Bat caves in Fiji

Status and conservation of roosting caves of
the Fiji blossom bat (*Notopteris macdonaldi*),
the Pacific sheath-tailed bat (*Emballonura semicaudata*)
and the Fiji free-tailed bat (*Chaerephon bregullae*).

Joanne Malotaux

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Prepared by: Joanne Malotaux, intern at NatureFiji-MareqetiViti

NatureFiji-MareqetiViti
14 Hamilton-Beattie Street
Suva, Fiji

Cover page picture: Wailotua cave. © Joanne Malotaux.

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INTRODUCTION

Bats are the only native mammals in Fiji. Three of the six bat species that occur on Fiji are cave-dwelling bats, these include the megachiroptera *Notopteris macdonaldi* (Fiji blossom bat), as well as two microchiroptera, *Emballonura semicaudata* (Pacific sheath-tailed bat) and *Chaerephon bregullae* (Fiji free-tailed bat). Populations of these three species have been declining and are currently considered Vulnerable or Endangered (Palmeirim, 2008a, Palmeirim, 2008b, Bonaccorso and Allison, 2008). Bat populations worldwide are declining. Most of the threats to bats are related to increasing human population, such as habitat degradation and destruction, overexploitation and roost site disturbance (Hutson et al., 2001, Mickleburgh et al., 2002).

Cave-dwelling bats in particular are very sensitive to roost disturbance, which has seen a recent intensification as a result of the increased availability of electric torches, enabling people to venture deeper into the caves (Palmeirim et al., 2007). In Fiji, bats are often considered a delicacy, and consumption poses a significant threat to the cave roosting populations, in particular when caves are located close to villages (Mickleburgh et al., 2008, Palmeirim et al., 2005). Another threat to the bats in Fiji is the loss of (native) forest, which leads to loss of foraging habitat. The introduction and spread of several predatory species like the mongoose and cat might also contribute to the decline of the bats (Palmeirim et al., 2005).

Lack of information about bats is a substantial problem. Fiji's bat species have been little studied, which makes it difficult to direct conservation efforts. Little is known about the ecological and economic services bats provide. Bats play vital roles in pollinating flowers, dispersing seeds and eating insect pests (Hutson et al., 2001, Mickleburgh et al., 2002). Fruit-eating bats either discard fruit seeds while chewing and swallowing the juice and pulp, or swallow the seeds, which are then later ejected with the bats' faeces. Blossom bats are known to play a key role in pollination of plants as well, feeding on nectar and/or pollen. Several plant species, both rainforest species and crops, depend on bats for pollination or seed dispersal (Fujita and Tuttle, 1991). The insectivorous microchiropterans have an important role in controlling insect numbers, including several agricultural pests (Hutson et al., 2001).

Lack of knowledge about bats also contributes to the generally poor public image of bats, which can lead to deliberate persecution (Hutson et al., 2001). Knowledge about bats is very limited, particularly in Fiji's villages. Bats are thought to be overabundant and have a high reproductive rate, and they are often suspected of damaging crops. Providing information on the important roles bats play in Fiji's ecosystem is vital for conservation of these unique bat species.

This report details the results of surveys of ten of Fiji's bat caves, the threats at each site, and recommendations for conservation measures and further research. The objective of these surveys is to contribute to the knowledge and conservation of Fiji's endangered bat fauna.

An important step towards protection of these species is increasing awareness of the important role the bats play in keeping ecosystems and agricultural crops healthy. Awareness and education campaigns have been started at communities near the roosting caves. This report summarizes the steps that have been taken, and provides recommendations on how to continue these efforts.

CHAPTER 1. CAVE-DWELLING BAT SPECIES

FIJI BLOSSOM BAT

The Fiji blossom bat (*Notopteris macdonaldi*) is a small, cave-dwelling bat which is restricted to Vanuatu and Fiji. In Fiji, the only known roosts of this species are located on Viti Levu. The Fiji blossom bat roosts deep in large limestone caves. It feeds on flowers and nectar (Mickleburgh et al., 1992) and generally forages in lowland forest, although occasionally on agricultural lands and in upland forest as well (Pernetta and Watling, 1978, Flannery, 1995). It has been recorded at high altitudes on the three largest islands in the Fiji Islands (Flannery, 1995, Scanlon, 2009). Several studies indicate that blossom bats play an important role in pollination and seed dispersal, not only of forest plants and trees but also of economically important crops (Levey et al., 2002, Hall and Richards, 2000).

Figure 1. Fiji blossom bat (*Notopteris macdonaldi*). Photo by Alivereti Naikatini.

Threats

The Fiji blossom bat is listed as Vulnerable on the IUCN Red List, because its distribution is very fragmented, and because there is a continuing population decline due to overexploitation and habitat degradation or destruction (Palmeirim, 2008a). There are only five known roosting colonies of *N. macdonaldi* in Fiji, while on Vanuatu no roosting colonies have been located (Palmeirim, 2008).

Cave-dwelling bats in particular are known to be sensitive to roost disturbance. Several of the roosting colonies of the Fiji blossom bat are subject to regular disturbance. Two colonies are regularly visited by tourists, occasionally by large groups of up to fifty people. The ceilings of these caves are quite high, which limits the impact of the visits on the bats, but it is not known what the effect of these tourist visits is on the colonies.

Four of the five known roosting caves are located quite close to villages, which often leads to increased roost disturbance. The bats have often been captured for consumption by the local villagers, as bat harvesting is a traditional custom of cultural significance. The bats are considered a delicacy, and used to be harvested in large amounts at the start of the *yam* season. However, this seems to be an outdated custom which is not (often) performed anymore, although the villagers do mention occasionally taking out a handful of bats. It is as yet unclear how many bats are currently being harvested, nor how often this happens.

It is unclear to what degree deforestation affects *N. macdonaldi*. Palmeirim (2007) suggests that the blossom bat might be particularly affected when forest is replaced by vegetation without usable food resources. Even so, the blossom bat is known to forage on agricultural lands as well, although this might not yield sufficient food throughout the yearly cycle. Two of the roosting caves are located in an area where little native forest is left. The bat populations in these caves are assumed to forage in the nearby Colo-i-Suva forest park, which is dominated by the non-native African mahogany. This

shows that they might not be as dependent on native forest vegetation as was originally assumed. The problem is that almost nothing is known about their feeding preferences and feeding range.

PACIFIC SHEATH-TAILED BAT

The Pacific sheath-tailed bat (*Emballonura semicaudata*) is an insectivorous bat which roosts in a large variety of caves, and possibly also in hollow trees and under overhanging cliffs. The local name is *bekabeka*. Colony size varies greatly, from caves being used by only a few individuals to a large colony in the Yasawa's with about 500 individuals.

Figure 2. Pacific sheath-tailed bat (*Emballonura semicaudata*). Photo by Paddy Ryan.

The Pacific sheath-tailed bat has a broad range throughout the Pacific (Helgen and Flannery, 2002). It has however seen a dramatic decrease in recent decades in most of the region, and it has disappeared from many of the islands it used to be common on (Bonaccorso and Allison, 2008). The Pacific sheath-tailed bat contains four subspecies, *Emballonura semicaudata semicaudata* is the subspecies occurring in Fiji (Koopman, 1997).

Figure 3. Pacific sheath-tailed bat (*Emballonura semicaudata*). Photo by Joanne Malotaux.

The Pacific sheath-tailed bat used to be widespread throughout Fiji (Palmeirim et al., 2005, Watling and Pernetta, 1978, Hutson et al., 2001) but has seen a dramatic decrease in recent decades. Several researchers mention seeing this bat in nearly every cave visited on the main island, Viti Levu (Gilbert, 1984, Watling and Pernetta, 1978). During the most recent large-scale survey of Fiji's caves, Palmeirim et al. (2007) report that the bat seems to have been extirpated from Viti Levu altogether. However, the interior of the island has not been surveyed, so the possibility remains that the species is still present there.

Threats

Reasons for the decline of the Pacific sheath-tailed bat are unclear. Palmeirim et al. (2007) suggests that introduced predators might be the most important cause of its decline. In Fiji it appears to be the domestic cat (*Felis catus*) that affects *E. semicaudata* the most. Pesticides are also known to adversely affect microbat populations, either by direct toxicity or by affecting insect availability (Hutson et al., 2001). During a fieldwork trip in Taveuni, several locals reported that pesticide use was quite widespread, and situations may be similar on the other islands.

Similar as for the other cave-dwelling species, roost disturbance might be a cause of its decline. Increased human populations and facilitated access to the caves lead to increased disturbances of the roosting caves. The combination of deforestation and tropical storms is hypothesized to have a

negative effect on the Pacific sheath-tailed bat as well, by affecting foraging habitat, forage availability as well as by damaging roosting caves (Palmeirim et al., 2005). However, this might not explain the sudden decline in this species, especially the possible complete disappearance of the bat from Viti Levu. Another possible reason for this large decline is disease. Microbats have been known to be severely affected by certain diseases (like white nose syndrome in North America), and one should consider the possibility that a disease has led to (or has contributed to) the extirpation of this species on several islands.

Research

Research should focus on detecting roosting caves of *E. semicaudata.* The surveys done by Palmeirim et al. (2007) suggest that the populations thrive better on smaller islands. Many smaller islands have not yet been surveyed. Furthermore, the interior of the larger islands can be searched for roosting caves as well. As in the case of the Fiji blossom bat, ecological knowledge of this species is very limited, which makes it difficult to direct conservation efforts. Determining the reasons for decline is also vital in planning conservation measures.

FIJI FREE-TAILED BAT

The Fiji free-tailed bat (*Chaerephon bregullae*) is a cave dwelling bat species that currently occurs in Vanuatu and Fiji. In Fiji, it is locally named *Kalakalavo*. The species is listed as endangered because of its limited distribution and limited number of roosting caves (Palmeirim, 2008b). In Fiji it has been recorded on Taveuni and Vanua Levu, but the only known nursing colony is located near Nakanacagi village in Vanua Levu. This might indicate the presence of one or more roosting caves in Taveuni. Chapter 4 contains a report that indicates the possibility of the presence of a *C. bregullae* roosting cave in northern Taveuni.

