet in the South Pacific, extending from Queensland, Manus and New Britain through New Ireland, Bougainville, Solomon Islands, Vanuatu, New Caledonia, Fiji, Niue, Tonga, and Samoa. The swiftlets on Atiu in the Cook Islands, Tahiti and the Marquesas are closely related though no one has made definitive comparisons with either morphological or DNA tools. Although the nominate subspecies was described from Samoa (Peale, 1848) it was not studied subsequently in that country prior to this (Tarburton, 2009). Peale, who was the first to describe the species, was taken to a single cave by the newly appointed and just arrived British Consul, where "he collected … birds and reported on … nests" and suggested that the clutch size was probably one (Peale, 1848).

Since then ornithologists have visited caves containing breeding colonies but have made very few useful observations mainly because almost all visits were one-off events made by persons unfamiliar with swiftlet behaviour and usually not well equipped to work in cave situations. An historic summary follows to help place the little published work in perspective.

- Whitmee (1875) visited a cave on 25 November 1874 where the "Cave Swallow" was plentiful and concluded from finding only young in the nests and none containing eggs, that the swiftlet "must breed very uniformly".
- Rollo H Beck observed swiftlets and 50 nests built of moss in a 300 foot-long lava cave near the Maloleilei Rest Home [7][1] six miles inland from Apia (Beck, n.d). This was 23-29 April 1924 and "fresh eggs and young swifts of all sizes as well as fresh nests were seen". There is some confusion here, for Correia, who worked with Beck, states that "Mr Beck found young swifts at Savai[i] island in Samoa, but never any eggs" (Correia, n.d.).
- Armstrong (1932) did not agree with Whitmee's assertion that their breeding was very synchronised. He recorded that the breeding season seemed to be from November to June; and that by the end of June the birds "had practically forsaken the tunnels".
- Crossin (Univ. Kansas Museum Records per David Seibel) found new empty nests, nests with eggs, and nests with young at all stages on 6 November 1968 in Tafatafa Cave [2]. Some were 275 m from the cave entrance (Crossin & Seibel, 1986).
- Dhont (1976) reported visiting a cave that contained 50-100 nests and, looking into eight nests, repeated Peale's (1848) assertion that the normal clutch size appears to be one. He recorded moult in breeding birds and claimed that they possibly bred all year round. Dhont said that cave was near Aleisa. I could not find anybody in Aleisa who knew of a cave anywhere near there, so he may have been speaking of one of the Lower Falemauga caves [11,12]. In reference to possibly the same cave Cedric Schuster directed me to ask the people at the Sliding Rock to tell me how to find the cave he had visited near there; but they claimed ignorance of such a cave.

1 Numbers in square brackets refer to the cave descriptions given in Tables 2 & 3.

- David Blockstein while working on the Tooth-billed Pigeon in northern Savai'i, following information from R. Crossin and D. Seibel (1986), visited Ofisa Plantation and Aopo Caves [24] collecting swiftlets and recording measurements and moult data (Blockstein, 1987).

These constitute the best records made prior to this study. Lovegrove (*pers comm*) from the University of Auckland, New Zealand while helping with Samoa's Biodiversity study visited O le Pupu Pu'e cave [1] in the National Park of the same name on 29 June 1982. He estimated that there were hundreds of birds nesting on the cave walls but none on the overhanging ceilings.

Muse & Muse (1982) recorded that several large swiftlet colonies on Upolu contained thousands of birds and this was confirmed by the villagers who led me to caves, commonly making the comment that prior to the cyclones there had been "thousands" or "many birds" in the caves. The cyclones that severely reduced the swiftlet populations were cyclones Ofa (Feb 1-3, 1990) and Val (Dec 6-9, 1991). Ofa passed 80 km west of Savai'i and with its winds reaching over 200 km/hr "less than 1% of forest remained unscathed in the eastern third of Savai'i" according to a Spot Satellite image taken two weeks after the event (Elmqvist et al., 1994). From a study of the two Forest Preserves on Savai'i (Elmqvist et al., 1994) it was found that they suffered 28% tree mortality and another 33% after Val.

Val passed over the Islands of Samoa, performing a loop as it did so, and with winds up to 240 km/hr completely defoliated the trees making up the canopy and sub canopy, as well as de-blossoming them and snapping off many twigs and branches (Epila-Otara, 1996). What this did to swiftlet numbers can be estimated by comparing a pre-cyclone and post cyclone census of two caves in American Samoa. The pre-cyclone census (Enbring & Ramsey, 1989) estimated 11,000 White-rumped Swiftlets and 10,000 Polynesian Sheath-tailed Bats (*Emballonura semicaudata*) occupied two caves in Anape'ape'a Cove on Tutuila. The post-cyclone census of the same two caves found only 20-30 swiftlets and one bat (Grant, 1993).

I began my surveys in 1994, three years after the cyclones, at which time the effects were still obvious by the large numbers of dead and damaged trees, the small size of the swiftlet colonies and the disappearance of most of the colonies of the Polynesian Sheath-tailed Bat. This bat is known as *Tagiti* by older Samoans and often confused with the swiftlet and called *Pea'pea'* or *Pea' pea'vai* by most Samoans.

Swiftlets occupy their natal cave site for roosting during the whole year and although this makes it easier to study some aspects of their behaviour it makes them vulnerable to human interference and sometimes vulnerable to specific predators. Their big brothers the swifts cannot echolocate, but as most swifts migrate, the reliability that predators might enjoy in finding them at one site throughout the year is reduced. Swiftlets do not have the protection that migration provides, but most echolocate and they nest up to one kilometre from the light of a cave entrance, thus increasing their chance of survival. All swiftlets use saliva to construct their nests, with most species building much vegetable matter into the structure. The White-rumped Swiftlet lives in compact colonies in Australia, Tonga and Fiji but in dispersed colonies in the Cook Islands. In Samoa at the moment it practices both strategies.

Methods

Contrary to what some Samoans told me, as some believe that lava is only found on Savai'i and not on Upolu, all major breeding sites of the White-rumped Swiftlet located in Samoa were in lava-tube caves or collapses and erosional fissures associated with them. Some caves are short and low while others are more than a kilometre long and may contain chambers estimated to be 45-50 m in height.

All these caves were mapped to ASF grades between 22 and 33 (ASF, 1999). The large caves of Salamumu #1 [9] & Aopo Cave [24] were mapped at ASF grade 33 with the main passage measured by cord and marker stations. All caves less than 100m were mapped at ASF grade 22, while intermediate-length caves were mapped at ASF grade 32.

The approach was to ask colleagues, acquaintances and village people about the location of caves near particular villages. This was a slow process and it took time to locate caves containing White-rumped Swiftlets. It helped to use the Samoan name for the birds – *Pe'a pe'a*. However, it proved useful to ask for the insectivorous Polynesian Sheath-tailed Bat (*Emballonura semicaudata*), *Tagiti,* as it was sometimes known and not always differentiated from the bird. It was also useful to ask for any caves, as it appears that the swiftlets previously used all caves and even rock overhangs and even now most caves contain a remnant of a swiftlet colony.

Most caves in which White-rumped Swiftlets nest are known as Pe'a pe'a caves or *Ana Pe'ape'a*, and therefore, although a useful name to know when seeking local help in locating caves, is not useful in distinguishing one from the other. Therefore I have used the name of the nearest village to identify caves. There is usually someone in each village who will know the whereabouts of the nearest cave, but they may not speak English and they may not be there when you want them. This means a lot of time can be spent in locating these caves. It is hoped that this paper will help solve some of these problems for future visitors and researchers.

In Samoa a person's name holds more importance than in European society and one of the reasons for this is that knowing the names of your ancestral lineage is proof of land ownership. Knowing the names of the relevant persons who own land or are related to the land-owner where a cave is located, is important to gaining a guide and access, hence some names are included in Tables 2 & 3. More detailed directions to some caves are held by the author. It is foolish to try looking for these caves without permission and a guide.

Swiftlets nest in the twilight zones of some caves as well as the totally dark zones of most caves they inhabit. This study shows just how small some of the colonies became after the cyclone but also measures the subsequent rate of colony growth in those caves that were re-visited. In the census data the term “current nests” is used for nests that contain moist (shining) saliva. The majority of such nests contained an egg, a pink naked young or a black-feathered young. Particularly in some of the smaller colonies additional data are reported as ‘roost sites”. These were identified by the presence of dinner plate-sized guano deposits on the cave floor. These sites were considered current if they contained the white component of the bird’s faeces as it was determined that the white colour remained for only 1-2 weeks after defecation.

Results

The Bird

The White-rumped Swiftlet is mid-range in size for swiftlets. It is about 110 mm long and has a wing-span of 275 mm, of similar size to the Pacific Swallow (*Hirundo tahitica*), but weighs 9 g, 4 g less than the swallow. Detailed dimensions are given in Table 1. As with most Apodids, this species was found to forage for invertebrates over a wide area. They could be found at any part of the main islands, though they concentrated over forests more often than cleared, farmed or occupied land. Unlike the swiftlets on Borneo (Medway, 1962) which concentrated their populations in a few large caves and then flew long distances to cover the forests of the island, Samoan birds breed in a wide scatter of populations, at least some of which used to be large but after the cyclones are all small. Harrisson (1976) spent 350 hours, mostly in helicopters looking for swiftlets only to find that on some occasions “the great mass of birds [was] not visible within 10-25 miles” of their nesting cave at Niah, Borneo. Samoan birds in contrast, do not have to travel that minimal distance to cover the whole of even the largest island (Savai’i), and their colonies are scattered over both islands.

Green moss-lined nest containing one egg.

This reduction in travel time to feeding grounds is proposed as one reason that Samoan birds did not leave their colonies until after sunrise and had all returned well before sunset, despite their ability to echolocate. By contrast, swiftlets in Borneo started leaving prior to sunrise and the greatest rate of return was 56 minutes after sunset (Medway, 1962). Another reason for the shortened foraging time of the Samoan birds could

Table 1: Details of White-rumped Swiftlet measurements

	Mean	***sd***	**Range**	***n***
Weight	9.03 g	0.93	6.6-12.3 g	170
Wing	119.3 mm	2.54	111-125 mm	165
Outer Rectrix	53.7 mm	2.2	46-59 mm	116
Central Rectrix	48.0 mm	2.0	44-55 mm	108
Length	109.9 mm	2.19	107-114 mm	19
Wing Span	273.2 mm	9.3	254-291 mm	18
Culmen	4.4 mm			1
Exposed Culmen	3.85 mm	0.23	3.5-4.2 mm	13
Head	17.3 mm	5.9	18.6-21 mm	4
Mid Toe	5.6 mm	0.8	3.8-6.4 mm	13
Mid Claw	3.9 mm	0.6	3-5 mm	12
Tarsus	10.3 mm	0.4	9.7-11.2 mm	12

be their smaller clutch size of just one. Birds from Fiji (Tarburton, 1986a,b) and Cook Island (personal observation, Dec. 1987 and Jan. 1988), leave their caves well before sunrise and most do not return to roost until after dark with some birds still returning at 11.30 pm. Both these swiftlets have broods of two.

