A survey of microbat habitat use within the urban landscape of Lismore, New South Wales.

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A survey of microbat habitat use within the urban landscape of Lismore, New South Wales.

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Cover Photo

This Lesser Longeared Bat (Nyctophilus geoffroyi) is a nocturnal insectivorous bat. Unlike many other microbat species, this one has a litter each spring, consisting of two pups. Photo credit: Terry Reardon, South Australian Museum and used courtesy of Adelaide Bat Care (www.adelaidebatcare.com.au)

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Abstract

Microbats play an important role in urban and natural environments. They are numerous in taxa and distribution, which identifies them as a major contributor to regional mammal diversity. They may also be important indicators for the health of the environments they inhabit. The present study aimed to conduct a survey of microbats to i) identify which species are present at Southern Cross University’s Lismore campus and within the Lismore city limits and ii) identify which habitats are utilised most frequently.

From November 2012 to January 2013, 18 transects (9 at SCU, 9 within the Lismore LGA) were surveyed from three broad habitat types; vegetated (>40% canopy cover), near water (≤40m of a water body) and urban (2 - 5 building ha⁻¹ including areas lit with lights at night). Transects were surveyed at night using ultrasonic equipment.

Seventy six individual records were analysed. Nine species were identified, including four that are recognised as Vulnerable in New South Wales. Vegetated transects accounted 65% (n = 49) of the data while 32% and 3% were attributed to the near water transects (n = 24) and urban transects (n = 3) respectively. Abundance was higher in the broader Lismore LGA (86% (n = 65)) compared to SCU, however, species richness was the same at both SCU and within the Lismore LGA (n = 6).

An increase in urban density resulted in a decrease in species richness and abundance. The results suggest that the retention of vegetated areas (both of natural forests and replanted “green” areas) within the urban landscape may be important for complete bat assemblages. Additional surveys are necessary to provide a more complete understanding of the species and their distributions.

Keywords: microbats, Microchiroptera, habitat use, urban landscape
# List of Contents

## Abstract

## List of Contents

## List of figures

1 **Introduction**

2 **Literature Review**

   2.1 *Why is biodiversity important?*

   2.1.1 Ecological goods and services

   2.2 *Urbanisation*

   2.2.1 Effects of urbanisation on Microbats

   2.2.2 Habitat use within the urban landscape

   2.3 *Bats as Indicators*

   2.4 *Biology*

   2.4.1 Little Bentwing Bat (*Miniopterus australis*)

   2.4.2 Gould’s Wattled Bat (*Chalinolobus gouldii*)

   2.4.3 Eastern False Pipistrelle (*Falsistrellus tasmaniensis*)

   2.4.4 Eastern Freetail Bat (*Mormopterus norfolkensis*)

   2.4.5 Lesser Longeared Bat (*Nyctophilus geoffroyi*)

   2.4.6 Greater Broad-Nosed Bat (*Scoteanax rueppelli*)

   2.4.7 Habitat requirements

   2.5 *Conservation Status*

   2.5.1 National Status

   2.5.2 State Status

   2.5.3 Current Recovery and Action Plans

   2.6 *Survey Techniques*

   2.7 *Public perception*

   2.8 *Disease*

   2.8.1 Hendra

   2.8.2 Australian Bat Lyssavirus

   2.8.3 SARS

   2.8.4 White-nose Syndrome

   2.9 *Definition of problem*

   2.10 *Aims and objectives*

3 **Methods**

   3.1 *Site Description*

   3.1.1 Climate

   3.1.2 Geology

   3.1.3 Vegetation

   3.1.4 Land Use

   3.2 *Survey Site Selection*

   3.3 *Habitat Categories*

   3.4 *Survey Timing*
Table of Tables

Table 1: Active acoustic survey of microbats was conducted from November 2012 to January 2013 in Lismore, NSW. The study focused on three broad habitat types; vegetated (>40% canopy), urban (2 - 5 building ha\(^{-1}\)) and near water (≤ 40m of a water body). Nine species were identified, including four Vulnerable species in New South Wales.  