Figure 4. Fiji free-tailed bat (*Chaerephon bregullae*). Photograph by Joanne Malotaux.

The colony is located in a fairly large mudstone cave near Nakanacagi village. It is possible though that it roosts in hollow trees as well, as does one of its close relatives in Australia, *Chaerephon jobensis (Palmeirim, 2008b)*. The Fiji free-tailed bat has been seen foraging in open spaces in many different habitats, varying from farmland, to coconut groves to (montane) forests (Palmeirim et al., 2005).

Threats

As the Nakanacagi cave is potentially the only nursing cave for the free-tailed bat in Fiji, the situation is quite precarious. Bats are occasionally captured by locals at the Nakanacagi cave, although this activity appears to have been reduced in recent years. However, consumption of the bats, especially during critical breeding conditions, could lead to overharvesting of the population.

Furthermore, the stand of native forest around the cave probably influences the climate in the cave, loss of or change in vegetation cover outside the cave may change the cave climate, which in turn could have negative effects on the bats.

CHAPTER 2. GENERAL RECOMMENDATIONS

Awareness and education

Awareness and education are almost universal requirements. It is important to encourage understanding of bats, their diversity, their role in the environment and conservation concerns. Bats suffer from a poor public image, and threats to bats are often related to ignorance of the bats and the important roles they play in ecosystem maintenance. The support of the communities living in the near vicinity of the bat caves is essential to the long term protection of the bats. To secure this support, a good level of awareness is needed in the communities about the importance and significance of these animals. The following chapters on the caves will each contain a brief section on recommended awareness activities. General awareness activities could include developing education programmes, including for example presentations at local villages, as well as school activities. It should also include creating and providing educational materials, aimed at a variety of groups, such as local communities, school children, tourists, landowners, as well as the general public.

Conservation actions

Threats to Fiji's cave-dwelling bat species include roost disturbance and loss, harvesting, introduced predators and deforestation. Apart from awareness and education, other actions can be taken to protect the bats and their roosts and habitat. As cave-dwelling bat species are in general very sensitive to disturbance of their roosts, measures should focus on protecting their roosting caves. In some instances, caves are regularly visited by tourists. Regulating these visits might reduce the negative impacts on the bats. In other situations, fencing or gating the cave might be an effective solution in reducing roost disturbance and protecting the bats from being harvested.

These bat species depend largely on good forest habitat, but much of Fiji's (native) forest has been lost. Native forest should be protected throughout Fiji, for the sake of the bats as well as for Fiji's other native and endemic species.

The next section will elaborate on more specific and directed conservation actions.

Research

Limited ecological knowledge is available on most of Fiji's bat species. This lack of knowledge makes it difficult to direct conservation efforts. Further research should include studying diet, foraging habitat, breeding season and habitat requirements among others. Monitoring population trends at the known roosts is highly desirable, to allow timely detection of any population declines.

More survey work is needed as well. During these surveys, we documented an up until now unknown roosting cave, and heard many reports on more caves all throughout Fiji. This shows that current knowledge on the location of caves is far from complete, and that information from local communities is invaluable in the search for roosting caves. Chapter 4 contains more information on the reports we have gathered throughout the surveys.

Resurveying several previously documented caves would be advisable as well. Many caves visited by Palmeirim et al. in 2000/2001 have not been revisited since, and it is not known what the current status is of these sites. Several of the caves have been identified as key conservation areas (Palmeirim et al., 2005), which we could not all visit during these surveys. Further surveys should focus on Tatuba cave (Viti Levu), the cave in Yaqeta (Yasawa's) and the limestone caves in the Lau Group (Palmeirim et al., 2005).

CHAPTER 3. CAVES

Nine of Fiji's bat caves were surveyed by Joanne Malotaux, intern at NatureFiji-MareqetiViti (NFMV), and Kelera Macedru, Conservation Officer at NFMV, from March-June 2012. The locations of all caves are shown in figure 5. Appendix 1 contains the coordinates of each cave, except for Maqai cave, as no GPS logger was brought on the visit to this cave. Most of these cave locations were obtained from the report of Palmeirim et al. (2005), who conducted an extensive survey of caves on 30 islands in Fiji in September 2000 – January 2001. In this report, several of these sites have been marked as key conservation sites, but most have not been visited since these surveys. The following chapters will report the results of our surveys at each cave, and will give recommendations for further research, awareness activities, and other conservation efforts.

Traditional village protocol was followed prior to each cave visit, and permission was obtained from the village leaders. These ceremonies offered the opportunity for conversation with the village elders, and provided us with the opportunity of explaining the objectives of our research and conservation activities. The villagers were often eager to learn about their cave and its bat colony. The meetings also allowed us to obtain information on several subjects concerning the bat cave and the colony, such as locating other potential roosts, estimating bat numbers and population trends, and determining potential threats to the colony. The same questions were asked to the guides who accompanied us on the trip to the cave, in an attempt to cross-check the information.

During each visit, we explored the caves as far as possible. In certain occasions, sections of the cave were inaccessible, or dangerous to access. It was often difficult to make a rough estimation of the number of bats in each cave, as many bats disperse when people approach and bats often roost on high ceilings or in crevices. The presence of white-rumped swiftlets (*Aerodramus spodiopygius*) in each cave also makes visual estimates very difficult.

Figure 5. Map of the Fiji Islands showing the locations of the ten surveyed caves. Coordinates of the cave sites can be found in Appendix 1.

WAILOTUA

The limestone outcrops of Viti Levu, the largest island of Fiji, contain a large number of limestone caves. The longest limestone cave is Wailotua Cave, located at the village Wailotua I in Tailevu (Gilbert 1984). The cave is home to a colony of Fiji blossom bats (*Notopteris macdonaldi*).

This chapter documents a four-day visit to the Wailotua cave and Wailotua I village by Kelera Macedru and Joanne Malotaux in February 2012. A survey of Wailotua cave and another nearby cave was undertaken to collect information on the caves and their bat fauna. Additionally, the guides and other villagers were questioned on their knowledge of the cave, the bats, harvesting habits and cave visits. This information is being used to create materials for both tourists and the local village, to provide information and raise awareness about bats and the important role they play in Fiji's ecosystems.

Fieldwork and social surveys were conducted by Kelera Macedru and Joanne Malotaux on February 21st, 2012 and from February 27th until March 1st, 2012. Permission to visit the Wailotua cave system was obtained by presenting an *i sevusevu* to Tui Wailevu in Wailotua I. At this ceremony, the objectives of the study were discussed, and some information on the cave was gathered.

The main cave, of which the entrance is located next to the village of Wailotua I, was visited twice, accompanied by several guides, Sikeli Tamani, Josua Cagi and Sainimere. On the second occasion we were accompanied by Tui Wailevu, Ratu Savenaca Bose (63 years old), who is currently the oldest person in the village and has explored the cave system thoroughly. A second cave system, of which the cave mouth is located higher up the hill above the village, was explored on the second day, accompanied by the Tui Wailevu and three other guides, Sikeli Tamani, Josua Cagi and Sainimere. All accessible parts of the caves were explored and searched for the presence of bats and/or swiftlets.

During the cave explorations the cave, its bat fauna and its history were discussed with the guides. In the evenings, lengthy kava sessions offered the opportunity to gather more information and stories from other villagers as well.

Results

Survey of main cave system

The entrance of the main cave (figure 6) is located very close to Wailotua village. The map in Appendix 2 shows the location of the cave. A footpath runs through the main passage of the cave, leading to a vast chamber with very high ceilings. East of this main chamber is a large cave mouth where the Wairuku river enters the cave. A map of the cave, drawn by Gilbert (1984) can be found in Appendix 2. Tui Wailevu mentions three other exits, one of which can be seen from the main chamber as a dim light in the western corner of the chamber ceiling. This cave mouth is located on top of the hill next to the village, and can be accessed following a path that starts at the top of the quarry. Forest cover around this cave mouth appears to be largely intact. The other two exits are neither visible nor accessible from inside the cave.

The guides mention that the footpath is only one of three tunnels leading towards the main chamber. The lower canyon passage is also mentioned by Gilbert (1984) and the guides also report a higher passage which is difficult to access. Access to the high-level passage is restricted as this is '*tabu'* area. Gilbert also reports another passage leading north from the main chamber, where the main stream leaves the chamber. We did not explore this part of the cave.

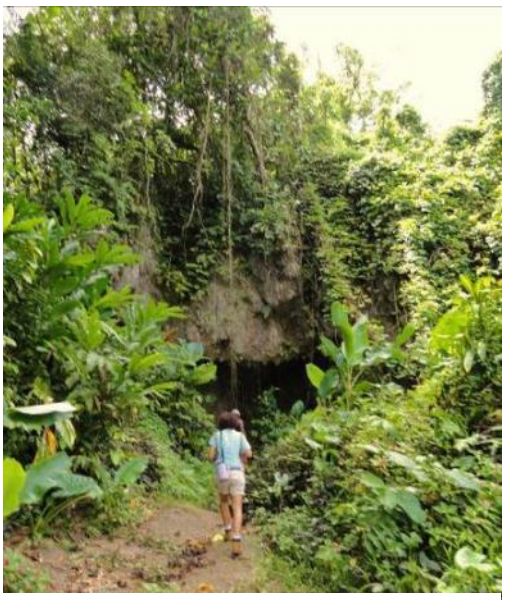

Figure 6. Western (main) cave mouth of Wailotua cave, situated close to Wailotua I village. Photo by Joanne Malotaux.

The white-rumped swiftlet (*Aerodramus spodiopygius*, local name *'kalaba'*, figure 7) is a small cave-nesting bird and can be observed nesting near both entrances of the main gallery and in parts of the main chamber. The white-rumped swiftlet is often confused with the bats in the dark of the cave. The main chamber harbours a large colony of Fiji blossom bats (*Notopteris macdonaldi*), locally termed '*Nai kua'*. The bats roost in hollow areas in the ceiling and fly in and out of several passages leading off the main chamber. It is not possible to estimate bat numbers inside the cavern, as the ceiling is very high, the bats are distributed unequally over the chamber ceiling, and many roosting places are not visible from the terrace in the main chamber.