Because caves are mostly difficult to find and there is no centralised caving or other body that might be interested in guiding ornithologists to these caves, I see value in recording the location of the caves I found as well as information about the cave and the location and size of the swiftlet colonies that inhabit them. The caves are described in the order in which I located them on each of the two islands (Tables 2 and 3).

Discussion

In the limestone caves of Queensland, Tonga and Fiji, the White-rumped Swiftlet nests in aggregations where the nests may sometimes be four deep on the cave wall (Smyth et al., 1980; Tarburton, 1986b, 1988a). This is the high density nesting strategy. They prefer elevated overhanging smooth surfaces where land-based mammalian and reptilian predators cannot reach the nests, and they mass their nests into a few of these areas. In the two caves that are used on Atiu in the Cook Islands, the nests are usually scattered metres apart, probably because their major predators are two species of crabs that can climb to almost all parts of those caves (Tarburton, 1990). These crabs appear to be best avoided by scattering the nest sites in a low density nesting strategy that reduces the chance of an individual nest being located and predated. The Samoan subspecies of the White-rumped Swiftlet is the only known population to utilize both high and low density nesting techniques. This may be due to the absence in some caves of really safe nesting surfaces with smooth rock overhangs that prevent predators such as rats, cats and pythons from reaching the nests. The varied behaviour may also result from the low population densities brought about by cyclones Val and Ofa, but this is less likely as reports prior to the cyclones did indicate high density nesting in some caves. Because some colonies nest on low ledges it is clear that predatory selection pressures have not forced all birds to roost in the ceilings of the tall caverns with smooth ceilings.

Some of the Samoan lava tube colonies inhabit caves with some of the smallest entrances I have found anywhere in the South Pacific. Samata-i-uta Sea Cave [38] and Falemauga Large Cave [4] also have the lowest ceilings beyond which I have found swiftlets nesting anywhere in the South Pacific.

Regarding the Polynesian Sheath-tailed Bat, I located only five individuals in 2 of the 41 caves surveyed in Samoa, and the population of 5 appeared to have declined to 2 over the 4 years I visited that cave. This bat also disappeared from caves on Rota and three other Mariana Islands, and declined drastically in Fiji and American Samoa (Tarburton, 2002; Esselstyn et al., 2004; Utzurrum et al., 2006). It is possibly only common now on Palau & Aguiguan (Hutson et al., 2001; Esselstyn et al., 2004).

Subsequent to my studies and without knowing about them Greg Middleton (2003) visited caves in Samoa 19 June to 8 July 2002. Besides publishing his diary, maps and photos he recorded comments about the approximate size of swiftlet populations. These were either “occasional swiftlets” or “many swiftlets” or “swiftlet nests” and/or “guano”. By using these comments to compare with my data, we can make some general statements about the status of some of the colonies as for 2002.

Between 1994-97 and 2002 it appears that White-rumped Swiftlets declined in Malololelei [7] and Letui [22] Caves; were still present in Anaseuao [19], O le Pupu Pu’e [1] and Aopo [24]; and had increased in Tafatafa [2], Satuiatua [32], Salamumu #2 [10], & Salamumu #3 [16]. Middleton visited three caves that I did not, and found many swiftlets in each of them. These were Tapueleele, Leos Cave at Patamea, and Short Peoples Cave at Paia.

Acknowledgements

I thank all the land owners mentioned in the text who gave permission to enter their caves and the guides for their time and knowledge. I also thank Greg Middleton and Charles Collins for their meticulous refereeing work on the first draft and Susan White for going the second mile in her editorial duties.

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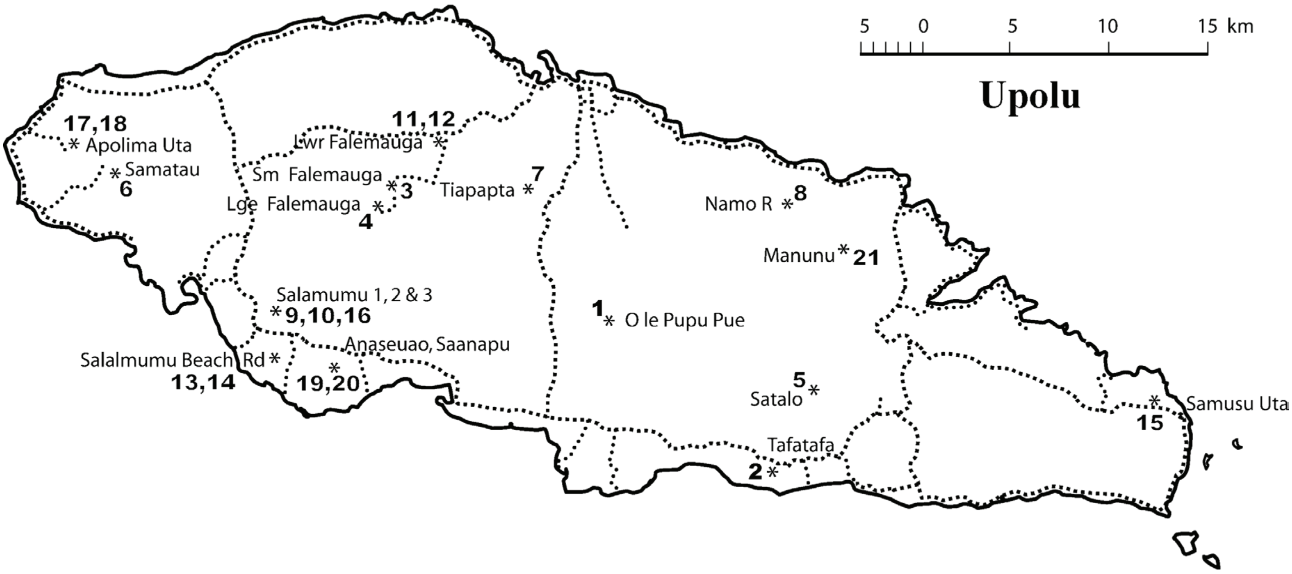
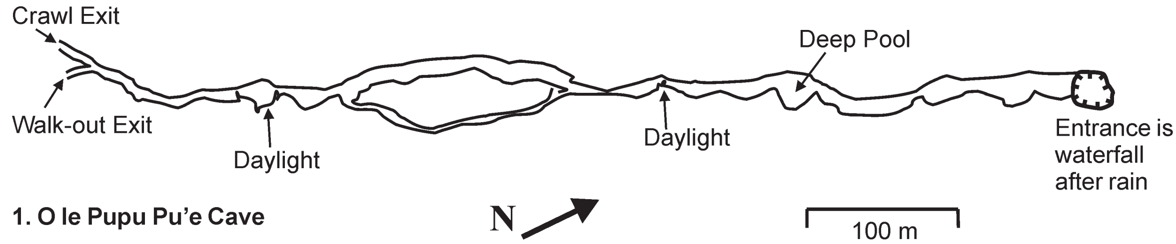


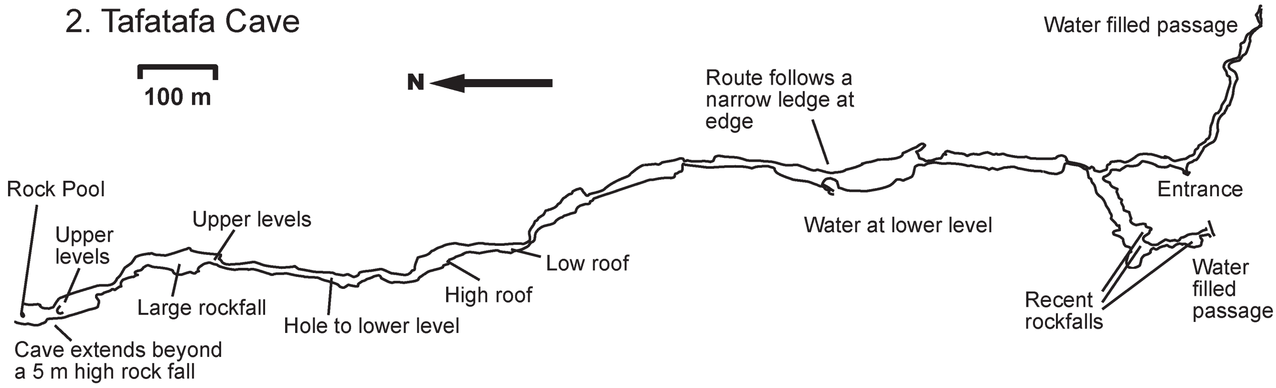
Table 2: Site descriptions – UPOLU

Cave	Location and Access	Cave Description	Colony Information
1. O le Pupu Pu'e	The best-known cave on Upolu, often shown to overseas visitors by the National Parks staff and guides, (available through the National Parks Department). Located in the O le Pupu Pu'e National Park on the north side of the main road. Access via a track (two hours walk) or Government Beef Farm (45 min walk). See also map in Ollier and Zarriello (1979).	A branch of the Tafitoala River runs through this cave and after heavy rain can make it dangerous to enter. At the upstream end the cave is up to 7 m high and 15 m wide and the deep pools can be waded carefully on the left hand side. There are 4 "daylight" openings, the third and the last can be used to exit. There is one 40 m long anabranch. The total length is about 650 m.	6.3.1994 – 9 nests in current use, all before the third daylight opening and none close together. 31.3.1994 – 23 birds mist and hand netted (DC & MT); total colony size estimated at about 27 birds. 14.10.1996 – increase to 72 nests; all were still located before the third daylight opening. Although Middleton (2003) mentions that he saw his first White-rumped Swiftlet in this cave he gave no indication of how many were encountered.



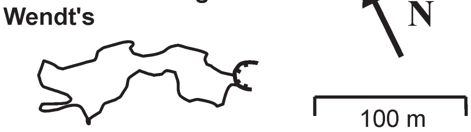
2. Tafatafa	The entrance is a 1.5 m hole behind the Tafatafa Village shop (now derelict, Middleton, 2003). Permission to enter the cave is obtained from the owner David Peterson at Matareva Beach. Visited by Iliffe & Sarbu (1990) and Middleton (2003).	This is a 1.8 km long branching tube. To the right is a 400 m conventional lava tube; the diameter decreases and it fills with water. The left is more complex. The first 100 m is a small tube which descends to a 70x10 m chamber. To the far left, a climb up to a very loose passage leads to another chamber. The immediate right is a 0.5 m high, 10 m long wet duck or crawl (depending on water level) opening into a large passage, which bends left and narrows before a chamber with fallen rock. On the far side, a negotiable but narrow ledge on the right wall allows access to more cave. See map on next page...	27.5.1994 – 1 nest downstream (to the right) of the entrance, (now destroyed); 9 nests in use to the left. 20.12.1994 – increased number of nests to 13. 6.8.1997 – increased number of nests to 18 Large swiftlet guano piles in the tube beyond the ledge were estimated to be about 5-8 years old. The former large colonies in this section of the cave had been reduced to one nest only, on my last visit in 1997. Even though Middleton (2003) did not visit all of the cave he recorded many swiftlets at 2 sites indicating that the colony has increased significantly.