Table 2: Thirteen files were sent to Ecotone Ecological Consultants Pty Ltd for comment by consultants Ray Williams and Amy Rowles. The results identified a correct assessment by the author at a species level 38.5%, at a genus level 23% and disagreed 38.5% of the overall assessments. Confidence levels used were: Likely (almost certain), Probably (not quite certain) and Possibly (quite unsure).
List of figures

Figure 1: Hibernating Little Bentwing Bat (*Miniopterus australis*) huddle together in their cave to keep warm. Photo Credit: B. Thomson

Figure 2: (1) Gould’s Wattled Bat (*Chalinolobus gouldii*) (2) Eastern Freetail Bat (*Mormopterus norfolkensis*), (3) Lesser Longeared Bat (*Nyctophilus geoffroyi*) and Greater Broad-Nosed Bat (*Scoteanax rueppellii*). Photo credit: B. Thomson

Figure 3: Greater Broad-Nosed Bat is one of the larger, more robust species of microbat. Because of their size, their flight is often described as clumsy and awkward. Photo credit: Terry Reardon

Figure 4: Harp nets are not always fruitful, are labour intensive and have been known to damage bats caught by the netting. This net was set in a fly way for seven days, and despite confirming bat activity through acoustic survey techniques, the harp net caught nothing. (Photo credit: K Howton)

Figure 5: Southern Cross Universities Lismore Campus is situated in Northern NSW, approximately 800 km north of Sydney.

Figure 6: The transects at Southern Cross University were chosen based on personal knowledge of bat activities. One transect per habitat type (Urban, Near Water, Vegetated) was chosen solely on random. Three replicates per habitat type were sampled twice.

Figure 7: The transects within the Lismore Local Government Area were chosen based on personal knowledge of bat activities. One transect per habitat type (Urban, Near Water, Vegetated) was chosen solely on random. SCU grounds can be seen in the bottom right corner of the map.

Figure 8: When a call is analysed, many characteristics are looked at. Only a full call sequence of more than three pulses can be analysed. This call of a Little Bentwing Bat (*Miniopterus australis*) is a long sequence and identification is highly likely based on this call.

Figure 9: Occasionally species calls are similar and a certain amount of overlap is common. Where ambiguity exists, the call identification was not reported in the results section. In this example, the call could be of an Eastern Freetail Bat (*Mormopterus norfolkensis*) or the unidentified *Mormopterus sp 2*.

Figure 10: Calls come in a range of call lengths, frequencies and tone variations. This call is possibly of a Greater Broad-Nosed Bat (*Scoteanax rueppellii*) or an Eastern False Pipistrelle (*Falsistrellus tasmaniensis*). It is displayed here to highlight the contrast between the calls of different species.

Figure 11: Occasionally, two individual bats can be identified from the one file recording. In this example, a Little Bentwing Bat (*Miniopterus australis*) (right) begins to call the instance that the Gould’s Wattled Bat (*Chalinolobus gouldii*) finishes.

Figure 12: A map indicating the land assets owned by Southern Cross University map (1:3000 scale). Source: (Newton Denny Chapelle Consulting Surveyors and Planning, 2009)

Figure 13: Identified as ID1, this was the first call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Possibly *Mormopterus norfolkensis* or *Chalinolobus gouldii*”. Amy Rowles assessment was “More likely *Mormopterus sp 2* or poss *Chalinolobus gouldii*” while Ray Williams’s assessment was “I agree most likely *Mormopterus sp 2* with feeding buzz”.