Figure 7. White-rumped swiftlets (*Aerodramus spodiopygius*) nesting along the cave walls. These cave-dwelling birds are often confused with the bats. Photo by Joanne Malotaux.

The blossom bats reportedly do not use the large cave mouth to the east of the main chamber (pers. comm. S. Tamani*)*. Apparently, Palmeirim et al. captured only swiftlets during several days of mist netting at this entrance during the cave survey in 2000 (pers. comm. S. Tamani). The bats are known to use the previously mentioned cave mouth higher up the hill (pers. comm. Tui Wailevu).

According to Tui Wailevu and several other villagers, a smaller bat used to inhabit the cave as well, but it seems to have disappeared. This presumably is the Pacific sheath-tailed bat (*Emballonura semicaudata*). Gilbert (1984) mentions the presence of this bat in nearly all caves he visited. Palmeirim et al. (2007) searched for it at the Wailotua cave, both with mist nets and with bat detectors, but did not detect the presence of any microchiropteran. No trace of *E. semicaudata* was found during this survey either.

Appendix 3 contains more information about the cave, as well as stories about the cave and the bats related to us by the villagers.

Visitors

The village and the cave were regularly visited by groups of tourists, but these visits have recently been stopped due to a breach in agreement between the village and Tourist Transport Fiji. The cave is still occasionally visited by tourists who pass by while traveling along the highway. The entry fee is 10 FJD per person for a guided visit into the cave.

Apart from tourists, the cave is also occasionally visited by large groups of students. The guides reported a visit by about 300 students from the University of Fiji in October 2011. In 2009 the cave was also visited by six buses of students from a primary school, which added up to about 350 students. The students go into the cave in groups of about fifty to sixty students. Inside the cave, signs of visits can be seen all over the cave as many visitors use charcoal to write on the walls.

Bat consumption

The villagers from Wailotua used to capture *N. macdonaldi* for consumption. The consumption of the bats is of cultural significance, and large-scale consumption only happens during a special ceremony which coincides with the *yam* season. The harvesting method is detailed in Appendix 3. On these special occasions, 100-500 bats are harvested. However, Tui Wailevu reports that the bats have not been harvested for about ten years, supposedly because they know now about the conservation status and importance of the bat. There are also reports that young boys from the village go into the cave and kill a small number of bats by throwing stones (H. Spencer pers. comm.). It is unclear how often this happens, and how many bats are killed.

Other potential disturbances

The villagers have installed a water collecting system; a 30mm polythene pipe runs from the large eastern entrance through the entire main passage of the cave towards the village. It is unclear whether this causes any disturbance to the bats, although it is unlikely to do so. Maintenance of the pipe might cause some disturbance.

Figure 8. The limestone quarry next to Wailotua village and close to the western cave mouth. Photograph by Joanne Malotaux.

A large limestone quarry (figure 8) is located on the west side of the hill, situated close to Wailotua 1 village and next to the western cave mouth. *Notopteris macdonaldi* is thought to prefer relatively undisturbed forests as foraging habitat; deforestation is thought to contribute to the observed population declines as well (Palmeirim et al., 2005). The disturbance by the quarry, combined with deforestation might put extra pressure on the blossom bat population in this cave[1].

[1] The Environmental Impact Assessment (EIA) for the Wailotua quarry recommended that no quarry activity be undertaken within a 200 m buffer zone either side of the cave mouth. This has not been complied with (Environmental Consultants Fiji, 2004).

Survey of second cave

The mouth of this cave is located further away from the village. A narrow trail leads from the top of the limestone quarry away from the village towards the entrance of the cave. The forest directly surrounding this cave mouth seems fairly intact, but the large quarry is not far away. From the cave mouth two chambers can be accessed. Large parts of the cave floor are covered in mud, which seems to indicate that there has been a big mudslide recently. In several passages leading away from the right chamber the mud layers are too deep to allow further exploration. Other passages are too small or too steep to explore further. Streams exit the chambers through small tunnels in the deepest corners of the cave. The villagers do not know whether this cave is connected to the other cave system, but it might be connected through small passages and waterways. Swiftlet nests can be seen on cave walls and ceilings, and guano covers the cave floor in several places. No signs of bats inhabiting the cave can be found.

The chamber that can be accessed through the left part of the cave mouth is also populated by swiftlets. Guano is piled up high on several parts of the cave floor. Despite reports of the villagers that this cave contains a bat species as well, no trace of living bats was found. Palmeirim et al. (2005) also reports no presence of bats in this cave.

Discussion and recommendations

Despite reports of the villagers of the presence of another bat besides *N. macdonaldi*, no trace of another species was found. As for the blossom bat population, according to the chief and several villagers the population has increased since the harvesting ceremonies were stopped. No reliable estimation of the number of blossom bats could be made during our visit. Palmeirim et al. (2005) say the colony has 'several thousands' of individuals. As the bats appear to use several exits, which are shared with the swiftlets, fly-out counts or mist netting at the exits would not readily lead to reliable population size estimates.

Concerning bat consumption, it is somewhat unclear when the last large-scale harvest of the bats took place. The Tui Wailevu appears to be aware of the conservation status and importance of the blossom bat, which is the reason that large-scale harvesting has not taken place for about ten years. Small-scale consumption of the bats still happens. While ideally the consumption should be stopped, minimizing consumption could be an acceptable solution as the population seems to have withstood a certain degree of harvesting for a long time (Palmeirim et al., 2007). According to the locals however, the population has increased since they have stopped large-scale harvesting. It is difficult to assess the impact of this harvesting, because neither the population size nor the off-take rate is known. As flying foxes are known to have a low reproductive rate, hunting of individuals can readily influence population numbers (Mickleburgh et al., 2008). It is recommended that population sizes be monitored on a regular basis to assess the effects of removal of individuals. Furthermore, whereas low-level consumption by itself might not seriously affect the population, the combination with other factors like roost disturbance might have a stronger effect.

The siting of a quarry so close to a large cave of national importance for both its bat fauna and tourism potential, in contravention of the recommendation of its EIA, is incomprehensible.

The number of tourist visits to the cave has recently decreased as the weekly stops of the backpacker bus at Wailotua village have been cancelled. However, the cave is still visited by tourists and large student groups. Furthermore, recent road developments lead to increased accessibility of the village and the cave, which in turn might lead to an increase in tourist visits to the cave. The noise and light produced at such visits might disturb the bats. If prohibiting tourist access to the main chamber – the roosting site – is not acceptable to the villagers, regulating visits to the cave is recommended. To minimise impact it would be important to set a maximum amount of visitors to the main chamber to limit roost disturbance. Minimizing noise, using weak lights, and not shining light directly on bats would also be recommended to reduce roost disturbance (Palmeirim et al., 2007).

The villagers have expressed interest in receiving information materials, both for the villagers themselves and to distribute to tourists and visiting researchers. The information collected in this survey will be combined with other literature on the cave and the blossom bat and will be made into information materials for the village, tourists and visiting researchers. We will provide guidelines for cave visits and information materials on how to distinguish bats from the abundant white-rumped swiftlet. Furthermore, a presentation will be given at the village to increase awareness of the importance and rarity of the blossom bat.

NABUKELEVU

During an awareness campaign near Nabukelevu village (Serua province, Viti Levu) Kelera Macedru heard of the existence of two caves populated by bats in the vicinity of the village. No record of these caves was known from any previous cave surveys on the island of Viti Levu. This chapter describes two visits to Nabukelevu by Joanne Malotaux and Kelera Macedru. The first visit, on 15th March 2012, was an exploratory survey of one of the caves. On the second visit to Nabukelevu, the 12th of April, we were accompanied by Hugh Spencer, director of the Australian Tropical Research Foundation and a bat researcher at the Cape Tribulation Research Station, Queensland, Australia. We intended to revisit the previously discovered cave, and, additionally, visit a second bat cave that was described by the guides.

Observations

In order to obtain permission to visit the cave site, an *i sevu sevu* was presented to the village elders at Nabukelevu. This ceremony offered the opportunity to discuss the purpose of our visit, and provide some information on (cave-roosting) bat species.

The cave is located at a fairly large distance from Nabukelevu; 10 minutes by car and another 2 hours hiking through the forest. We were accompanied by several guides from Nabukelevu village; Pita Nailobau, Vunidilo Tawake, Emoni I Curuivunu and Pala Niukula. The route starts out as a wide track, however, the path becomes narrower as one continues, and all but disappears eventually. In dry weather, the route will most likely be easier to access. The cave was discovered when the locals were hunting for wild pigs and is only occasionally visited due to its remote location. The guides harvested two bags of guano during the visit. This is not done regularly, as the distance to the village is too large.

The cave mouth is large and opens up into a long, high passage (see figure 9). A few white-rumped swiftlets (*Aerodramus spodiopygius*) can be seen flying in and out of the cave. A very thick layer of dry guano covers the cave floor. Bats can be seen roosting on the walls and ceilings of the cave, and many fly up when disturbed by the light or noise. Red eye reflections can be seen in torchlight, which indicates a Fiji blossom bat (*Notopteris macdonaldi*) colony. Capturing an individual confirmed this. Palmeirim et al. (2005) report that the blossom bat usually roosts at several hundred meters from the entrance, where very little light penetrates, while in this cave the bats were seen roosting

Figure 9. Entrance to Nabukelevu Cave, Serua Province. The cave mouth opens up into a high and wide passage, which harbours a large colony of Fiji blossom bats (*Notopteris macdonaldi*). Photo by Joanne Malotaux.

close to the entrance of the cave as well. As the cave passage is fairly short and straight, all parts of the passage are dimly lit.