2. Tafatafa Cave

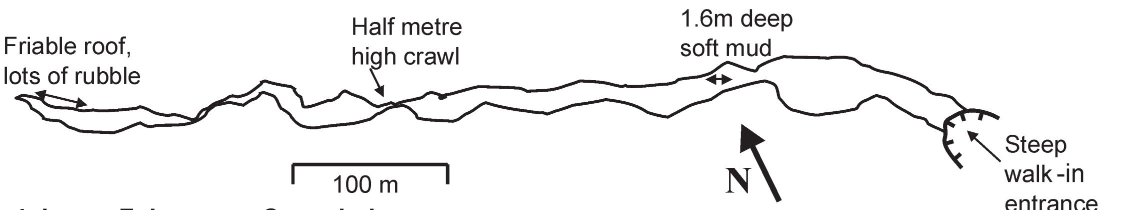


Cave	Location and Access	Cave Description	Colony Information
3.Falemauga – Small Cave (Wendt's)	This cave is on Dr Wendt's property on the north side of the University of the South Pacific's farm "Lalonea". His permission is needed to visit it.	The cave entrance is a 3 m high, 4 m wide opening in the bottom of a 5 m deep slump. The cave narrows to 1x2 m and then enlarges to 2 m before narrowing and sloping down to a larger terminal chamber.	11.9.1994 – 24 active nests scattered the full length of the cave. This cave was censused monthly for 2 years (1994- 1996) and the colony size remained constant. On my last visit (27.10.1997) there were 31 active nests indicating a slight increase.

3. Small Falemauga Cave: Wendt's

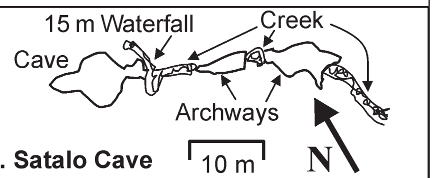


Cave	Location and Access	Cave Description	Colony Information
4.Falemauga – Large Cave	Located on "Lalonea", the University of the South Pacific farm property. Permission obtained at the Alafua Campus. It is a 300 m walk to the cave entrance: a large hole about 14 m across with a steep slope into the large lava tube.	190 m inside, the cave levels off and narrows where the soft mud is shoulder deep. This can only be crossed on the far left if there has not been any heavy rain for about 2 weeks. The cave is 545 m long, reducing to a 0.5 m high crawl at 265 m from ~13 m in height. It terminates in rubble and unstable roof. Just inside the entrance is a stone sleeping platform.	11.9.1994 – at least 57 nests prior to the crawl. 9.7.1997 – 49 nests before the crawl and 33 after it; a total of 82 nests. This decline in nests before the crawl illustrates the variation that can occur in these colonies. From rat tracks in the mud and the pile of flight feathers at the crawl, it was evident that rats were catching swiftlets at the crawl and were the likely cause for the decline..



4. Large Falemauga Cave: Lalonea

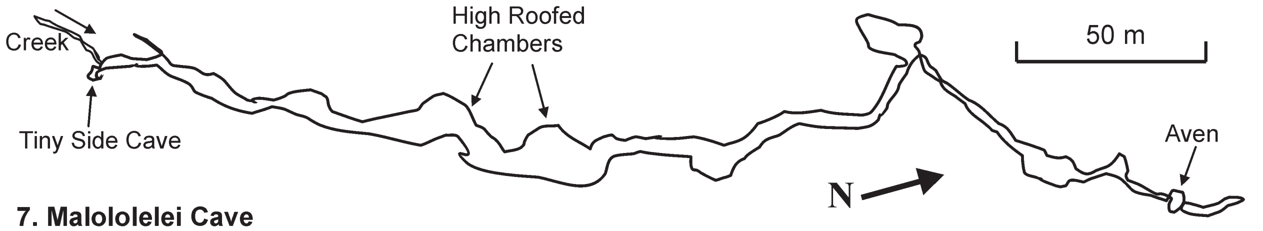
Cave	Location and Access	Cave Description	Colony Information
5.Satalo Cave	David Peterson (Matareva beach) is the best guide. A track to the village heads inland 750 m east of a concrete culvert on the round-island road. A total walk of 1.7 km. The cave is 50 m below 2 arches and behind a waterfall, access is via the right bank.	Water does not currently flow through the cave so the guano can be quite deep. The cave is only about 60 m long and is nowhere totally dark.	Prior to the cyclones the 2 arches were covered with swiftlet nests (D. Peterson, pers com.) 15.9.1994 – 28 nests on the arches. The total number of nests was 103, many of which were less than 3 m from the floor.



5. Satalo Cave

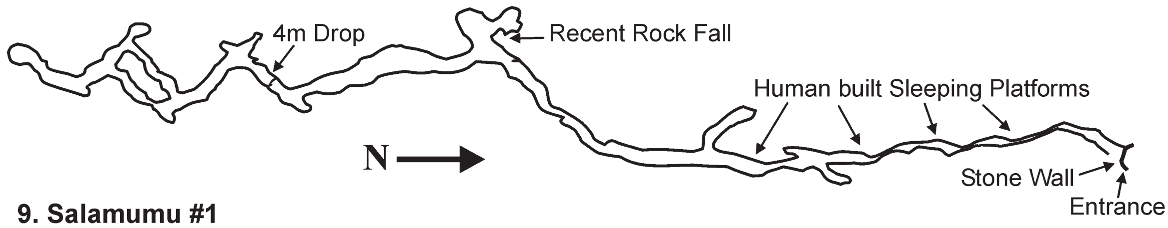
Cave	Location and Access	Cave Description	Colony Information
6. Samatau Cave	About 5-6 km along the road heading inland, 250 m east of Samatau SDA Church, Access permission and guidance from Mr Asaua Fitu at the single house.	The cave is 43 m long with the ceiling not far above head height.	12.12.1994 – 9 active nests all in the twilight zone.

Cave	Location and Access	Cave Description	Colony Information
7.Malololelei (Tiapapata) Cave	Permission should be gained from the Methodist Church Office, above the Methodist Bookshop on Beach-Front Road, Apia. The best guide is Moi who lives on the main Cross-Island Road at Afiamalu. Middleton (2003) mapped this cave.	The creek flows through the cave. The main cave passage averages ~6 m in height with several larger chambers (roof height maximum ~ 9 m). 40 m before the cave ends and ~280 m from the walk-in entrance, is a spectacular 10 m high smooth-walled aven (daylight opening) with tree ferns providing a picturesque second entrance for the swiftlets and insectivorous bats. The cave extends significantly beyond the collapse pit (Middleton, 2003) but the passage can be full of mud from about 40 m beyond the pit. Just to the right of the obvious 10 m diameter main entrance is a small squeeze into a 10 m long cave (Tiny Side Cave). Labelled “hole 2.5 m up wall” by Middleton (2003) on his map.	Tiny Side Cave – 1 occupied nest 1 m from the floor, each visit. In the main cave, nests from 3-8 m above the cave floor appear sporadically on suitable parts of the walls of the main cave from about 30 m inside until 20 m before the spectacular opening at the far end. No nests occurred after that opening during the period of my visits. 28.5.1995 & 1.10.1995 – 83 nests 16.11.1997 – 108 nests Sadly Middleton (2003) only mentions swiftlets just inside the entrance to this cave. There used to be a lot more further in.



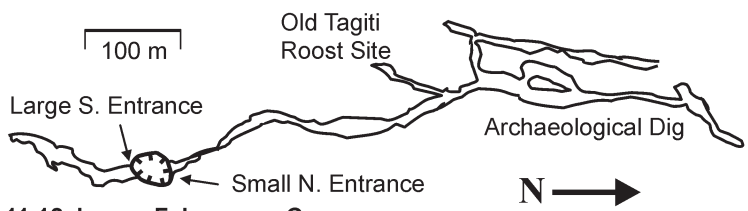
7. Malololelei Cave

Cave	Location and Access	Cave Description	Colony Information
8.Namo River Cave	A rock overhang on the true right bank, 30 minutes walk up river from Solosolo Village. The owner (Liasi) lives in the fale by the east side of the bridge across the Namo River, edge of Solosolo and is happy to show visitors if he sees you have a genuine interest.	The two big cyclones caused landslips that half filled the cave so the roof is now just above head height.	26.5.1995 – 2 active nests and white droppings at 3 other sites indicating a colony of about 7 birds; 6 were circling the entrance.
9. Salamumu #1 Cave	The lady owning the cave lives 250 m west of the cave on the inland side of the road near a wide car park. Mapped by Iliffe & Sarbu (1990) and visited by Middleton (2003).	The natural entrance is 2 x 3 m and has been infilled by a solid stone wall with a narrow opening. Inside there are extensive stone sleeping bunks and mollusc remains indicating past occupancy. One stone axe head was found and was taken by David Butler to the Environment Department. Short extensions occur left and right after the highest sleeping platform. The cave is a complex tube and the main tube extends for 1.5 km, although Iliffe & Sarbu (1990) mapped 3487 m. Cave surveyed and mapped 25.6.1995 by M. Tarburton, K Tarburton, D. Butler.	1,000 very old swiftlets nests clearly pre-dating the cyclones estimated.. 1.6.1995 – 1 swiftlet, 1 current nest, 2 birds roosts. 25.6.1995 – 2 active nests and 1 dead nestling on the cave floor.