7
Figure 14: Identified as ID2, this was the second call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Possibly Nyctophilus geoffroyi”. Amy Rowles assessment was “Nyctophilus sp”. Ray Williams assessment was “Agree but too shot to ID”. 46

Figure 15: Identified as ID3, this was the third call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Likely Scotorepens sp1 or possibly Scotorepens orion”. Amy Rowles did not comment. Ray Williams’s assessment was “Frequency a little too high for Scotorepens orion. Could be Scotorepens greyii or Scotorepens sp1 if NE NSW”. 47

Figure 16: Identified as ID4, this was the fourth call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Possibly Nyctophilus geoffroyi”. Amy Rowles assessment was “Not Nyctophilus”. Ray Williams’s assessment was “Possibly Scotorepens orion or Scotoeanax rueppellii”. 48

Figure 17: Identified as ID5, this was the fifth call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Possibly Scotoeanax rueppellii or possibly Scotorepens Orion”. Amy Rowles did not comment. Ray Williams’s assessment was “Agree”. 49

Figure 18: Identified as ID6, this was the sixth call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Possibly Mormopterus norfolkensis or Mormopterus sp2”. Amy Rowles assessment was “More likely to be Mormopterus sp2”. Ray Williams’s assessment was “Mormopterus sp2”. 50

Figure 19: Identified as ID7, this was the seventh call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Unknown, but possibly Vespadelus darlingtoni”. Amy Rowles assessment was “Possibly Miniopterus schreibersii oceanensis”. Ray Williams’s assessment was “not identifiable”. 51

Figure 20: Identified as ID8, this was the eighth call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Vespadelus troughtoni or possibly Vespadelus vulturnus”. Amy Rowles did not comment. Ray Williams’s assessment was “Probably Vespadelus vulturnus”. 52

Figure 21: Identified as ID9, this was the ninth call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Possibly Scotoeanax rueppellii or Scotorepens orion”. Amy Rowles assessment was “Chalinolobus gouldii”. Ray Williams assessment was “Most likely Chalinolobus gouldii”. 53

Figure 22: Identified as ID10, this was the tenth call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Likely Falsistrellus tasmaniensis”. Amy Rowles assessment was “wouldn’t say likely”. Ray Williams’s assessment was “more likely Scotorepens Orion”. 54

Figure 23: Identified as ID11, this was the eleventh call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Scoteanax rueppellii or Scotorepens Orion”. Amy Rowles assessment was “Chalinolobus gouldii”. Ray Williams assessment was “Most likely Chalinolobus gouldii”. 55

Figure 24: Identified as ID12, this was the twelfth call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Possibly Mormopterus sp2 and Miniopterus australis”. Amy Rowles assessment was “Mormopterus sp2 or Mormopterus norfolkensis or Chalinolobus gouldii”. Ray Williams assessment was “a bit too high for Mormopterus sp2 probably Mormopterus norfolkensis but not typical”. 56

Figure 25: Identified as ID13, this was the last call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Falsistrellus tasmaniensis”. Amy Rowles did not comment. Ray Williams’s assessment was “Falsistrellus tasmaniensis or Scotorepens Orion. Could also be Scotoeanax rueppellii except freq a bit high”. 57
1 Introduction

The global demands for urbanisation are increasing as rapidly as our population (Rockström et al., 2009; van der Ree et al., 2005). Urbanisation modifies natural habitats, often in extreme and irreversible ways. These changes are viewed as a leading cause of biodiversity loss (Puppim de Oliveira et al., 2011). The retention of natural ecosystems within the urban landscape may support a large array of biodiversity (Threlfall et al., 2012a, 2012b; Threlfall et al., 2011).

Microchiropteran bats, called microbats (hereafter bats) are one of the most diverse and geographically dispersed groups of mammals. Only the order Rodentia (rodents) exceeds bats in the number of species known globally; over 1116 species of bats described internationally, with 90 bat taxa recognised in Australia (Environment Australia, 1999; Simmons, 2005). Thus, microbats are often a major contributor to regional mammal diversity and should not be overlooked during conservation planning (Basham et al., 2011; Schultz et al., 1995).