The other cave mouth can be seen at the end of the passage. The floor slopes down steeply in the middle of the passage, which makes it difficult to explore the entire length of the cave. One of the guides climbed down and could not find any passages leading away from the main passage. However, the head of the *mataqali* (clan) at Nabukelevu village mentioned a small tunnel in the side of the main passages leading to a second chamber. This chamber reportedly does not contain any bats.

The colony probably contains several thousands of bats, but it is next to impossible to assess the number of bats in the cave as the ceiling is very high, and not the entire length of the cave is accessible. A good estimation of the actual number of bats can be done by doing a fly-out count or by using a night scope or thermal imaging camera to count the roosting bats on the ceiling.

During the second visit to this cave, a bat detector was used to check for the possible presence of microbats, in particular the Pacific sheath-tailed bat (*Emballonura semicaudata*). However, no trace of this bat species was found during this survey.

Cave dwelling bats are known to be quite sensitive to disturbance of their roosts (Hutson et al., 2001, Mickleburgh et al., 1992, Palmeirim et al., 2005). During the second survey of the cave, the bats seemed much more heavily disturbed than during the first visit. Most bats left their roosting sites and flew deeper into the cave. Whereas during the first visit, we had managed to take several pictures of the bats roosting on the ceiling, the agitation of the bats during the second visit made this next to impossible. We entered the cave with a similar amount of people, but the main difference was that we brought more and brighter torches during the second visit. The amount of light seemed to be particularly disturbing to the bats. Palmeirim et al. (2005) already suggested that, in order to minimize disturbance to the roosts, weak and red lights should be used near the bats, and shining lights directly on the bats should be avoided. This observation lends strength to Palmeirim's advice.

The guides had reported on the existence of another cave in the area, which was visited during the second visit to Nabukelevu on the 12th of April. The cave turned out to be a limestone cliff overhang, which purportedly harboured bats several years ago. This is not unlikely, as individuals of the Pacific sheath-tailed bat (*Emballonura semicaudata*) are known to roost under overhanging cliffs. However, during this survey, not a trace of bats could be found at this site.

The discovery of an additional colony of *Notopteris macdonaldi* is of high importance, as up until now there were only four known roosts of this species in Fiji (Palmeirim, 2005). Two of these four roosting caves are known to be visited by tourists on a regular basis, and consumption of bats is a fairly common occurrence at several caves. The discovery of this large, remote and relatively undisturbed colony of *N. macdonaldi* is of great value.

Recommendations

Awareness

Although the cave is not likely to be subject to regular disturbance by the locals or tourists due to its remote location, the landowners and villagers should be made aware of the uniqueness and significance of the Fiji blossom bat population in this cave. The local guides indicated that the land on

which the cave is located belongs to a clan residing near the coastal area of the Serua province. Before initiating awareness activities, it is important to find out who the land belongs to. Cooperation of the landowners and villagers would be easier to secure when the locals are made aware of the key ecological role of this species. An awareness campaign would include a presentation at the village, as well as providing information materials on the cave and its bats.

Research

Further research at this cave should include an assessment of the population size, as well as establishing a monitoring programme to allow a timely detection of population decline.

Protection

In the general area in which the cave is located logging is taking place, mainly selective logging of mahogany. Deforestation in general can lead to habitat loss or a reduction in foraging habitat quality, and *N. macdonaldi* is believed to be particularly dependent on good forest habitat (Palmeirim, 2005). Logging in the natural forest around the cave mouth – although unlikely due to the remote location of the cave – can affect the microclimate in the cave. Possibilities of protecting the area surrounding the cave should be investigated.

During the second survey at the cave, a feral cat was seen climbing the walls of the cave. Feral cats are known predators of bats. The effect of predation on this colony is probably fairly limited, as the ceiling of the cave is very high, and it will be difficult for the cats to reach the bats. Fencing might be an option to keep predators (and potentially humans) out of the cave (Long 2004).

WAINIBUKU

Wainibuku cave is a spacious limestone tunnel in a rural area close to the Colo-i-Suva Forest Park on Viti Levu. The last documented visit of this cave was in 2000 (Palmeirim et al., 2005). The cave was surveyed by Joanne Malotaux and Kelera Macedru on the 28th of March 2012, accompanied by three guides. A short survey of the cave was undertaken and information on the cave, the bats and cave visits was gathered from the guides. The cave was revisited on the 11th of April, during which we were accompanied by Hugh Spencer.

In order to obtain permission to visit the cave site, an *I sevu sevu* was presented to the village elders at Wainibuku. This ceremony offered the opportunity to discuss the purpose of our visit, and provide some information on the Fiji blossom bat and its importance.

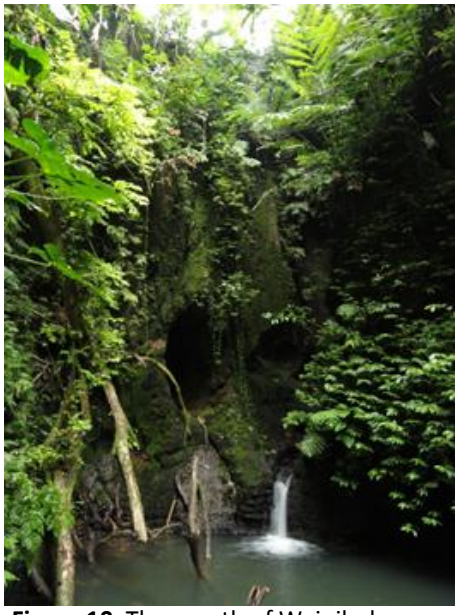

Figure 10. The mouth of Wainibuku cave, where the stream exits the cave. Photo by Joanne Malotaux.

Observations

The cave mouth is located at the edge of Wainibuku village. The forest cover around the cave mouth (see figure 10) is still fairly intact, but there are large clear-cut areas at a short distance from the cave mouth.

The passage is about 200 m long, between 5 and 15 m high and between 2 and 5 meters wide. A stream flows through the cave and forms a number of deep pools throughout the cave, as well as a pool in front of the entrance. The entrance of the cave is located close to the village and agricultural fields. The cave is inhabited by many swiftlets and cockroaches. Somewhat deeper in the cave, at a junction with a short dry passage, Fiji blossom bats (*Notopteris macdonaldi*) are roosting in ceiling pockets. A few thousand bats are roosting in the cave, although the number of bats was difficult to estimate due to the large amount of swiftlets in the cave. The ceiling of the cave is fairly low, and the bats are quite severely disturbed when the cave is visited. Several of the ceiling pockets were occupied by 200-300 bats when we entered the cave.

Figure 11. Fiji blossom bats (*Notopteris macdonaldi*) roosting in the ceiling pockets in Wainibuku cave. Photo by Joanne Malotaux.

After the junction, the passage continues for about 130 meters according to Gilbert (1984), but is not easily accessible, as the stream that runs through that part of the cave is too deep to wade through. According to the guides, there are no bats roosting in the deeper parts of the cave. During the second visit of the cave, on the 11th of April, the cave was searched for the presence of microbats using a bat detector. No trace of microbats was found. The guides also had not reported seeing any other bat species in the cave.

Discussion

During the second visit of the cave, brighter torches were brought along to allow a more thorough survey of the cave. But, similar to the situation during our second survey of Nabukelevu cave, the bats were much more heavily disturbed during the second visit, even though the number of people visiting the cave was the same as during the first visit. During the first visit, we managed to take pictures of the bats roosting on the ceiling, but during the second visit the bats had fled within several minutes and left the ceiling pockets empty. This observation again shows that light seems to be a large disturbing factor for the Fiji blossom bats. The ceiling in Wainibuku cave is much lower than in the other caves, which increases the degree of disturbance by people entering the cave as well.

The guides reported that bats were regularly harvested. Similar to the customs at Wailotua cave, the bat harvesting ceremony coincides with the *yam* season. At this moment of the year the bat is 'ready for harvesting' according to the guides. It is unclear how many bats are harvested at these occasions. Fires are lit in the cave, which drive the bats towards the exit which is blocked off with thorny branches in which the bats get caught. On a second visit to the cave however, the locals mentioned that the traditional harvesting is 'something of the past', it does not happen anymore. It is nevertheless possible that the bats are still being consumed, although in smaller quantities, as the guides did mention harvesting about twenty bats on some occasions.

Recommendations

Awareness

The villagers were not aware of the importance and rarity of the bats. The chief was intrigued to learn that there are only five known roosting colonies of the Fiji blossom bat in Fiji. It would be important to bring to the attention of the locals the significance of the bat colony that roosts in their cave. Because the cave is located so close to the village, locals often enter the cave, and the bats are occasionally harvested. A presentation will be given at the village, and materials will be provided, including cave guidelines, how to identify the bats, and how to distinguish bats from white-rumped swiftlets. It is recommended to continue these educational activities, in order to reach a larger part of the community.

Research

Further research should include assessing and monitoring colony size at this cave, as well as increasing the knowledge of the ecology of the Fiji blossom bat. Knowledge about the diet of the Fiji blossom bat can be used in the awareness campaigns, to show the local communities in which ways this bat can be useful to them.

KALABU

Kalabu cave is a large limestone cave that is located in a rural area just 3 km south of Wainibuku cave. Kalabu cave is a high, 150 m long tunnel that runs right through the ridge on which Kalabu village is situated. Both Kalabu and Wainibuku cave are owned by the same *mataqali* or clan. The cave contains a large colony of Fiji blossom bats (*Notopteris macdonaldi*). On April 11th 2012, Joanne Malotaux, Kelera Macedru and Hugh Spencer visited Kalabu village, accompanied by Senivalati Vido, an officer at the Forestry Department, and several local guides, with the intention to survey the cave and its colony.

The entrance to the cave is in the middle of the village, and requires a steep climb down to the cave mouth where the stream enters the cave. It is however not easy to enter the cave because of the stream. According to the local guides, the pool at the cave entrance is too deep to wade through, and the current can be quite strong. We did not attempt to enter the cave, as we were not adequately equipped at that moment. To venture further into the cave, one would need a raft to keep equipment dry, and ropes in case of strong currents.