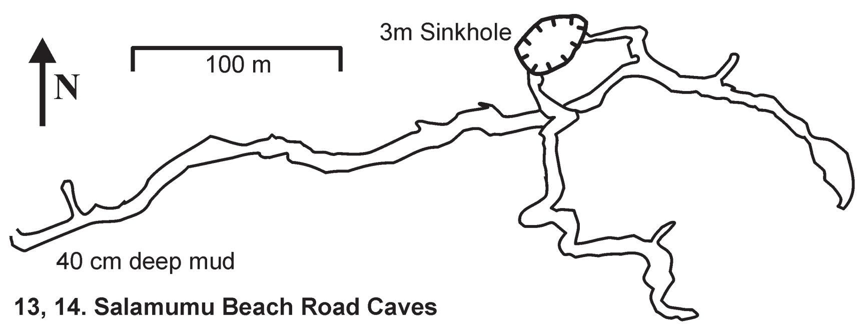


9. Salamumu #1

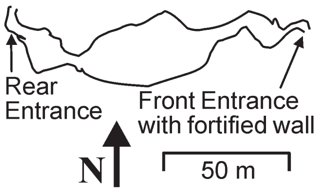
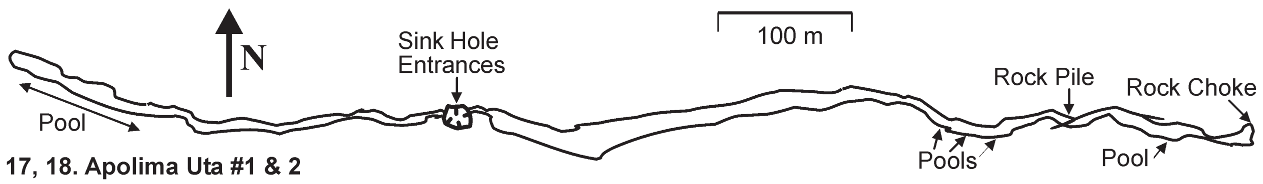
Cave	Location and Access	Cave Description	Colony Information
10. Salamumu #2 Cave	This cave is 40 m from the land owners' home and is one third full of their rubbish and when I pointed out three swiftlets flying into the cave entrance they could not believe birds would nest in there.	A small cave which tracks under the road and at right angles to it, but does not open on the south side. Traversing the rubbish pile poses a hazard.	1.6.1995 – 3 widely spaced nests in current use. Middleton (2003) recorded lots of swiftlets and their guano so this colony appears to have increased. I wonder if flies from the rubbish provide extra food to the swiftlets. They do eat flies (Tarburton 1986a, 1994).
11, 12. Falemaunga Caves	These caves are located on Kitona's property and he can usually be found in the Apia Market. Steve Brown of Ecotours Samoa can also gain permission and lead people to it. These caves were surveyed and mapped by Freeman in 1943 and later visited by Middleton (2003). Map published in Freeman (1944).	There are 2 caves at this site. A large opening on the south side of the collapse 180 m long, descending then climbing until closure. A small opening on the north side of the collapse leads through 680 m of lava tube, with large variations in passage height. The cave contains an old Polynesian Sheath-tailed Bat roost site. Freeman's (1943) archaeological dig is still evident in an anabranch of the cave just before the terminus.	6.7.1995 – The shorter cave with the large opening contained 51 nests and the longer cave (small opening) contained 11 nests and 4 individual roost sites.
13, 14. Salamumu Beach Road Caves	The entrance is in a collapse and access is via a 3 m climb down a live tree. Tua, who lives next to a very large fig on the Upolu Island ring road 200 m west of the lady who owns the Salamumu caves, can guide to these caves.	One cave opens to the SW and the other to the SE from the bottom of the collapse. Both caves are very muddy. The SE cave has two trends and the right hand one crosses under the SW cave and ends in knee-deep mud.	17.3.1996 – The SW cave contained 8 nests in current use and 6 additional roosting sites, while the SE cave contained 3 active nests and1 roost site.
15. Samusu Uta Waterfall Cave	Opposite a Roman Catholic Church 3 km west of Samusu, lives Taua Tinu who can guide to this rock overhang. The site is 1 km closer to Samusu on the road side and 4-6 m from the waterfall (depending on river flow).	This is a lava overhang near the waterfall in a very moist environment.	19.5.1996 – 3 active nests in a well-lit situation where liverworts and mosses grow very close to the nests.



11,12. Lower Falemauga Caves



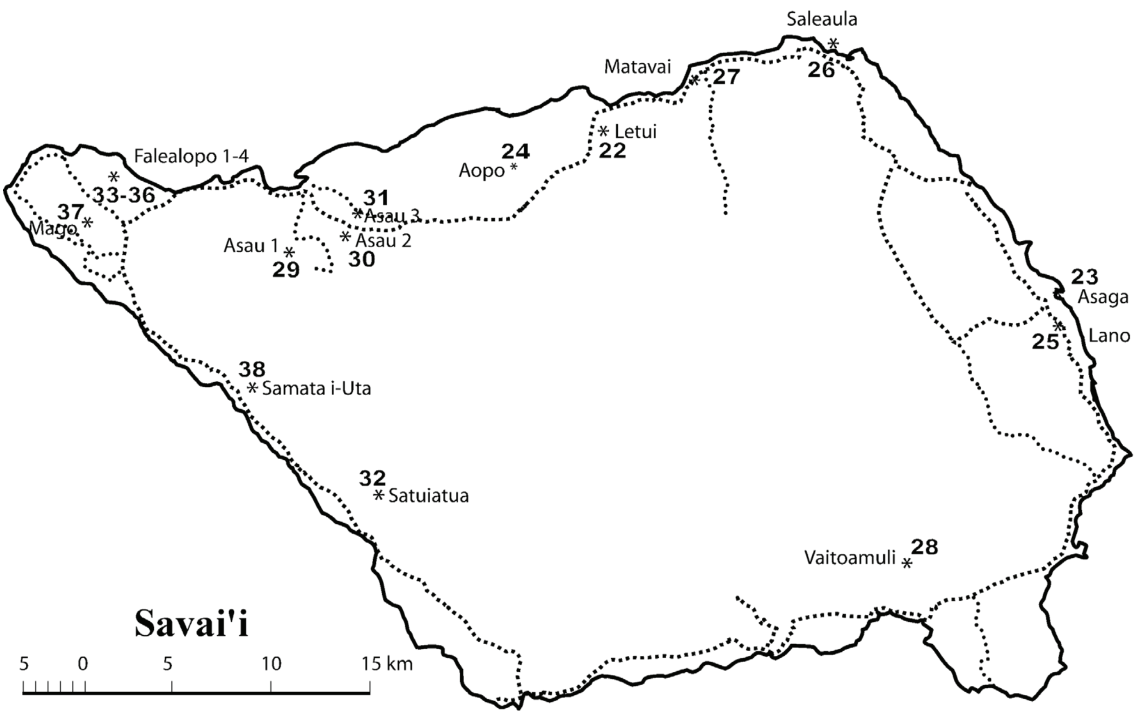
13, 14. Salamumu Beach Road Caves

<table>
<tr><th>Cave</th><th>Location and Access</th><th>Cave Description</th><th>Colony Information</th></tr>
<tr><td>16. Salamumu #3 Cave</td><td>The small entrance is 100 m NW of Salamumu #2 Cave. This is the cave Middleton (2003) called Salamumu II.
16. Salamumu #3
</td><td>This cave has historically been used for human habitation, presumably during times of warfare. The entrance has been blocked with natural stones to allow access only through a narrow slit. There are human sleeping platforms throughout much of the length of this short cave. There were several sections of guano sludge.</td><td>1.6.1995 – Although there were only 12 nests in use the areas of old guano indicated that there was a large colony here prior to the cyclones. Middleton (2003) noted there were lots of swiftlets, demonstrating the recovery of this colony.</td></tr>
<tr><td>17. Apolima Uta #1</td><td>A few metres before the Apolima Uta Village sign, which is possibly now used in a nearby shed (Middleton 2003), on the round island road, turn inland for 2.5 km. The 15 m diameter sink-hole containing the entrance can be seen 20 m off the road to the left.</td><td>This cave has a large opening (5 m diameter) in the collapse and heads seaward (west) for 300 m. The cave has several chambers 10 m wide and 10 m high and much of it contains water deepening closer to the coast. There are some white and coloured calcite formations and in one pool a 9-10 cm long thin minnow-like white fish with darkish fins and no eyes was observed.</td><td>12.11.1996 – 8 active nests.</td></tr>
<tr><td colspan="4">
17, 18. Apolima Uta #1 & 2</td></tr>
<tr><td>18. Apolima Uta #2</td><td>The entrance to this cave is in the same collapse as Apolima Uta #1 Cave. Entrance mostly covered with Mile-a-minute creeper.</td><td>The entrance is ~1 m diameter. The cave is a 600 m long straight passage about 5 m in diameter. At 100 m is a 150 m section of knee-deep very sticky mud. At 150 m after the mud are 3 clean pools of water before a collapse, followed by another pool and a high rock pile that ends in a choke.</td><td>12.11.1996 – 2 two active nests in this cave, 65 m apart.
This entrance is one of the smallest I have known swiftlets to use anywhere. There were 2 or 3 red-stained domes, below which were the fine red-brown guano remains that confirmed former use by the Sheath-tailed Insect Bat.</td></tr>
<tr><td>19. Anaseuao Cave #1</td><td>A sign for this “tourist” cave was erected in 1997 on the round island road near the village of Saanapu. The people in the nearest fale on the seaward side of the road will find a suitable guide. The entrance is 1.5 km from the road.</td><td>The cave has clean smooth rock and extends 700 to 800 m towards the road. It has 2 branches extending for 100 m and 300 m, with very low ceilings. The cave has calcite flowstone over wall rock, which has traditionally been called the King of Samoa’s throne. This name comes from the incident referred to in the name of the cave where the local village people were chased into the cave and trapped in there by a large fire lit over the entrance by an opposing village. When all seemed lost an old talking Chief of the trapped group came to the entrance and pleaded continuously all day in an oratory that so impressed the opponents that they released the trapped group. John Lyons returned to this cave on 6 occasions and mapped it thoroughly (Lyons 1997). Subsequently Middleton visited this cave and resurveyed it (2003). An earlier description had been made (Freeman 1943) with a more elaborate (and possibly more accurate) telling of the name origin.</td><td>25.11.1996 – 13 nests in current use
Several protrusions from the ceiling showed the red discolouration characteristic of Sheath-tailed bat roosts.
Middleton (2003) shows two sections of cave as having scattered swiftlet nests in 2002, so it would appear this colony has not increased very much since the cyclones.</td></tr>
</table>

Cave	Location and Access	Cave Description	Colony Information
20. Anaseuao cave #2	The entrance is located on the seaward side of the same collapse where Anaseuao Cave #1 begins.	The cave is 80-100 m long and is much larger in cross-section than the longer cave.	25.11.1996 – There were no current nests but the remains of about 12 pre-cyclone nests were counted.
21. Manunu cave	This cave is on the south bank of the Falefa River near the village of Manunu.	Only 45 m long, both ends open into the river bank and has no truly dark zone. The overhang is lava that has been eroded into and exposed by the river.	24.11.1997 – 20 current nests in spite of its being close to the village.

Table 3: Site descriptions – SAVAI'I

Cave	Location and Access	Cave Description	Colony Information
22. Letui Tourist Cave	This cave is 12 m off the inland side of the round island road, 60 m west of a rectangular water tank, about 1 km west of Letui. The tank and cave entrance are sometimes hidden by creepers but at other times every pebble is visible and signs advertise its tourist potential.	The 3-8 m deep collapse leads to an 85 m cave that runs under the road. This dry cave averages 3 m in diameter. The overhangs on the south side of the collapse do not lead to any other caves. Middleton (2003) reports that it has been fitted with electric lights; probably not a helpful addition for the swiftlets that breed (bred?) there.	25.2.1994 – 1 current but empty nest. However, 20 birds came in to roost at sunset. 7.7.1994 – 15 active nests and 3 active roost sites. 12.2.1995 – 3 nests in use. 5.10.1997 – 8 nests and 3 roost sites. Middleton (2003) did not report any swiftlets or their nests, just guano, but without comment on its age.