Individual bat species often have specific habitat requirements. They are recognised as an important indicator of levels of biodiversity because of these niche environmental requirements. This recognition has resulted in their internationally high conservation status (Jones et al., 2009).

With the pressures of habitat loss and fragmentation, disease, fire and inadequate representation in the public reserves system, it is a necessity that conservation of biodiversity also occur on private lands. Given the modification of habitats resulting from urbanisation, identifying which species are present in disturbed habitats plays an important role in conservation biology and management.

This study was undertaken to fill existing knowledge gaps regarding microbat habitat use at Southern Cross University (SCU). The results of this study may be used by SCU Sustainability Policy Advisory Committee during the formation of a Fauna and Flora Management Plan. It is important that an adequate understanding of the literature regarding microbat habitat use and general management be considered. Thus, this report starts with a literature review. It then identifies what habitat types are utilised more readily by microbats within the urban landscape before making recommendations regarding their management.
2 Literature Review

2.1 Why is biodiversity important?

Biodiversity provides valuable goods and services directly and indirectly for human populations. These goods and services underpin the vitality of health care systems and forestry productions (Adenle, 2012). Moreover, biodiversity contributes to food and agriculture which is essential for feeding the world’s human population and improving quality of life. Conservation and sustainable use of biodiversity play a critical role for the survival of humans (Food and Agriculture Organization of the United Nations, 2012a, 2012b).

2.1.1 Ecological goods and services

The term ecological goods and services (EGS) has been used since the 1970s (Costanza et al., 1997; Costanza et al., 1970; Rockström et al., 2009). It refers to the beneficial by-products received by humans from the natural functioning of organisms within their environment.

Microbats, for example, are highly mobile mammals that are able to exploit all aspects of their landscapes, natural or urbanised. They exert a natural control of arthropod pest species (Kalka et al., 2008). Each individual, depending on conditions, can consume 40 – 100% of its body weight per night (Lentini et al., 2012; Saikia, 2007). This control of pests reduces agricultural loss through insect herbivory (Lentini et al., 2012), may reduce the risk of disease such as the mosquito born Ross River Fever and exerts a natural control of the insect populations.

2.2 Urbanisation

Urbanisation modifies natural habitats, often in extreme and irreversible ways. The greatest habitat transformations have occurred where entire natural ecosystems have been removed and replaced with human dominated landscapes (van der Ree et al., 2005). The demand for urbanised areas in relation to the number of people supported within cities, and the extent of city boundaries is increasing (van der Ree et al., 2005). Currently, 50% of the world’s population is residing within urbanised environments, however, this number is predicted to increase to 66% by 2025 (United Nations, 2012). This pattern of urban sprawl is evident on the eastern seaboard of Australia, which has undergone dramatic changes since the establishment of European settlement in 1788 (Australian Bureau of Statistics, 2010).

2.2.1 Effects of urbanisation on Microbats

The level of disturbance and the resulting fragmentation experienced during urbanisation is often inhospitable to many of the endemic mammal species (McKinney, 2002) which may require larger areas of habitat with room to disperse to outlying areas (Law et al., 1998; van der Ree et al., 2005). The species that do remain are those that can tolerate a high level of disturbance, can easily navigate and traverse the urban clutter and can utilise the resources contained within it (Law et al., 1998; van der Ree et al., 2005). Microbats are highly mobile allowing them to persist in the fragmented urban landscape, unlike many terrestrial mammal species (Basham et al., 2011).

Although bats can fly between supporting remnants, habitat requirements can vary amongst species (Basham et al., 2011). In a study of microbats in Townsville, Queensland, researchers...
found that species richness and total foraging activities declined with increased urbanisation (Hourigan et al., 2006). Additionally, the study revealed that species with an ability to exploit open and edge habitats were more widespread. In one American study, researchers report that species that naturally forage in open areas now also exploit streetlights for foraging opportunities (Avila-Flores et al., 2005).