The villagers do not seem to enter the cave often, due to its low accessibility. The major problem at this cave site is that the cave is used as a 'trash dump'; the area around the cave mouth is littered with garbage. As the streams runs into the cave from this cave mouth, large amounts of garbage will end up inside the cave. While raising awareness is undeniably a good first step towards conservation of the bat population in this cave, it does not change the fact that there is no garbage collection in the area, which leaves the villagers without a good option for their waste disposal.

The locals mentioned that, similar to the situations at Wailotua and Wainibuku, the bats used to be harvested in large amounts at the start of the *yam* season. Fires were lit inside the cave and the cave mouth was blocked off to trap the bats and allow the villagers to catch them. According to the villagers, this large-scale harvesting does not happen anymore.

Recommendations

Awareness

Most villagers are not aware of the importance of this cave and its colony. Increasing awareness among the villagers is recommended. An awareness campaign can include giving a presentation (or multiple presentations) to explain the importance and usefulness of the bat and the significance of this bat cave, as well as providing awareness materials. Another way to make the local community more aware is to place a sign at the entrance of the cave.

The main problem at this cave site seems to be the dumping of rubbish down the gap in which the cave mouth is located. One of the objectives of the awareness campaign would be to explain the detrimental effects this can have on the bat colony. Further conservation actions should focus on finding alternatives for garbage disposal in this village, and can possibly also include a clean-up event in the village.

Research

We were not able to enter the cave due to the deep and fairly fast-flowing stream at the entrance of the cave. A further study should be well prepared to take this hurdle. Future research should focus on assessing and monitoring colony size, and determining the threats to this colony. Again, information on the ecology of this bat can help direct conservation efforts, and will also contribute to the awareness campaigns.

TAVUYAGA

Tavuyaga cave is a lava tube at the base of Tavuyaga hill, near Vuna village in the south of Taveuni. The cave was visited on 16th April 2012, by Joanne Malotaux, Kelera Macedru and Hugh Spencer, accompanied by Sipiriano, a National Trust Officer at the Bouma National Heritage Park, and several local guides. The cave consists of two tunnels. The entrance of the first tunnel is located in a collapse hole of about 3 meters deep (figure 12). This cave mouth is located at only several meters distance from farmland. The first tunnel is littered with cans, bottles and plastic. The gallery is about 20 m long, and to the side of the other cave mouth there is an opening to the second gallery, which, according to is about 50 m long, and 1-2 meters wide and high. A colony of Pacific sheath-tailed bats (*Emballonura semicaudata*) roosts in the second part of the cave. The number of bats is difficult to estimate, about 1-2 dozen bats were flying around when we entered the cave. Palmeirim et al. (2007) estimates the colony size to be 'a few dozen'. During the survey, we did not fully explore the cave to minimize the disturbance to the bats.

Figure 12. Cave mouth of Tavuyaga cave. The cave mouth is located in a collapse hole of about three meters deep, and is largely covered with vegetation. Photo by Joanne Malotaux.

Recommendations

Awareness

The cave is situated close to farmland, and is often used by locals as can be seen from the amount of litter that is present at the cave mouth and inside the cave. An awareness and education campaign should be started in southern Taveuni, in order to provide information on the importance, rarity and benefits of this cave-dwelling bat.

Other actions

Palmeirim et al. (2005) note as well that much of the cave entrance is covered by vegetation. It is possible that the entrance might become blocked in the future. If necessary, vegetation should be removed to prevent the entrance from becoming blocked. However, care should be taken not to remove too much of the vegetation, as this might change the microclimate in the cave. Bats have been known to abandon roosting caves after slight changes in microclimate (Hutson et al., 2001). It would be advised to monitor microclimate – humidity, temperature, etc. – to detect any changes that might influence the suitability of the cave as a bat roost.

One of the potential threats to the Pacific sheath-tailed bat are introduced predators (Palmeirim et al. 2005). The cave at Tavuyaga however is easily accessible to other species. The absence of the mongoose on Taveuni might be one of the reasons for the bats' continued presence on the island. It is recommended to continue the efforts to prevent this invasive species from colonizing Taveuni island. Predation by feral and domestic cats is another suspected cause of the decline in Pacific sheath-tailed bat numbers. Ideally, cats should be eliminated from the islands. This is generally not a

feasible option, an alternative is to minimise the establishment of feral cats by neutering village cats in cooperation with the villages. Fencing the entrance of the cave at Tavuyaga can also aid in excluding predator species, and potentially also humans (Long and Robley 2004).

Other activities could include cave restoration at Tavuyaga cave. The cave is regularly used by locals, and beer bottles and other garbage litter the cave mouth and its surroundings. A cave clean-up could be organised at night, after the bats have left the cave.

Research

A fly-out survey is recommended to estimate the colony size, possibly with the use of a thermal vision camera. Regular monitoring is advised to detect any changes in colony size. Bats are known to be very sensitive to small changes in microclimate. It would be advised to monitor microclimate – humidity, temperature, etc – to detect any changes that might influence the suitability of the cave as a bat roost.

As noted before, little is known about the ecology, diet and foraging habitat of the Pacific sheath-tailed bat. Research on the ecological characteristics of this bat species would allow more directed conservation efforts.

WAITABU

Waitabu cave is a small wash-out cave located north of Waitabu village, on the eastern coast of Taveuni (figure 13). The cave harbours a small colony of Pacific sheath-tailed bats (*Emballonura* semicaudata). The cave was visited on 19th April 2012, by Joanne Malotaux, Kelera Macedru and Hugh Spencer, accompanied by Sipiriano Qeteqete, a National Trust Officer at the Bouma National Heritage Park. The cave is only accessible during low tide, as the cave is located along a narrow rocky coastline. The cave mouth is located at about 9 meters above the boulders that form the coastline. There are two other small caves at knee-height, which are flooded during high tide. The locals know the cave as a bat cave, and upon arrival the disturbed microbats can be seen flying around the cave mouth. A few dozen were seen flying around and hanging near the entrance of the cave. It is possible that there are other rock-cleft roosting sites in the immediate area.

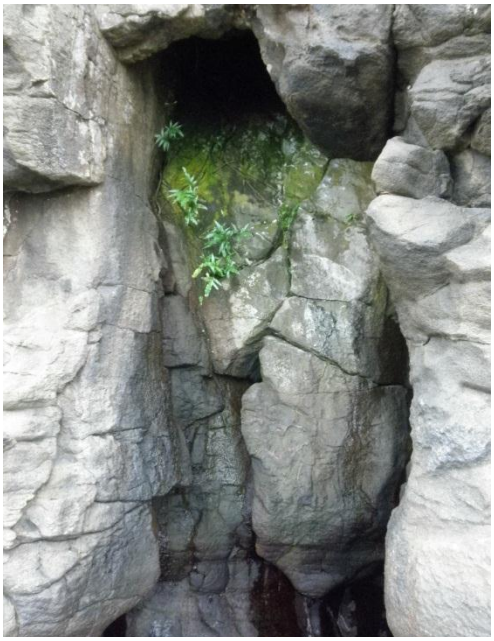

Figure 13. Entrance to Waitabu cave. The cave mouth is located about 9 meters above the coastline. Photo by Joanne Malotaux.

Recommendations

Awareness

It is advisable to start awareness activities and provide awareness materials at Waitabu village, to provide information on the importance and rarity of the Pacific sheath-tailed bat. The cave is not under immediate threat by the local community, as the cave is not easily accessible.

Research

Further research can include assessing the colony size and monitoring the population trends at both caves. This can be done through fly-out counts during moonlight surveys, or possibly with the use of a thermal imaging camera.

Using rock climbing equipment, the cave can be more fully surveyed to determine the size of the cave and the exact location of the roosting colony. It is to be questioned however whether this information is worth disturbing the bats for. Any surveys of the cave structure should be done at night after the bats have left to forage.

Other research on the Pacific sheath-tailed bat could include studying foraging habitat and diet. This information can be used to direct further conservation efforts on Taveuni island, and can also be presented back to the people of Waitabu village, to support efforts of protecting the Pacific sheath-tailed bat.

LOVONI

Two caves were visited near Lovoni village, Ovalau. Both caves contained small colonies of Pacific sheath-tailed bats.

Lovoni I

Lovoni cave is a small cave at about 40 minutes walking from Lovoni village, Ovalau (figure 14). The cave was visited on June 23rd 2012, by Joanne Malotaux and David Patterson, accompanied by two guides from Lovoni village, Balei Seruki and Jale. The cave harbours a colony of about 100 Pacific sheath-tailed bats (*Emballonura semicaudata*). Several dozen white-rumped swiftlet (*Aerodramus spodiopygius*) nests dot the walls of the cave. The cave is merely 8 meters long, and about 1-2 meters wide at its widest point. The cave is located in fairly undisturbed forest. Several tracks run through the forest, which are used for wild pig hunting. A small dalo farm is located on the lower slopes of the hill on which the cave is situated, which is slowly being extended further uphill, although it is still at a fair distance from the cave location. The guides report that this bat has been here for several decades. This bat is reportedly not consumed in the local communities; the guides note that only the big *beka*, the Pacific flying fox (*Pteropus tonganus*) is hunted for consumption.

Figure 14. Entrance to Lovoni cave. Photo by Joanne Malotaux.

Lovoni II

On 27th July 2012, Lovoni village was visited again, this time by Joanne Malotaux and Kelera Macedru, this time to survey another cave near the village. Our guides were Balei Seruki and Jalei. The cave was located at about an hour walk from Lovoni, up in the hills. It is a small cave, merely about 7 meters deep, and 8 meters wide at the widest point. The cave harbours several dozen Pacific sheath-tail bats, that mainly seem to roost in a hidden crevice at the back of the cave. No swiftlets or swiftlet nests were seen in the cave. The cave is located in good forest, but the lower slopes of the hills on which the cave is located is are for a large part covered by dalo and yaqona farms. The cave does not seem to be visited often, only our guide Balei seemed to know of the existence of this cave.