<table>
<tr><th>Cave</th><th>Location and Access</th><th>Cave Description</th><th>Colony Information</th></tr>
<tr><td>23. Asaga Cave (Ana o le Imoa.)</td><td>The entrance is 300 m seawards of the edge of the weathered lava flow. Access is through the coconut plantation on the north. Tugilima from the Asaga School can guide. Middleton (2003) obtained a guide who was not able to find this cave, instead taking him to the less significant Ana Sumu the Fish Cave, a frequent problem.</td><td>The 2 m diameter entrance is to a tube of similar dimensions until it opens into a 5 m high, 20 m wide chamber for 170 m after which it narrows. The cave ends with the 1 m high tunnel being filled with water. On the 5.10.97 visit it was observed from debris in the ceiling crevices that the whole of the entrance tunnel had been filled with water and that freshly sprouting coconuts had been distributed throughout much of the length of the cave.</td><td>27.2.1994 – 3 nests in current use and a partly constructed nest at the end of the large section; one old nest and 6 -7 birds were observed in flight.
8.7.1994 – 5 nests in use
5.10.1997 – 4 nests in use. There were 3 roost sites on the last visit indicating that probably most birds had survived the recent flooding of the cave.</td></tr>
<tr><td rowspan="2">24. Aopo Cave</td><td>The cave is a walk 400 m along the "track" before turning right and 200 m into the bush, 2 km along a road to the north of the western end of Aopo Village.
To visit this cave one needs to pay 5 Tala to the Pulenuu at the Aopo Village. He will organise a guide whom you will drive to where the vehicle is parked before the walk.</td><td>This extensive cave has a frequently-connected lower and upper tube system. The easiest place to descend to the lower passage is at the climbable slot (see map). Much of the cave is clean rock although it ends in mud pools.
Middleton (2003) mapped part of this cave but ran out of time to locate the climbable slot and get to the end of the cave. His map is more accurate than my sketch map.</td><td>27.6.1996 – Most of the 120 nests in current use were in the upper tube.
Middleton (2003) recorded many swiftlets (nests?) so presumably this colony is doing well.</td></tr>
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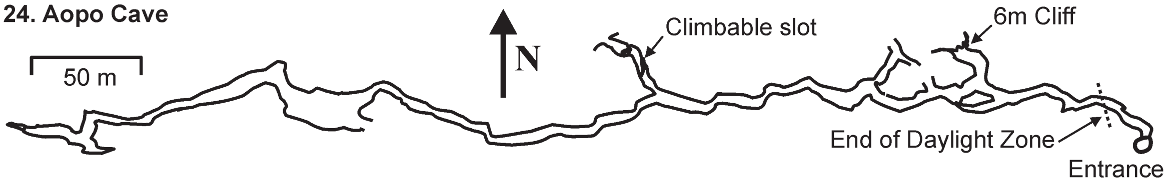
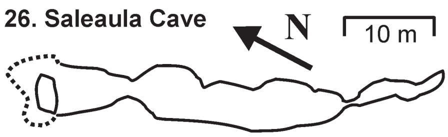
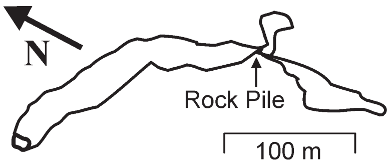
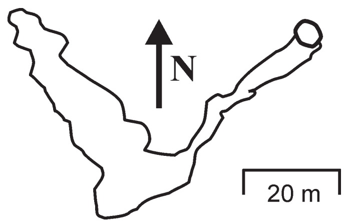
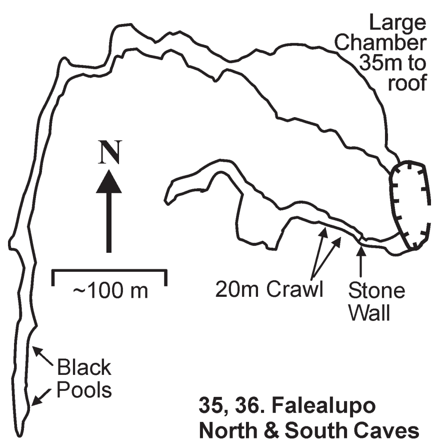


</td></tr>
<tr><td>25. Lano Cave (Ana o le Malie)</td><td>It can be reached in a conventional vehicle. Taeao Apineru from the Lano village showed the cave to me, but this is one of the few caves where most people could guide you.</td><td>The cave opening and much of the passage is large as it extends northwards under the road. It is 630 m long and has 3 large holes in the floor. The first 2 are climbable to an experienced and fit person, though the second had a very bad smell from a huge volume of decaying matter. The third hole is 13-15 m deep and is vertical on the near side. The far side is near vertical and gives access to a 3 m diameter tube that opens to daylight 13 metres further on. Evidence of large logs with branches and other flood debris indicating recent flooding in this section.</td><td>26.2.1994 – at least 42 nests in use ranging between 7.2 to 13 m above the cave floor. The sub-colonies were spaced widely throughout the length of the cave, with most in the totally dark section.</td></tr>
<tr><td>26. Saleaula Cave (Church Cave)</td><td>Referred to as Church Cave by Middleton (2003). On a track that runs inland on the south side of the AOG Church 3 km south of Saleaula Village. The entrance is on a ridge.</td><td>The 2 m diameter entrance opens to a 50 m long cave with some boggy patches, exposed tree-roots, and a roof height ranging between 1.4 to 3 m.


</td><td>10.7.1994 – 8 active nests, all in the twilight zone, 2 partly built nests and 4 roost sites. The innermost part of the cave is too low for swiftlets to use for nesting.
Middleton (2003) did not report any swiftlets or nests.</td></tr>
</table>

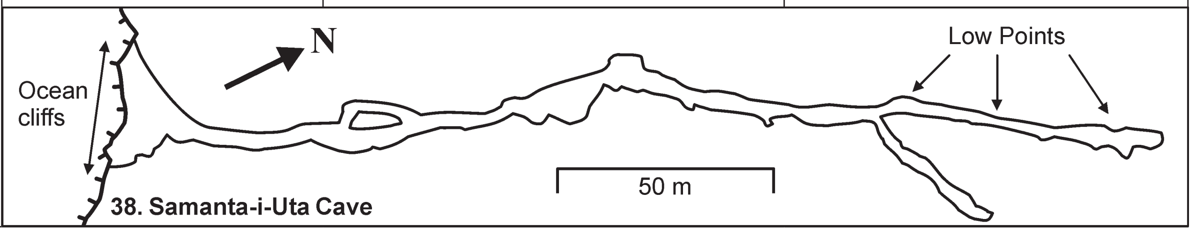
Cave	Location and Access	Cave Description	Colony Information
27. Matavai Water Cave	This cave is well known by all Matavai Village residents as it is on the edge of the village and is used for washing. It is best to seek permission from the villagers as ownership of the cave is disputed and we found it was better to have paid somebody than nobody if a dispute erupts.	There are two large openings. The one to the right is the shortest and used for village bathing and washing. The one to the left has knee to waist-deep water in the entrance but 120 m of dry cave extends behind the water.	10.7.1994 – Only 2 currently active nests were located in the left cave, though the village guide said there had been many before the cyclones.
28. Vaitoamuli Cave	This cave is difficult to find and as ownership is clear, it is best to contact the owner (Iulio Malaeesala) directly. His fale is in the centre of the village on the coastal side behind a tomb that has black stones in white cement. Alternatively the resident American Deputy Principal (David Brindisi) and his Samoan wife who live in the cyclone-fenced school houses right by the main road, can organise permission for you. The cave is approximately 2 km inland.	The cave is relatively large and we did not reach the end. The cave is over 632 m long and extends at least 160 m past the second and larger roof collapse although decreasing in size. Inside the entrance, the cave forks; the south-east branch to the right does not go very far, the north-west trend is the one that leads to the main cave.	11.7.1994 – 62 active nests all in total darkness, 1 nest behind the second rock fall. No swiftlet nests in the south-east branch. The 20 swiftlets flying in this area appeared to be there because they were flushed into the rear of the cave and not because they were travelling to distant nests.
29. Asau #1 Cave	The cave is some 5-8 km inland at about 600-700 m altitude. The best guides are Petau Ofisa and his wife Naoupu who live in a green-roofed fale 1 km along the vehicle track opposite the Harbour turnoff from the Asau-Aopo road (the old road to Aopo),	The cave opening is 1.5 m in diameter with a 3 m climb down to a narrow (averaging 1 m in width) short cave of just 30 m.	11.2.1995 – 3 active nests and 3 roost sites in the twilight zone.
30. Asau #2 Cave	The cave is 500 m along the track from Asau #1 cave on the seaward side and 8 m from the track. The cave was discovered by observing the circling and diving swiftlets near Asau #1 cave.	The opening is 3 m high and 6 m wide but there are sections in the cave that are up to 10 m in height, along with some very narrow and other broad sections. It extends for 220 metres.	11.2.1995 – 29 active nests were grouped into several favourable locations, well out of reach of humans and in totally dark sections of the cave.
31. Asau #3 Cave	This cave was also discovered by noticing the circling and diving swiftlets. The entrance is 3 km below Asau #1 Cave and inside the arc made by the west branch off the main track. It is 15-18 m from the track and not obvious. Petau was surprised to find this cave but should remember where it is.	The cave passage is 60 m long, 5-8 m wide but averages only 1.8 m in height.	11.2.1995 – all 17 nests in current use were low due to the low profile of the cave. Their presence in these numbers suggests that they are not disturbed.