The availability of suitable roost sites within highly urbanised areas is limited and unlike studies from North America, Hourigan et al. (2010) found no evidence of roost fidelity in Townsville. The same study found a high diversity of microbats in urban areas while studies from the northern hemisphere report the opposite. These spatial differences highlight that some species will adapt to urbanisation better than others and that perhaps the degree and scale of urbanisation are important factors for consideration (Basham et al., 2011).

2.2.2 Habitat use within the urban landscape

Previous studies have suggested that the prevalence of some species may be assumed based on the geological and floral structure of urban sites. Basham et al (2011) reported significantly higher bat activity in bushland remnants with fertile shale soil when compared to gully and ridge remnants of sandstone origin. The survey, conducted in Sydney, also found that the amount of bushland within 0.5 – 3 km surrounding a site and the tree density were common indicators of species presence. They identified that species richness may have a correlation with the area of bushland, the abundance of tree hollows and the average tree diameter. They concluded that bushland remnants within cities may have high conservation values for insectivorous bats and that the retention of some natural ecosystems within the urban landscape may be important for the conservation of biodiversity (Basham et al., 2011).

2.3 Bats as Indicators

Bats serve as ideal indicators of biodiversity (Jones et al., 2009). They display taxonomic stability, are easy & quick to survey and monitor for population changes and are distributed around the globe. Bats are a high trophic level species; the insectivorous bat feeds on insect prey which in turn is dependent on plants. Changes in bat communities in terms of species richness and diversity may indicate problems within the ecosystem (Jones et al., 2009).

Bats utilise a wide range of suitable food sources (insects) which are identified as the favoured indicators for a large array of environmental degradation issues (Jones et al., 2009). Insects comprise a large proportion of terrestrial species richness, are often habitat specialists and have significant roles in ecosystem functioning. This makes them sensitive to small scale change; however, monitoring for changes in insect communities is difficult. Thus, changes in bat community structure may infer environmental changes such as increased levels of pesticide, declining water quality and climate change stressors. Although the graded response to habitat degradation displayed in bat communities should be correlated with the responses of other, harder to sample taxa (Jones et al., 2009).
2.4 Biology

There are currently 29 described and five not yet formally identified taxa of microbats recognised in New South Wales (Churchill, 1998; Pennay et al., 2004). All but nine have been identified as part of the assemblage present in the Northern Rivers of New South Wales.

As management decisions could potentially impact on the habitat of bats, a general understanding of the differing needs of the species present is considered essential. To highlight the difference in species needs in terms of habitat, roosting, nursery and feeding requirements, some local examples are detailed below. These summaries should serve as a starting point for further investigations regarding management decisions.

2.4.1 Little Bentwing Bat (Miniopterus australis)

The Little Bentwing Bat (Figure 1) is a small dark chocolate brown coloured bat, approximately 45 mm long in body length, with a short distinctive muzzle and small triangular shaped ears. They are known to occur along the eastern seaboard and ranges from Cape York in Queensland to Wollongong in New South Wales (Churchill, 1998).

This species roosts in caves, tunnels, mines and tree hollows. Large maternity colonies form in spring during the breeding season and are sometimes shared with Eastern Bentwing Bats (M. schreibersii) (Dwyer, 1968). It is thought that Little Bentwing Bats may rely upon the body heat provided by the Eastern Bentwing to raise the temperature in the maternal colony which is critical for the survival of their young (Churchill, 1998). Males and juveniles disperse in the summer. Only five maternity colonies are known in Australia.

Although this species has no commonwealth status, it is listed as Vulnerable in New South Wales (New South Wales Office of Environment and Heritage, 2012d).

![Figure 1: Hibernating Little Bentwing Bat (Miniopterus australis) huddle together in their cave to keep warm. Photo Credit: B. Thomson](image)
2.4.2 Gould’s Wattled Bat (Chalinolobus gouldii)

The Gould’s Wattled Bat (Figure 2) is a highly adaptive bat that occurs throughout Australian habitat and climate zones, with the exception of Cape York, Queensland (Churchill, 1998). It has brown fur which tends to be darker to the head and shoulders and white underneath (Churuszcz et al., 2002). The ears are broad and short. The face is short with a lobe of skin, called a wattle, present at the corners of the mouth.