The guides mention the existence of several other caves further from the village, on the other side of the mountain ridges surrounding the valley in which Lovoni village is located. They note that several of these caves also harbour the *bekabeka*, the Pacific sheath-tailed bat.

Recommendations

Awareness

Although the cave does not seem to be under immediate threat of human disturbance, spreading awareness about the importance and usefulness of this bat species is a first step in protecting the

roost(s) on this island. The Pacific sheath-tailed bat seems to have disappeared from Viti Levu altogether, so protecting the colonies on smaller islands like Ovalau Island is important for conservation of the Pacific sheath-tailed bat in Fiji.

Research

Further surveys should focus on detecting possible other roosts of this species on Ovalau Island. Following up on the reports of the guides is recommended, as well as perhaps inquiring in other villages about the presence of caves on their land. A network of trails for pig hunting crosses the bush in the interior of Ovalau, which are intensively used by pig hunters from the local communities. These people could possess valuable information on the location of other bat caves. Our guide during both visits, Balei Seruki, is the most knowledgeable person according to many villagers, and seems to know the surroundings very well.

Palmeirim et al. (2005) visited this cave in January 2001 and reports merely a dozen Pacific sheath-tailed bats. During this survey, the colony was much larger. A bat count at this cave should be done, to accurately determine the number of bats in this colony. Monitoring the colony is desirable, to show any increases or declines in population size.

MAQAI

Maqai cave is located on Qamea, a small island north-east of Taveuni Island (figure 15). The cave was visited on the 9th of July 2012 by Joanne Malotaux and David Patterson, accompanied by Bale, an employee at Maqai Beach. The cave is situated along the coastline about 10 minutes walking north of Maqai Beach eco-resort. No GPS coordinates were taken during this visit, but several employees of the resort know the location. It is a small and narrow cave, about 1 meter wide, and about 12 meters long, and can only be visited during low tide.

Figure 15. The entrance to Maqai cave. The cave is about 12 meters long. Photo by Joanne Malotaux.

The cave harbours a small colony of Pacific sheath-tailed bats. Merely a dozen bats were seen in the cave, although some bats might have fled the cave upon our arrival through one of several openings in the ceiling of the cave. Several people reported that the colony was much bigger merely a year ago. The manager of the resort mentioned that the number of bats was so high only a year ago, that he abandoned the plan of turning the cave into a cyclone shelter. Several of the local employees mentioned the colony being much bigger on previous visits, and reported seeing the '*bekabeka*' (small bats) also roosting beneath nearby cliff overhangs. One of the local employees reported the presence of another bat cave nearby his village on the western coast of Qamea, and the existence of more small caves along the entire coastline of the island. The general consensus among the locals was that the bats seemed to be moving or migrating between the different caves. The cave is occasionally visited, but the bats are reportedly not consumed. The locals mention eating the 'big bats' (presumably the Pacific flying fox, which is fairly abundant on Qamea), but not the small bats.

Recommendations

Awareness

The manager and employees of Maqai Beach eco resort have expressed their interest in obtaining more information on the bat colony. NatureFiji-MareqetiViti is creating educational materials on Fiji's bats, and will provide these materials to the resort. As all employees at the resort are inhabitants of villages on Qamea, the information might also reach the local villages on the island.

Research

It would be advised to follow up on the reports of the Maqai staff members of the other bat caves on the island. The Pacific sheath-tailed bat currently seems to be dependent on the smaller islands in the Fiji group, so protection of these small (but potentially many) roosts on small islands like Qamea is vital to the conservation of this species. Monitoring colony size in this cave (and other caves on the island) might provide some information on the movements of the colonies between the different caves. Radio or GPS tracking would be ideal, but likely beyond the scope of any studies in the near future.

NAKANACAGI

Nakanacagi cave harbours the only known colony of Fiji free-tailed bats (*Chaerephon bregullae*) in Fiji. The cave was visited on 23rd May 2012, by Joanne Malotaux, Kelera Macedru and Kolinio Moce. We were accompanied by several guides from Nakanacagi village. The cave is locally termed *Qara ni Bekabeka* and is located at about 20 minutes walking distance from Nakanacagi village, Vanua Levu. The cave is located in an agricultural area, but the forest immediately surrounding the cave is well preserved. The cave is about 500 meters long, and a nursing colony is located in a wide crevice at about 50 meters from the large upstream entrance to the cave system. The ceiling of the large chamber where the bulk of the colony roosts is low, between 1 and 3 meters at most places. Further downstream, more adult bats could be seen roosting in crevices in a more spacious part of the cave. The downstream opening is very small; a grown man has difficulty fitting through. This opening is reportedly used by kids to collect guano.

The guides report that the bats used to be so abundant in this cave, that they could walk in and simply grab armfuls of bats from the ceiling. They note that the colony size has decreased considerably. Local villagers used to capture and consume the bats from the colony occasionally, but this has supposedly stopped (or at least decreased significantly) since researchers (Palmeirim et al. 2005) first visited the cave in 2000 and explained the importance of the site.

Kelera Macedru and Kolinio Moce had both visited the cave at Nakanacagi in March 2011 (Macedru, 2011), and noted that the colony seemed much larger now than during their first visit. This might mean that the colony has increased in size in the last year. Another explanation however can be that females use secondary roosts outside the nursing season. During the visit in June 2012, a large number of pups could be seen. It is possible less individuals use the cave at Nakanacagi as a main roost outside the breeding and nursing season, which might explain the seemingly lower number of bats in March.

Recommendations

Awareness

As this cave is the only known nursing colony of the Fiji free-tailed bat in Fiji, protecting this site is vital for the conservation of this species. Raising awareness on the importance of this bat and the great uniqueness and significance of this colony is an important first step. During our visit to Nakanacagi village, a presentation was given at the village. The audience mainly consisted of children (about 30 children, between the ages of 5 and 15), but several adults also came in and listened. Both the children and the adults showed great interest in learning more about the bats, and were seemingly proud when they found out this was the only colony of this bat species in Fiji. Continuing this awareness campaign is needed to reach a larger part of the local community, in order to stop harvesting and reduce disturbance to the colony.

Research

It is important to monitor this colony on a regular basis, as the loss of this colony could result in the extinction of this bat species in Fiji. Research should include colony size, diet, foraging habitat preferences, and threats.

Future research could also include searching for more bat roosts, either permanent nursing caves, or temporary roosts outside the nursing season. It is very well possible that the bats roost in hollow trees or under cliff overhangs.

Cave gating

The cave at Nakanacagi harbours the only known colony of Fiji free-tailed bats in Fiji. The Nakanacagi elders have voiced the wish to have the site protected, and to prohibit visits to the cave unless for stated bat monitoring purposes by researchers (Macedru, 2011). Gating the cave at Nakanacagi Village can be one way of protecting the bats by preventing humans from entering the cave and disturbing or even killing the bats.

The cave has two (known) cave mouths (see figure 16). The largest cave mouth (*Naivunivuni*) is the most commonly used. The other cave mouth (*Nabakola*) is located on the other end of the cave. This cave mouth is very small; a large adult has difficulties fitting through. This entrance is reportedly used by kids to collect guano. Both cave mouths could be gated to prevent people from entering the cave. However, gating is not an easy decision. The protection of caves with gates has at times led to declines of the bat population or even abandonment of the cave. Each bat species tends to have varying ability to negotiate a gate structure. Bat gating activities have to be done with careful consideration of the nature of the site and the requirements of the bat species using it (Fant et al., 2009).

Figure 16. The (known) cave mouths of Nakanacagi Cave. Left: The largest and most frequently used cave mouth. Right: The narrow opening downstream. This cave mouth is mostly used for guano collection. Photos by Joanne Malotaux.

Risks of gating

Microclimate changes

The placement of gates at the cave mouths brings along several issues. First of all, some cave mouths are not feasible to gate for certain physical reasons. If they are feasible to gate, the gate should be placed in such a way that it does not restrict the airflow. Changes in airflow cause changes in the microclimate (temperature, pressure, humidity) in the cave (Roebuck et al., 1999), which can have great consequences for the ecosystem. Bats have been known to abandon caves after minute changes to the microclimate (Hutson et al., 2001). The impact of cave gates on white-rumped swiftlets is not known.

Impact of the gate on the colony

When placing the gate, bat flyways should also be taken into account. Surveys are needed to determine whether the bats actually use the cave mouth that is to be gated, or whether they use other openings possibly higher up the hill. From inside the cave, faint light can be seen coming from higher up in the cave, which indicates that there are more cave mouths than the two commonly used entrances. It is possible that the bats use these openings to exit and enter the cave. If the bats do not use the main entrance, gating is an obvious answer to restricting access. However, if the bats do use the two main cave mouths, the design of the gate should be such that bat flight is not impeded. Different bat species have different requirements. Some bat species are known to fly between horizontal bars, as long as the spacing is large enough (but then again not wide enough to allow human entry). Other bat species however require a larger flight space. The Mexican free-tailed bat (*Tadarida brasiliensis*) for example does not accept a gate unless a space 2-3 meters tall is left open above the gate (Elliot, 2011). Such a large open space then also might again allow human access to the cave.

It is difficult to predict the response of the bats to the gate. Even so-called ‘bat friendly’ gate designs have been known to affect the bats negatively, even to the point that the bats abandoned the cave (Michael Pennay, personal communication).

Testing the gate

The reaction of the bats to the gate itself can be tested by building a dummy gate. The gate can be constructed out of pvc tubing and temporarily installed at the cave mouth, to observe how the bats react to the cave gate. The spacing between the bars can be adjusted to see how this affects outward and inward flight patterns. Using a night scope or thermal vision camera would be advisable when testing the gate.

Issues when the decision to gate has been made

If the decision to gate has been made, the construction of the gate will have to be carefully planned and executed. The downstream cave mouth is a very small and narrow opening. One horizontal bar would be sufficient to prevent people from entering the cave through this opening. The gate at the main entrance would be more complicated. Building the gate can seriously disturb the bats and the swiftlets that inhabit the cave. The colony in Nakanacagi cave roosts not far from the main cave mouth, and the construction might seriously affect the colony. Hiring an experienced cave gate designer can increase the efficiency of the construction process, thus decreasing the time needed to construct the gate.