Cave	Location and Access	Cave Description	Colony Information
32. Satuiatua Cave. (Ana Ole Sau; Cave of the Breezes)	Also known as Ana Ole Sau; Cave of the Breezes (Middleton, 2003). The cave entrance is 2.5 km from the primary school and up the inland slope. Mate and her sons manage the Beach Resort in Satuiatua village and I can recommend their service as well as that of Mate's brother Tauia Lepua in guiding one to the cave.	The entrance is the lower end of a 500 m long lava tube and bifurcates appear ~100 m in. The right branch was initially dark (Middleton, 2003, shows it reaches a gorge) and the left one surfaced at the 500 m point. The cave is dry and easily traversed. Middleton (2003) visited and surveyed this cave.	3.10.1997 – The right branch contained 14 current nests and the left branch 43, totalling 62. The colony has suffered predation from a Barn Owl (Lulu) judging from a Barn Owl feather just inside the entrance, near a large pile of swiftlet flight feathers, which I estimate came from 30-40 birds. That so many birds survived the cyclone may be explained by whatever the explanation is for the survival of a large colony of Tongan Fruit Bats (*Pteropus tonganus*) that roost just east of here. Middleton's (2003) map records many swiftlets (presume nests?) suggesting this colony may have increased.
33. Falealupo #1 Cave	This cave is west of the Falealupo School on the opposite side of the road and the best guide is Tapu Aeaeau, a teacher from the school. Tapu's friend (Seumamutafa Fetaui) can also act as a guide to the caves in this area.	The cave tube extends 300 m to a rock pile that reaches the roof but does not block the passage completely. To the right over the pile is a 100 m extension, and to the left is a 20 m extension. The cave up to the rock pile was still littered from human occupation during cyclones.	4.10.1997 – 16 current nests were found before the rock fall and 1 in each extension, totalling 18 nests. Most were in the totally dark zone.  **33. Falealupo #1 Cave**
34. Falealupo School Cave	About 100 m from the school house, past a very large fig that having survived both cyclones succumbed to a fire in 1996. The area was mostly weeds such as Mile-a-minute and sensitive plant.	This 100 m cave has a small cross section but is fairly wide where it branches to the right.  	4.10.1997 – 10 active nests were found in this cave indicating that the birds are not molested.
35. Falealupo South Cave	This cave is on land owned by Lagolago and its entrance is south past the school and west of Lagolago's fale. This cave entrance is in the south end of a linear collapse.	The cave is 225 m long but a man-made ceiling-to-floor wall of stones has been built 30 m into the cave where the roof is only 1 m from the floor. This obscures the way into a 20 m crawl to a larger chamber where villagers used to hide from their enemies.	4.10.97 – the first 2 of the 15 nests were in twilight but the rest were well inside beyond the low difficult crawl. I suspect the birds have another route into the large chamber.



35, 36. Falealupo North & South Caves

Cave	Location and Access	Cave Description	Colony Information
36. Falealupo North Cave	The entrance to this cave is in the north end of the same linear collapse referred to above. Same access arrangements as for Falealupo South Cave.	This ~320 m or more long cave is the mirror image in shape to Falealupo South Cave. It initially has a 13 m high roof and a wide chamber that narrows to end in black coloured pools of water.	4.10.1997 – The first nest was 25 m inside and 35 m from the floor while the last was only 2 m off the floor. There were at least 14 current nests, the majority of them difficult to discern due to height except from the floor faecal remains.
37. Mago Cave	A well-known cave on the south part of the loop road. The entrance is 100 m off the road opposite owner's (Vaogo Setu) fale. The same guides from Falealupo (see above) can guide. Asking for the landowner or the cave helps location. Entrance fee 10 tala/vehicle charged.	This cave has a large cross-section with five collapses in the early section. The first, second and fourth collapses are free climbable but the others are roof daylights. The cave ends 420 m beyond the last collapse and 412 m from a stone wall.	4.10.1997 –The first two nests were in the twilight and 85 m apart. The other 16 nests were all in complete darkness, one of which was unusual for Samoan nests in that it was totally self supporting (at 5.8 metres above the floor), rather than being on a ledge or protuberance.
38. Samata-i-uta Sea Cave	The cave is right on the 38 m high sea cliff edge of the village. The landowner (Esau Tilo) is the best guide. It is best to ring Faifeau on 56036 and ask for Esau; then call back 5-10 min later to speak to Esau. Esau charges 5 tala for access.	The cave entrance is 20 m from the top of the cliff and during the cyclones the entrance and first third of the cave passage received substantial coral sand deposits. There is no protective reef on this part of the island. The cave is about 250 m long with an average height of 2 m. There are 3 low points in the cave; 99 cm, 40 cm and 37 cm in height. It is normally a very dry cave except in very high seas.	7.11.1997 – 3 nests were found, 1 beyond the 99 cm low point. A partly-built nest was at a height of 1.44 m. A roost site was at 1.41 m above the floor. This cave and the swiftlet colony have significance to this village and they name their cricket team *Ana Pe'a pe'* to commemorate both. In spite of this the men that accompanied me including the owner did not venture very far into the cave, citing the presence of spirits for their reticence.



Book Review

Tufas and Speleothems: Unravelling the Microbial and Physical Controls

H.M. Pedley and M. Rogerson (editors)

The Geological Society, London, Special Publication 336, 2010, 362 pages.

This is not a text book, but a group of 17 papers, with a brief introduction by the editors, conceived at a workshop held in the UK in 2008 and presumably written after that date as there are cited papers from 2009.

The theme of the book is indicated by the title, and the objective is to improve understanding of the biological and chemical influences on carbonate precipitation associated mainly with ambient temperature freshwater carbonates. Its stated aim is to bring together the separate research themes of tufas (dominated by sedimentologists and biostratigraphers) and speleothems (dominated by geochemists).

The authors are mainly researchers from Europe, together with the middle east (Israel and Turkey) and Canada. The papers are mainly on specific field or laboratory studies in the same region, but also include a few reviews that are more general in scope. There are no Australian based papers, but many of the papers refer briefly to Australian studies, such as the work on north Australian tufas by Drysdale's team, and on speleothems in several areas (eg Treble, Contos, Cox, James and Goede).

The introduction by the editors has a short overview of the field, emphasising the interplay between biological and physical processes, and describing the gradation from the physico-chemical dominated speleothems through the barrage and palludal tufas to the biologically dominated oncoids and lacustrine carbonates, with the spring-fed travertines as another physico-chemical member. It also notes the emergence of the new field of geobiology. Both tufas and speleothems provide proxies for climate studies.

The first paper, by Brian Jones, is the most useful for a general karst reader as it provides a useful review of microbes in caves, and their role as agents of both corrosion and precipitation of calcite. He lists the biological types present, and how they get there; their role in both destruction and construction of substrates, in both the twilight and dark zones. He concludes that microbes may play an important role in the development of speleothems, but in most cases it is difficult to know if they have played an active role or were merely passively involved.

The next 12 papers deal mainly with tufas. The first, by González-Muñoz et al., provides a useful review of the role of bacterial biomineralisation, the wide range of minerals produced, and the current models for their generation. They then report a study of the effects of a single species which can precipitate a wide range of minerals – indicating that the mechanisms involved are neither mineral nor species specific, but universal and dependant on the local environment.

Other papers in this section deal mainly with specific field or laboratory (flume) studies on a variety of tufas in various settings, but many of the conclusions are of general interest. There is also a study by Bindschedler et al., on calcite nanofibres in caves and calcareous soils, including pedogenic calcretes, which the attribute to fungal hypae. Speleologists will note a brief mention by Özkul et al., of constructional caves in spring tufas in Turkey.

Finally a group of four papers covers speleothems and spring travertines, and the environments in which they form. Baldini describes the effects of soil-derived CO_2 in cave air, and concludes that soil temperatures is the main control on this. Variations in CO_2 can trigger either precipitation or corrosion and this can skew the proxy signals used in paleoclimate studies towards a particular season. Fairchild et al., and Mattey et al., study seasonal variations in speleothems and drip-waters respectively. The latter found strong variations as a result of rapid chimney ventilation of the cave air in autumn. These studies are important in making deductions about climate from the speleothem record. The final paper by Hammel et al., discusses the morphology of travertine terraces, teracettes and microterracettes – concluding that there are multiple processes involved.

Reviewed by Ken G. Grimes.

Helicitite, (2011) **40**(2): 51-54

Sand structures cemented by focussed flow in dune limestone, Western Australia

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Abstract

Pendants, pillars and concretions of cemented sand are exposed in a dune limestone cave in southwest Western Australia. These are the result of focussed flow of carbonate-saturated water through the sand in a very early stage of eogenetic diagenesis. Vertical vadose fingered flow has cemented the pillars and pendants, and horizontal phreatic flow has produced a layer of elongated concretions along a bedding plane. Later cave development has exposed the cemented sand bodies.

Keywords: syngenetic karst, eogenetic diagenesis, concretions, speleogens, sand speleothems, fingered flow, dune calcarenite, Australia.

Introduction

This short note draws attention to cemented sand features in a calcarenite cave, which have significance in the broader study of focussed flow through sandy sediments.

Witchcliffe Cave (6MR-1), in the Margaret River area of southwest Western Australia, occurs at the inland edge of a belt of coastal dune calcarenite, close to the steep-dipping contact with the underlying impermeable granite (Hall & Marnham, 2002). Dunes in a similar setting 40 km to the south are at least 600 ka old, based on speleothem dating in caves (Eberhard, 2004).

This is an area of syngenetic karst, where the karst and cave formation has occurred simultaneously with the calcareous dune sands being cemented into limestone (Bastian, 1964; Grimes, 2006; Webb & Grimes, 2009).

Boodjidup Brook cuts a narrow, 80 m deep, valley through the dunefield to the sea. The cave entrance is in a vertical cliff in the side of the valley and about 25 m above the valley floor, which suggests that it predates the present valley. The cave is a single broad chamber with a gently undulating ceiling 1-2 m high above a flat sandy floor (Figure 1 and see detailed map in Webb & Grimes, 2009). A large stalagmitic mound outside the cave indicates that there has been some cliff retreat since the cave formed. A spring emerges from rubble at the cliff base, about 5 metres beneath the cave floor. This might be at the contact with the underlying granitic basement, but there is no outcrop to confirm that.