Although they are found in virtually all habitats, roosts are usual made in tree hallows, particularly Red River Gums (*Eucalyptus camaldulensis*). They are also known to utilise buildings as roost sites. Female form colonies while males tend to be solitary or join colonies of other species. Colonies using tree hallows for roost sites can number from eight to 40 while those that use buildings can double that number (Churchill, 1998).

Copulation occurs in June, and the female stores the sperm over her winter torpor (called hibernation in some countries). Fertilisation occurs at the end of winter with pregnancy lasting 3 months. The twin offspring are usually delivered September to November (North to South regional variation). The offspring take just six weeks to achieve adult size and independent from that time (Churchill, 1998).

2.4.3 Eastern False Pipistrelle (Falsistrellus tasmaniensis)

The Eastern False Pipistrelle has dark fur above and paler grey fur on its underside. It is a larger, more robust bat, measuring around 65mm long and weighing as much as 28 grams (Churchill, 1998). Its long but slender ears are set well back on its head, overlapping when pressed together. They are known to occur along the eastern seaboard and ranges from southern Queensland to Tasmania.

This species is known to prefer moist sclerophyll forests with trees taller than 20m (Churchill, 1998). Roost sites are generally hollow tree trunks of eucalypt trees (Churchill, 1998), but have also been found under loose bark and in buildings.

Colonies can consist of three to 36 individuals and are usually single sexed, although mixed colonies do sometimes occur. They enter torpor during the winter months, are pregnant in the spring and early summer. They produce a single offspring in December, which lactates until the end of February (Churchill, 1998).

They predate on insects that fly above or just below the forest canopy. Their flight is generally direct and fast, with sudden directional changes. They have been known to fly up to 12kms form their roosting site to forage (Churchill, 1998).

Although this species has no commonwealth status, it is listed as Vulnerable in New South Wales (New South Wales Office of Environment and Heritage, 2012a). Disturbance of roosting and breeding sites, loss of habitat, particularly roosting sites and the use of pesticides adjacent to foraging areas are all listed as threats (Churchill, 1998).
2.4.4  Eastern Freetail Bat (Mormopterus norfolkensis)

The Eastern Freetail Bat (Figure 2), also known as the Mastiff Bat is a medium size bat that measures 55mm in length and up to 10g in weight. It has dark brown fur on its upper side, tending to be lighter underneath. It is known to occur along the eastern seaboard east of the Great Dividing Range, from the south of Sydney to Brisbane (Churchill, 1998).

This species has been recorded in a range of habitats from dry sclerophyll forests and woodlands, to rainforests and mangroves (Churchill, 1998). This species is opportunistic in terms of roosting; they have been found in natural environments such as tree hollows and beneath loose bark, and in man-made structures such as metal capping on telegraph poles and roofs (Churchill, 1998). They are usually solitary, although, they have been recorded in communal colonies with other bat species. Little is known regarding the diet, foraging habits and reproduction of this species.

Although this species has no commonwealth status, it is listed as Vulnerable in New South Wales. Loss of suitable roost and foraging sites, and the use of pesticides adjacent to foraging areas are all listed as threats (New South Wales Office of Environment and Heritage, 2012b).

2.4.5  Lesser Longeared Bat (Nyctophilus geoffroyi)

The Lesser Longeared Bat (Figure 2) is a common species throughout Australia, absent only from the east coast of Queensland. It has light grey fur on its back and white fur on its belly. It is a smaller but heavier bat, measuring up to 50mm in length and 14.5 grams in weight.