Before the decision whether to gate can be made, thorough research of the cave site and bat population is needed. Monitoring population trends is necessary. It is not known whether the population is currently stable, decreasing or perhaps even increasing (as a result of the reported lower harvesting pressure). During a survey early 2011, several data loggers were placed inside and outside the cave to measure cave microclimate.

It is strongly advisable to assess population size of the bat colony before instalment of a gate, in order to have baseline data to compare the effects of gate construction with (Grandison et al., 2000, Herder, 2000). Behavioural changes of the bats after placement of the gate should be documented as well. Monitoring of the microclimate before and after the gate is also needed to check whether the gate causes any changes in microclimate (Grandison et al., 2000, Fant et al., 2009).

After construction, the gate itself needs to be periodically checked and maintained. The gate can be subject to vandalism and erosion, and regular maintenance is needed to make sure the gate still fulfils its purpose and does not endanger the bat population in any way (Fant et al., 2009).

Alternatives to gating

The risks of gating the cave at Nakanacagi are high. If the bats do not tolerate the cave gate, the cure may be worse than the disease; the bats may be lost from Fiji completely, as this is currently the only known roosting cave of the Fiji free-tailed bat. Gating is generally only used as a very last resort, where other options are not feasible. Before embarking on such a risky operation, alternatives have to be explored.

Education and awareness

It has to be considered whether education, awareness-raising and putting up signs may be a better use of the limited sources of the organization. An awareness campaign has been started in May 2012 with a presentation to a group of children and several adults at Nakanacagi village. Educational materials are currently being produced and will be distributed among the villagers. It is recommended to continue this campaign. Revisiting the village for another presentation and involving the local children can be a first step. During the first visit, we have reached merely a small part of the community that lives in the vicinity of the cave. A more large-scale approach might be needed.

Signage

It would be advisable to place warning and interpretive signs at the cave mouths, with information about the cave, the bat population and their national and international significance. This will not achieve the same degree of protection as gating would, but it will at least contribute to increasing awareness among the locals that actually visit the cave.

Fencing

A less drastic alternative to gating would be fencing the area around the cave. While potentially less effective in keeping people out than a gate, the effect on the bat population will be minimal. Additionally, fencing will protect the vegetation around the cave mouth.

CHAPTER 4. CAVE REPORTS

During the surveys and while traveling around the islands, I heard many reports of other bat caves. Due to lack of time, I have not been able to check up on many of these locations. In this section, I will note down the approximate locations of all caves, as well as any further information on the cave and the contact information for any future surveys at these sites.

MATEI, TAVEUNI

During a visit to Matei, on the northernmost tip of Taveuni Island, I visited an resident of Matei, Dougie Cammick, to check up on a bat that had flown into his wall several days before. It turned out to be a Fiji free-tailed bat (*Chaerephon bregullae*). The only known roost of this species is in Nakanacagi cave on Vanua Levu. It is possible that the bat travels to Taveuni to forage, but we were told about a big bat cave in the hills above Matei, reportedly with the same bat as the Fiji free-tailed bat found at Dougie Cammick's house. He described the bats flying around the lights on his property every night. Both Dougie Cammick and several locals reported that the cave is very big, and that it harbours 'a lot' of bats. One of the local farmers visits the cave every few months to collect guano, and collects several big bags on each occasion, which indicates that there is a large and steady supply of guano.

Dougie Cammick and his colleagues at the Taveuni Island Resort in Matei also mentioned the existence of several other small bat caves up in the hills above the farmlands south of Matei. This might also be well worth exploring, although the large cave has priority. They noted two more caves south of the wharf on the western coast of Taveuni, contact person for these caves is Keith Douglas.

Contact information

Dougie Cammick	8644509
Tiko	9257285 - Pig hunter from Naselesele village. Has visited the large cave on several occasions.
Neomi	No phone number. Ask Dougie Cammick or Tiko for contact details. Local young man. Regularly visits the cave to collect guano.
Keith Douglas	Phone number unknown. Ask Dougie Cammick for further details. Knows the location of a cave on the west coast of Taveuni.

QAMEA

When visiting the cave near Maqai Beach Eco Resort, the local staff of the resort informed us on the existence of more bat caves along the coast of Qamea. Henry Hatherly, the manager of the resort, informed us about Maqai cave. Several local employees know about more caves elsewhere on the island. It is likely that the Pacific sheath-tailed bat is dependent on small islands like Qamea for its survival. Contact Maqai resort or Bamboo office for more information and for further contact details.

MATAGI AND LAUCALA

Matagi island and Laucala island are both located to the north east of Taveuni, respectively to the north and to the east of Qamea. Both are private islands. Several people have reported the existence

of bat caves on both islands. A bat cave with *bekabeka* – possibly Pacific sheath-tailed bats – is supposedly located on Matagi Island. Laucala island is said to have a large cave with slightly larger bats, which might indicate a Fiji blossom bat colony. However, access to these islands is fairly difficult, as both islands are privately owned, and have expensive resorts. The bat caves on these islands are no high priority though. It seems unlikely that the bat caves on these islands are under large threat of disturbance, as development of the resorts mostly takes place along the coast, and seems focused on keeping most of the natural values intact.

LOVONI, OVALAU

As noted in the section on two bat caves near Lovoni village on Ovalau, the interior of Ovalau island is reported to contain several more bat caves. Palmeirim et al. (2005) noted two more caves without any bats, but they did not visit any other locations. Balei Seruki, our guide, said several more caves are located higher in the mountains, on and over the ridges that surround the valley. According to many of the Lovoni villagers, Balei has the most knowledge on the environment. Few of the other villagers had heard of the bat caves.

Lovoni village landline: 603 0297.

LAU

An employee of the Agricultural Station in Mua, Taveuni, mentioned that they use bat guano on several of the islands in the Lau group as manure, as the soils are often not quite fertile on many of these islands. She specifically reported on the existence of two bat caves on Ono-I-Lau, and said these caves contained 'hundreds of *bekabeka*' when she last visited them 'a couple years ago'. It seems however, that the locals are also often mining guano from white-rumped swiftlets, which might not always be distinguished from the bats. The island of Totoya is also said to have a cave with a colony of *bekabeka*.

Palmeirim et al. (2005) visited several islands in the Lau group. Several caves with small colonies of Pacific sheath-tailed bats were found, but colonies were often small, and many caves were empty, even though locals reported seeing an abundance of bats in many locations. It is recommended to revisit the caves Palmeirim at al. surveyed, as well as surveying several other islands in the Lau group. Again, smaller, more sparsely populated islands like the islands in the Lau group might harbour the remaining population of the Pacific sheath-tailed bats.

NAKAUVADRA RANGE

During a Biodiversity Assessment in 2008 in the Nakauvadra Range in the Ra Province, three Pacific sheath-tailed bats were detected with the use of a bat detector (Morrison and Nawadra, 2009). Pacific sheath-tailed bats were suspected to have disappeared from Viti Levu, as no trace of them was found on the island during the surveys by Palmeirim et al. (2005). No roosting caves were found during the assessment. More surveys need to be conducted to locate the presence of any roosting colonies, and to search for the presence of any other bat species. The Fiji blossom bat (*Notopteris macdonaldi*) could also be present in the Nakauvadra Range.