The cliff exposure shows that the ceiling of the cave is at a stratigraphic break between an upper unit of flat, thin-bedded and moderately-hard calcarenite and an underlying unit of softer, more cavernous and less well-bedded calcarenite. This boundary possibly represents

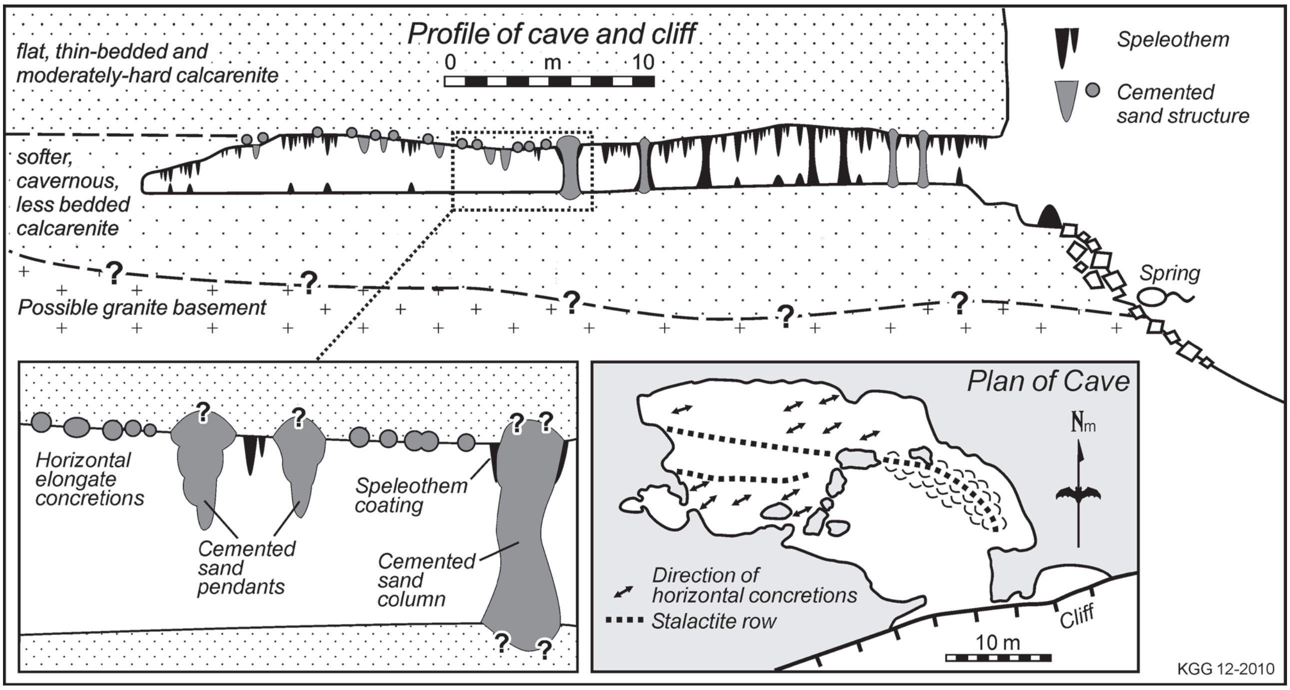

Figure 1: Diagrammatic cross-section of the cave and content. Based on a map by B. Loveday, 1986

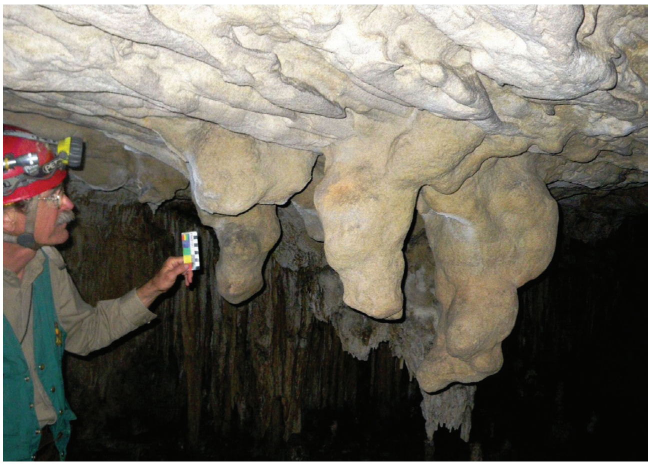

Figure 2: Elongated horizontal concretions in the ceiling and several small sand pendants. Photo by Jay Anderson.

a short time break between two dune units, but there is no obvious soil or calcrete hardpan formation that might indicate an extensive period of exposure before the upper unit buried the lower one.

The cemented structures

Two types of cemented-sand structures occur in the cave, but neither were seen in the cliff face outside, so we cannot tell how far they extend above or below the cave level. They are formed within the dune limestone and appear to be a result of focussed cementation that preceded cave development. Solution and erosion of the less-cemented dune sand to form the cave has left these harder structures protruding onto it.

Horizontally elongate sand concretions

Elongate concretions are exposed in a single sub-horizontal layer in the ceiling of the rear section of the cave. They are not seen in the entrance area, but the high density of speleothems there may be concealing them.

The concretions are hard, white to pale grey (lighter than the surrounding less cemented dune sand), horizontal elongated cylinders tapered at each end – from 5 to 30 cm wide and up to 2 metres long. The smaller ones are reminiscent of French loaves or bread-sticks, but with a greater variety of shapes, and some have coalesced into composite structures (Figure 2). The concretions are aligned parallel to each other with a direction that is consistent across the chamber with a magnetic bearing between 050° and 072° (average 063° from 11 measurements, Figure 1). This direction is roughly parallel to the cliff face and perpendicular to the edge of the dunefield. It differs from the direction of two prominent (joint-controlled) lines of stalactites that strike 095° and 102°. The broad flat ceiling of the cave may be a consequence of the presence of this layer of partly-cemented sand.

Ceiling pendants and vertical pillars of cemented sand

These are also of cemented dune sand, but differ from the concretions in being softer and the same colour as the surrounding pale brown dune sand. The original shallow dune bedding is visible in places within them, so they are not the cemented fill of a solution pipe. However, there are no broken examples, so one cannot see whether they have a central pipe. They are rather lumpy structures hanging from the ceiling, 15 to 60 cm in diameter and up to 2 m long with the longest ones reaching the floor to make pillars (Figures 1, 2 & 3). They are best developed in the rear section of the cave but a few also occur in the entrance area. Some pendants are partly coated with white speleothem material and it is possible that thick bulbous stalactites seen near the entrance might have a core of cemented sand hidden behind an outer layer of speleothem. Some pendants show a case-hardening effect – possibly from surface cementation associated with the later speleothem coatings.

Figure 3: Columns and pendants of cemented dune sand. Pale areas are a secondary speleothem coating.

At the ceiling the pendants and concretions co-exist, but it is not possible to judge which formed first.

Discussion

Williamson (1980) briefly described these features, but interpreted them as due to erosion by a strong phreatic stream flow. Both types are interpreted here as the result of localised cementation of the dune sand by carbonate-saturated waters, followed by exposure in the cave by the erosion of the surrounding, softer, less-cemented sand. Strictly speaking, they are neither "speleogens" nor "speleothems" but a hybrid of the two with localised precipitation followed by erosion.

The horizontal elongate bodies appear to be typical concretions such as occur in many sandstones, including calcarenites (e.g. McCullough, 2003). These grow by cementation within the pores between the sand grains. If elongated the orientation of a concretion may indicate a structural control (e.g. by a porous bed) or the direction of water flow. In the case of the concretions in Witchcliffe Cave both factors may be involved. They are found in a horizontal layer that may be a porous bed or a bedding plane, but are also elongated into rods with a consistent direction which might indicate a past, horizontal, flow of water, probably at or beneath the old watertable. The rods are symmetrical and oriented 063-243°, which is sub-parallel to the cliff and valley direction (Figure 1) so are probably not related to the modern drainage towards the valley, but rather to an earlier flow direction, westward towards an old coastline, that occurred before the present valley formed. An eastward flow is much less likely because of the ridge of impermeable granite in that direction. McCullough (2003) made a similar deduction for elongate concretions in dune limestones in Victoria. The gently-inclined "sand stalactites" described by Diller (1899) may be similar.

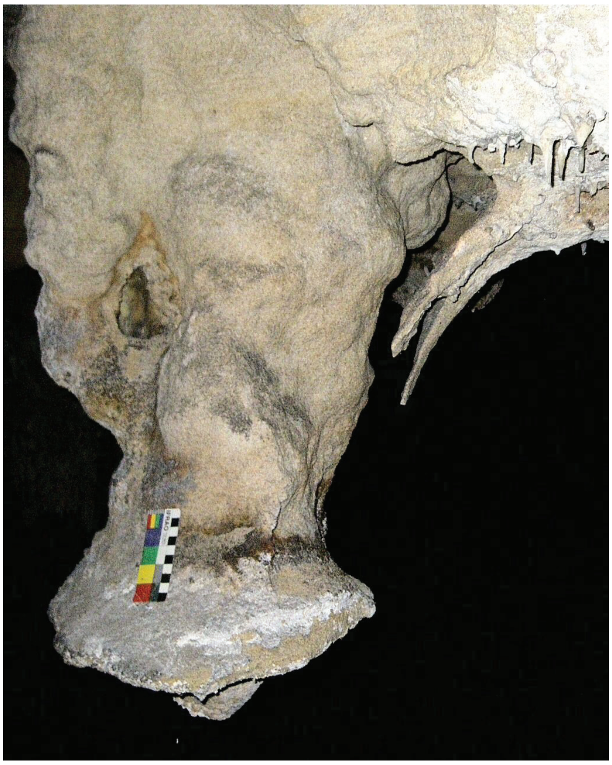

Figure 4: Sand pendant with speleothem coating on right, now partly separated by later weathering.

The vertical pendants and pillars are similar to concretions but bigger and suggest a focussed vertical, vadose, flow. There are strong analogies with the "sand speleothems" of Loch Ard Gorge in Victoria (Grimes, 1998), although those formed in a beach sand that had filled a pre-existing cave. One can also compare the pillars to the larger Nambung Pinnacles (McNamara, 1995; Lipar, 2009; Grimes, 2009), and there are analogies with the pendants, pillars and pinnacles seen in laterite and sandstone karsts (Grimes & Spate, 2008; Aubrecht, et al., 2008, plates 1 & 2).

There is an extensive literature on "fingered flow" in sandy soils (e.g. Dekker & Ritsema, 1994; de Rooij, 2000). After rain, downward vadose flow through dry porous sand tends to focus spontaneously into fingers of wet sand surrounded by dry sand. It is easier for water to flow through sand that is already wet, than to enter dry sand. The downward flow can also be focussed by other factors such as stem flow from overlying trees, down tap roots or by variations in the permeability of the caprock (Grimes, 2009).

Where the focussed vertical flow is saturated, localised cementation occurs, as here. Where it is under-saturated, solution pipes can form, as seen elsewhere in the region. Solution pipes are, in fact, the more common result (Grimes, 2009).

Timing of the events

The location of the cave 25 m up the side of the valley suggests that it predates at least the final stage of valley incision. The horizontal concretions would have been cemented before the present valley was cut, as their orientation does not suggest a water flow towards that. Both of the processes of localised cementation (horizontal and vertical) would have occurred before the cave formed. However, the relative timing of the two types of cemented feature is difficult to deduce. Although the two forms co-exist it is not possible to decide whether the concretions were later forms penetrating the pendants or whether the pendents were a later cementation that surrounded the concretions. However, it has been deduced above that the horizontal concretions formed in phreatic conditions, and that the pendants and pillars were cemented by vertical vadose flow.

It is possible that as the dunes stacked up against the granite slope the local water table may have risen in accord with the surface, so that within each individual dune unit there would have been an initial vadose stage, followed by a phreatic stage as more dunes were stacked above it, and then, considerably later, a return to vadose conditions as the valley was cut and the local watertable dropped. Changes in sea level would have had little influence as the granitic basement would have provided a local base-level. The cave would have formed near the top of the watertable, possibly as the watertable was dropping; so, given that both types of cemented structure predate cave formation, it seems likely that the cementation of the pillars and pendants by vertical vadose flow of saturated water came first and at a very early stage in diagenesis and syngenetic karst development.