This species has been found in all Australian habitats and in all climate zones. They will often use loose bark, tree hollows and buildings as roost sites. Although they are usually found solitary or living in small groups of two to three individuals, one large colony of several hundred bats has been observed in a building and a group of 50 individuals found in the Nullarbor. In some areas, maternity colonies of up to 15 females have been found up to 12kms from foraging areas. This species is known to move roosts regularly (Churchill, 1998).

This species has been known to display two hunting methods; it has been plucking prey from the ground or surface of plants as well as catching prey mid-air. The flight of this species is slow, but highly manoeuvrable (Churchill, 1998). In forested areas, they usually forage six to 10 meters off the ground. In open areas, they fly much lower; between one to four meters above the ground. Moths form 60% of their diet.

Mating occurs in autumn, producing a single litter, generally twins, each year in late spring. The pups lactate until weaning, around early February.
Figure 2: (1) Gould’s Wattled Bat (*Chalinolobus gouldii*) (2) Eastern Freetail Bat (*Mormopterus norfolkensis*), (3) Lesser Longeared Bat (*Nyctophilus geoffroyi*) and Greater Broad-Nosed Bat (*Scoteanax rueppellii*). Photo credit: B. Thomson
2.4.6 Greater Broad-Nosed Bat (*Scoteanax rueppellii*)

The Greater Broad-Nosed Bat (Figure 2) has dark reddish brown fur on its back with slightly paler fur on its belly. It is a large, robust bat, measuring up to 95mm and weighing as much as 35 grams (New South Wales Office of Environment and Heritage, 2012c). The ears are triangular, slender and have a rounded tip. It is often visually mistaken for Eastern False Pipistrelle, however, the Greater Broad-Nosed is noticeably larger (Churchill, 1998).

Found along the eastern seaboard from the Atherton Tablelands in Northern Queensland to southern New South Wales, this species prefers habitats that are moist. They are only found at lower altitudes; below 780m to the northern extent of their range and up to 500 m to the southern extent (Churchill, 1998).

The Greater Broad-Nosed Bat utilises tree hollows as roost sites, as well as available building spaces. Maternal colonies are known to form in the summer, when males are totally excluded from the colony. A single pup is born in January, noticeably later than other species in the same range distribution.

The flight of this species is slow and clumsy, with poor manoeuvrability (Figure 3). Because of their awkward flight, their choice of prey is restricted to other slow flying insects such as large moths and beetles. They tend to hunt within 20 m of the ground, on vegetated edges. It is suspected that they predate on other bat species in the wild and are known to feed on other bats in captivity when caught in traps during surveys (Churchill, 1998).

Although this species has no commonwealth status, it is listed as Vulnerable in New South Wales (New South Wales Office of Environment and Heritage, 2012c). Disturbance to or loss of normal & maternal / foraging sites, and the use of pesticides adjacent to foraging areas are listed as threats. It is recognised that changes in climate are also likely to impact on this species (Wilson, 2006).

2.4.7 Habitat requirements

Microbats require two essential habitats; one suitable to diurnal roosting and sufficient for extended periods of torpor and other sites for nocturnal foraging. Some species are highly mobile and will transverse the landscape from roost site to foraging site. Lunney et al (1988) reported that there is no evidence that microbats travel more than 2 km from their roost sites and that some species, such as the Gould’s Longeared Bat (*Nyctophilus gouldii*) will stay within 1 km of their roost. Churchill (1998) recalls a radio tracked *F. tasmaniensis* moving 12 km from where it was foraging to its roost site.

Bullen and Dunlop (2012) surveyed microbats in Western Australia using stable isotope analysis of fur samples and acoustic survey techniques over five habitat types. The isotope signature of the seven bat species surveyed revealed that the insects preyed upon are primarily feeding on the ground cover within the specific habitats surveyed. Results from the acoustic survey showed that bat activities aligned with the projected foliage density.
Figure 3: Greater Broad-Nosed Bat is one of the larger, more robust species of microbat. Because of their size, their flight is often described as clumsy and awkward. Photo credit: Terry Reardon

2.5 Conservation Status

In order to effectively manage biodiversity, it is important to understand the conservation status of the targeted species. International, national and state laws exist regarding threatened species, their conservation and management. The associated lists of threatened species generally identify the biology of species, populations and / or communities at risk as well as any associated threatening processes.