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APPENDIX

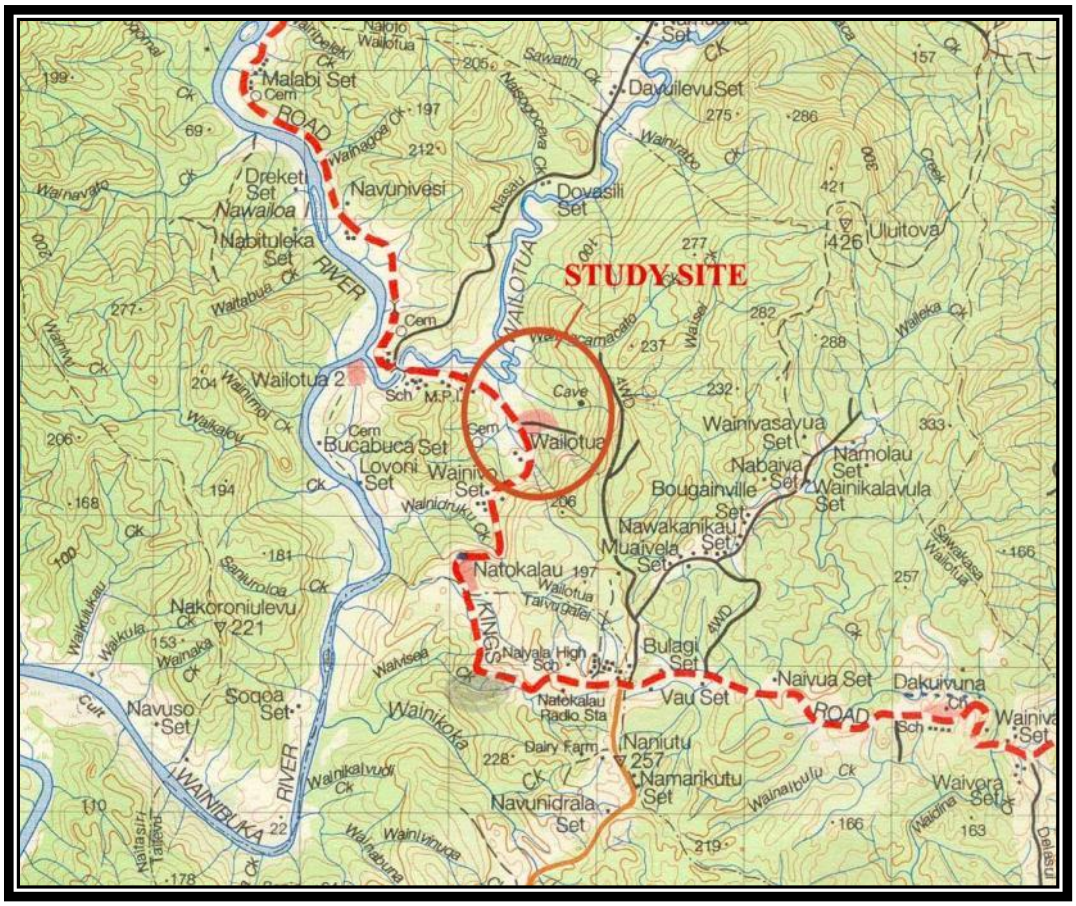
APPENDIX 1. CAVE COORDINATES

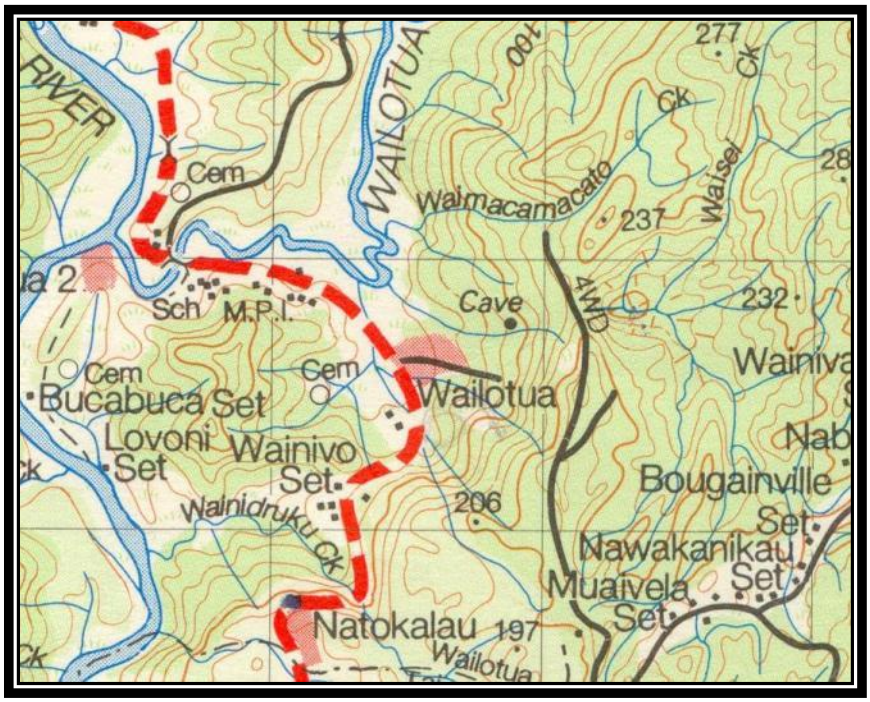
Wailotua	17º 45.67' S, 178º 24.46' E
Wainibuku	18º 3.52' S, 178º 29.26' E
Kalabu	18º 5.17' S, 178º 28.99' E
Tavuyaga	16º 59.48' S, 179º 55.22' E
Waitabu	16º 48.75' S, 179º 51.24' W
Lovoni I	17º 41.47' S, 178º 46.5' E
Lovoni II	17°41’28.03”S 178°46’37.49”E
Nakanacagi	16º 36.57' S, 178º 58.38' E

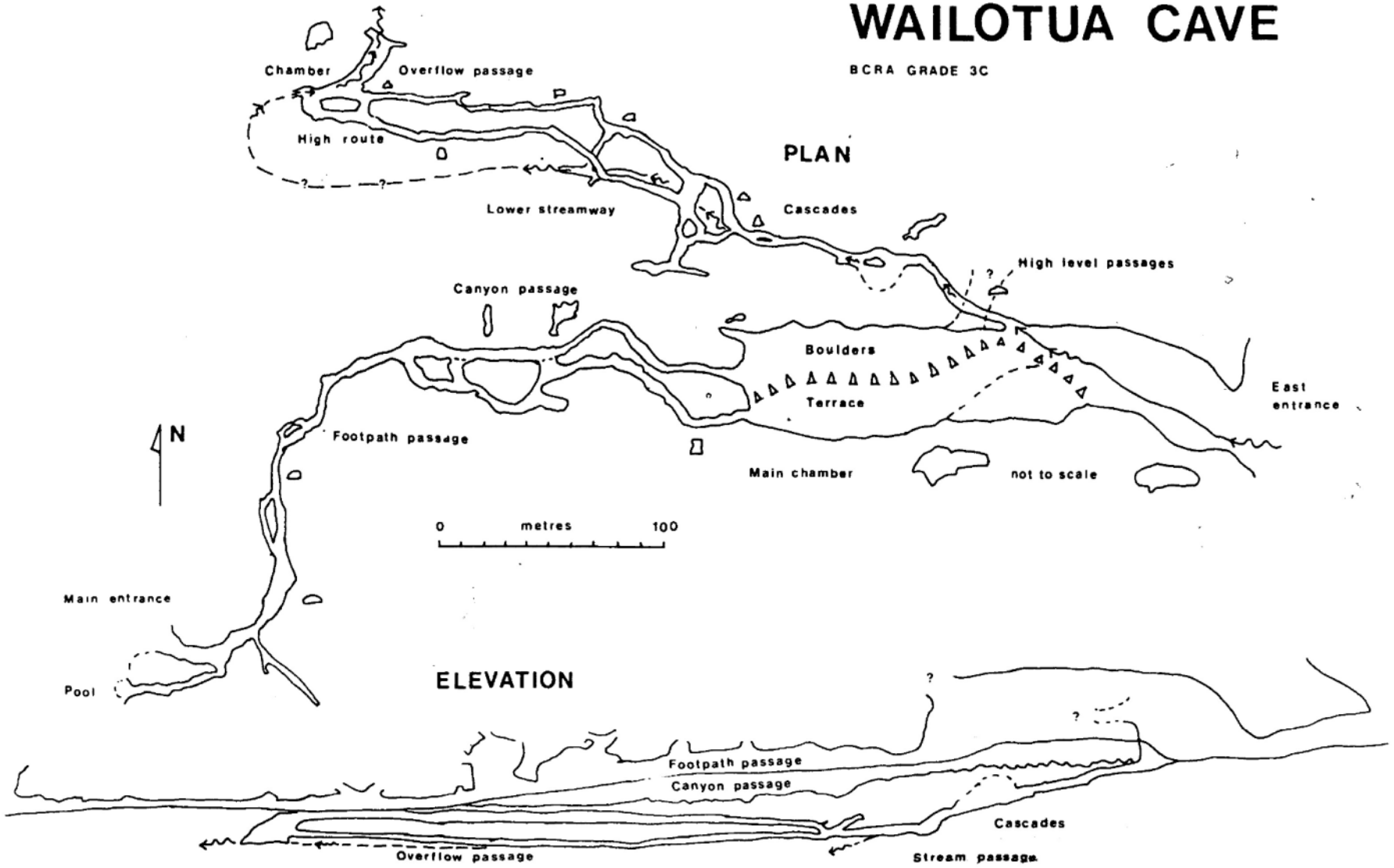
The coordinates of Maqai cave are not known.

APPENDIX 2. WAILOTUA MAPS

Maps of the study site, Wailotua I village in Tailevu, with the western entrance of the cave located to the east of the village.







Map of the Wailotua cave, taken from Gilbert (1984). The main entrance shown on the map is located next to the village Wailotua I. The main chamber is the roosting location of a large colony of *Notopteris macdonaldi.*

APPENDIX 3. WAILOTUA CAVE: ADDITIONAL INFORMATION

History of the use of Wailotua 1 cave

- The cave was a refuge for the ancestors of the villagers of Wailotua I, during cyclones and tribal wars.
- The cave was also a place that was used for the slaughter of people during the days of cannibalism in Fiji. This is called '*bakola*' locally, which means individuals slaughtered for consumption.
- The cave was a meeting spot in which a young man could engage with a young woman that he intends to marry, by requesting her hand in marriage whilst being alone with her inside the cave.
- Within the long passage in Wailotua cave a rock formation in the shape of a six-headed snake can be found. The formation assists the local guides in relating the story of a six-headed snake inhabiting the cave. A rock formation is forming on the floor below the snake formation, which is said to be the 'saliva of the snake'. Before Christianity, indigenous people believed in spirits. One of these spirits took the form of a snake in the cave. The village of Wailotua 1 was known as 'Ono', which is the Fijian word for the number six. The name referred to the six-headed snake believed to be residing in the cave. A higher level passage opens up above the formation, this is a taboo area however and visitors are not allowed to enter (personal communication S. Tamani, 2012).
- The Wailotua cave was also believed to be a meeting area for spiritual deities from Fiji. The ancestors of the Wailotua visitors would worship these spirits by performing the traditional *meke*, a dance, in the main chamber (*rara*) of the cave. The *meke* is now regarded as a form of devil worship and is no longer performed by the indigenous people, therefore any further details of the dance are unknown (personal communication Ratu Savenaca, 2012).

Bat harvesting method

Related by Tui Wailevu, Ratu Savenaca Bose.

Bats are consumed at special occasions by order of Tui Wailevu himself. The harvest coincides with the start of the *yam* season, as the bats supposedly taste best at this moment of the year. A specific *mataqali* (clan), known as *Mataqali Na-Colawe*, is responsible for the harvesting of the bats for the Tui Wailevu. The harvesting was done by lighting several bamboo fires in the main chamber (*rara*) to drive the bats towards a small dead-end passage, the *tuvu*, where the bats would be captured and killed by members of the harvesting *mataqali*. Between 100 and 500 bats would be harvested at these occasions (pers comm. Ratu Savenaca).

Other Comments

Tui Wailevu, Ratu Savenaca Bose is said to be the oldest person residing within the village of Wailotua I, at the age of 63 years. According to Tui Wailevu, stories are passed down from their elders. The knowledge among individuals residing in the village at this time is limited; most villagers do not know much about the stories related to the cave.