We know that caprocks and solution pipes occur quite early in syngenetic karst (Bastian, 1964; Grimes, 2006), it seems that vertically focussed cementation can also occur then.

Acknowledgements

Thanks to Matej Lipar and Susan White for discussions of fingered flow and comments on the draft. Anne Wood, of the Department of Environment and Conservation, arranged access to the cave.

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Publication Review

RETHINKING EASTERN AUSTRALIAN CAVES

by Osborne, R.A.L., 2010: pages 289–308 *in* Bishop, P. & Pillans, B. (eds) *Australian Landscapes*. Geological Society, London, Special Publications, **346**. DOI: 10.1144/SP346.15

Author's abstract:

There are some 300 bodies of cavernous limestone in eastern Australia, extending from Precipitous Bluff in southeastern Tasmania to the Mitchell Palmer region in north Queensland. These impounded karsts, developed in Palaeozoic limestones of the Tasman Fold Belt System, contain many caves. The caves have a suite of features in common that allows them to be thought of as a major group: the Tasmanic Caves. The Tasmanic Caves include multiphase hypogene caves such as Cathedral Cave at Wellington and multiphase, multiprocess caves such as Jenolan with Carboniferous hypogene and younger paragenetic and fluvial elements. Active hypogene caves occur at Wee Jasper and possibly at five other localities. The Tasmanic Caves are one of the most complex suites of caves in folded Palaeozoic limestones in the world. Field techniques developed to study these caves are now being applied to complex caves in central Europe: in the Czech Republic, Hungary, Poland, Slovakia and Slovenia.

Review and Critique

Review papers on Australian karst in books and journals with a wider geomorphological focus are always welcome as this leads to a better appreciation of the significance of karst in the Australian landscape.

Osborne's paper is in two parts, firstly a review of the evolution of scientific study and ideas about the Tasmanic Caves, followed by a summary of Osborne's recent ideas about their genesis.

The history of Australian cave studies began with fossil excavations in the 1830s, and paleontology was the main focus during the 19th century with little description of the caves that held the fossils. The first half of the 20th century saw more cave exploration and description and the appearance of initial theories of genesis. However the paper is very concentrated on the NSW literature and by such emphasis, implies that similar work, e.g. Stirling (1887), Kitson (1907) at Buchan, was not undertaken in the other colonies and states.

Systematic scientific studies of both caves and the karst received a major boost with the "Jennings era", 1952-1984. This saw the introduction of karst hydrology and process geomorphology and the sediments were now being studied in the context of the host caves. Towards the end of this period Jennings introduced the term nothephreatic, referring to water moving slowly in cavities in the phreatic zone and also to the resultant solutional forms: isolated cavities with sculptured hollows, pendants, bellholes, and partitions which were incompatible with the prevailing concept of strong directed conduit flows. Osborne's comment that "nothephreatic is now generally used to indicate laminar flow in phreatic conduits (Field 1999)" is out of date (and it may never have been universally accepted), and Field's revised lexicon (2002) reverts to the original Jennings usage. Jennings had always advocated that the caves were relatively young, but towards the end of his life he and others began to question the age of both the caves and the landscapes associated with them and paleokarst deposits were recognised within some caves.

The following 'era', 1979-1995, overlaped with the end of the Jennings era, and saw disagreementargument about the ages of the landscapes, with the rejection of a recent age for the "Kosciusko Uplift" as the starting point for erosion of the present topography. This naturally led to the suggestion that the caves might also be older. Studies at Timor, Bungonia and Buchan led to the eventual acceptance of "old caves in old landscapes". The paleokarst cavities and deposits within the caves at Wombeyan, Jenolan etc. had to be even older, and some could date back as far as the Paleozoic.

The final period, 1996-2008 could be called the "Osborne era" as most of the cited papers are by Osborne, but the author has modestly avoided that appellation. Osborne continued his studies of the paleokarst with isotope dating to provide actual numbers. However, he began to think that the cave development was more unusual than had been suggested before, and different to the styles seen elsewhere. He described a suite of features, including "nothephreatic" sculpturing that he considered to be formed by hypogenic fluids: e.g. partitions and "halls and narrows systems" in steep-dipping beds, cupolas (large blind avens), breakdown in small areas. He also noted paragenetic effects and multi-phase and polygenetic systems. At the same time studies elsewhere in the world were recognising the significance of hypogene processes and the resulting cave features.

This all leads into the final section of the paper "A new synthesis", which is summarised in his abstract (reproduced above). Here he argues that the caves range in age from extremely old to currently active; and most originate by internal rather than surface processes and have little relationship to the current surface development. Complex caves are seen to be either multi-phase or multi-process, or both.

We have no problems with the descriptions or the multi-phase and multi-origin concepts in general, but we feel that the hypogene origin is seriously overstated and unjustified without adequate field studies for "most" or even a "large group" of the Tasmanic caves. The author himself admits there is little evidence for the source or chemistry of the postulated hypogenic waters, and he provides no arguments or cited papers to support statements such as that "active hypogene caves occur at Wee Jasper".

This paper is seriously limited by the extension of a good hypothesis, which has been well documented and established in some areas, e.g. Jenolan, to areas where work either has not been done, or evidence does not support the concept and the assertions of hypogene speleogenesis are at best unproven. This overstatement of hypogene formation of all caves in the Tasmanic karst areas diminishes, rather than enhances, the understanding of hypogene as one of a group of nothephreatic processes in the impounded karsts of Eastern Australia. Nevertheless, the paper does offer the opportunity for a robust discussion of the relative roles of processes and forms in these impounded karsts hosted in eastern Australian Paleozoic carbonates.

Discussion

A review such as this is not the place for a detailed criticism, but, given that a book publication does not provide a direct avenue for discussion papers, we would offer *Helictite* as a venue for possible future debate on the concepts raised by this publication. We note below a few topics that we feel need discussion.

The first step is to ensure that we are all using *hypogene* in the same way. Over the past few years there appears to have been a shift in the meaning of "hypogene". Osborne in this paper (p.299) seems to define the term as..."Caves formed by groundwater moving upward through the rock mass, as a result of heat, density or pressure, are known by a number of terms including non-meteoric, hypogene, thermal, hydrothermal, artesian and per ascensum." Osborne also quotes Klimchouk (2007, p. 6) for a similar definition. We are comfortable with this definition; it acknowledges the issue of deep seated and ascending aggressive water but does not confuse it with other slow moving water of more shallow origins. But there remains the borderline issue of deep phreatic loops which pick up some heat before returning to the near-surface – are these hypogene? And how deep or hot do they have to be to qualify?

However, recently some authors (not Osborne) have extended the usage of "hypogenic" to include the formation of flank margin caves by the mixing of fresh and sea water in a near-surface situation (see Palmer's discussion, and support, of Mylroie's usage in Palmer (2007, pages 209-210). Palmer (page 209) defines hypogenic caves as simply being caves that "owe their origin to processes beneath the surface". He expands this in the following paragraph by saying "solutional aggressiveness is generated at or below the watertable" but that still implies that nearly all mixwater corrosion would be classed as "hypogenic". Later (page 210) he comments "Yet, many people restrict the term hypogenic to processes involving rising water", but does not appear to support that view. Is this a case where a positive definition is changed to a 'negative' definition i.e hypogene now equals “any aggressive water not derived from the surface", rather than “aggressive water derived from depth"?

Having agreed on the usage of the term, the next step should be a discussion of what are the reliable *diagnostic criteria* for recognising the influence of hypogene waters in caves, followed by a search for those signals in the various cave areas.

Many of the morphological features described by Osborne are typical of *nothephreatic* flow – slow moving water circulating in the phreas. While hypogene circulation is also nothephreatic in character and produces similar sculpturing, nothephreatic morphology does not automatically imply a deep-seated, hypogene, source for the water. Nothephreatic features (isolated chambers, pendants, juts, spongework etc) are common in other karst systems. For example, shallow dune limestone caves where such features are found in isolated mixing chambers within the porous calcarenites, and the waters are derived horizontally from nearby swamps or the sea. As such, "nothephreatic" is a useful non-genetic term, and is more appropriate than "hypogene" in describing the various sculpturing effects, which are automatically labelled "hypogene" by Osborne.

References and related reading

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Reviewed by Ken G Grimes & Susan Q White.

Information for Contributors to Helictite

Scope

Contributors from all fields of study related to speleology will be considered for publication. Suitable fields include Earth Sciences, Speleochemistry, Hydrology, Meteorology, Conservation, Biospeleology, History, Major Exploration (Expedition) Reports, Equipment and Techniques, Surveying and Cartography, Photography and Documentation. Comprehensive descriptive accounts of the exploration and morphology of individual caves will be welcomed, but simple trip reports and brief cave descriptions are not adequate. Papers overall should not exceed 20 printed pages in length (text prints at about 1000 words per page). Contributors intending to write at greater length or requiring any advice on details of preparation are invited to correspond with the Editors. All manuscripts will be read by referees. "News and Views" and short "Letters to the Editor", expressing a personal view or giving a preliminary report of interesting findings, are welcomed, and will be given preference for speedy publication.

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Once authors have dealt with referee's comments, they are requested to submit a copy of their final manuscript by email or on CD as well as a hard copy. If sending text as a word processing document (Microsoft Word etc.), please also send a copy as plain text on the same disk. Illustrations and tables must be sent in separate files, not embedded in the main document. See later section on electronic submissions.

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The S.I. system (Australian Standard AS 1000) should be used unless citing historical data, in which case the original units should be quoted and appropriately rounded metric equivalents added; e.g. 100 feet (30 m). North Americans should note the correct spelling of "metre".

References

References should be listed alphabetically at the end of the manuscript and cited in the text by the author's name and the year of publication (e.g. "(Gray, 1988)"). Where there is more than one paper by the same author in one year the letters a, b, c, etc. should be added. If there are more than two authors, the first name followed by "et al." should be used in citations, but all names must appear in the reference list. References should be checked particularly carefully for accuracy. If journal titles are abbreviated, this should follow the "World List of Scientific Periodicals", which is available in most large libraries.

The following examples illustrate the style:

Gray, M.R., 1973: Cavernicolous spiders from the Nullarbor Plain and south-west Australia. *Journal, Australian Entomology Society*, **12:** 207-221.

Vandel, A., 1965: Biospeleology. *The Biology of the Cavernicolous Animals*. Pergamon, London. pp. 524.

Wigley, T.M.L. & Wood, I.D., 1967: Meteorology of the Nullarbor Plain Caves. *In:* J.R. Dunkley & T.M.L. Wigleey (eds), *Caves of the Nullarbor. A Review of Speleological Investigations in the Nullarbor Plain. Southern Australia*: 32-34. Speleological Research Council, Sydney.

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VOLUME 40 (2) 2011

Helictite

Journal of Australasian Speleological Research

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Helictite Commission, Australian Speleological Federation Inc.

Printed by Campus Graphics, La Trobe University, 3086, Victoria. 2011