2.5.1 National Status

The national law governing biodiversity is the Environment Protection and Biodiversity Conservation Act (1999)) (Department of Sustainability, 2009). Since European occupation, 27 species of mammals have become extinct in Australia including one bat. Three bat species are listed as Critically Endangered, two are Endangered and five species are identified as Vulnerable. None of these species occur within the study area.

2.5.2 State Status

In New South Wales, 17 species of microbats have conservation status under the Threatened Species Conservation Act (1995) (New South Wales Office of Environment and Heritage, 2011). One microbat species is listed as Extinct (N. howensis), one as Endangered (Mormopterus eleryi) and 15 as Vulnerable (New South Wales Government, 2013). Some of these species occur within Northern New South Wales.

2.5.3 Current Recovery and Action Plans

Three national recovery plans exists covering five microbat species. They are the National recovery plan for the Bare-rumped Sheathtail Bat, National recovery plan for Cave-dwelling Bats, Rhinolophus philippinensis, Hipposideros semoni and Taphozous troughtoni 2001 - 2005 and the National recovery plan for the Large-eared Pied Bat Chalinolobus dwyeri(Department of Environment and Resource Management, 2011; Schultz et al., 2007; Thomson et al., 2001). These recovery plans describes the conservation issues regarding the
species in question, their current status, known habitats and distribution, their biology and ecology, and identified threats and recovery objectives.

Additional national microbat recovery plans are being drafted under the EPBC Act (1999) for *M. schreibersii bassanii* and Eastern Long-eared Bat (*Nyctophilus timoriensis*). A recovery plan for the megabat Grey Headed Flying Fox (*Pteropus poliocephalus*) is also being drafted. No date for draft completion is listed (Department of Sustainability, 2012). Although not policy, a guideline for surveying bats in Australia is also published with the above recovery plans (Department of Environment, 2009).

### 2.6 Survey Techniques

There is some debate in the literature about which survey method best answers the questions of species richness and relative abundance. Traditionally, bat surveys were conducted using invasive netting techniques such as harp traps (Figure 4) and mist nets. Gukasova and Vlaschenko (2011) argue that while techniques such as acoustic recording do capture fragmented data regarding both species richness and abundance, it does not provide data regarding population structure, or the condition of sampled individuals. They highlight the lack of standardisation in the methodology employed during mist net surveys in Europe, however, they state that survey techniques using mist nets is still effective and adequate for survey purposes.

The capture technique described in the above paper is labour intensive, and was known to injure a percentage of the bats captured. Additionally bats were able to avoid the cumbersome nets, resulting in skewed survey data.

The development of acoustic recording devices such as the Anabat II Bat Detector (Titley Scientific, Brisbane) has allowed for non-invasive sampling of microbat community compositions, habitat use, temporal activities and distribution, in particular that of rare species.

Passive acoustic sampling involves leaving the equipment *in situ* overnight to passively record bat activities. This survey technique allows for temporal patterns in activity to be examined. The inherited risk of leaving expensive equipment in the field during urban based surveys is that the equipment may be disturbed, damaged or stolen.

Active acoustic sampling involves the surveyor to walk each transect at a slow pace, tracking the recorder back and forth in an effort to capture a call. If a bat is detected or observed, the equipment is manually orientated in an attempt to maximise the calls sequence length. Generally, active sampling is for a limited time – generally around 20 minutes per transect.

Brooks (2009) sampled several habitat types over a three year period and employed both active and passive acoustic methodologies. The results of that study summarised that activity pattern analysis by habitat class and species groups were generally the same when the two sampling techniques were compared, however, a finer scaled analysis of individual species revealed a difference in results. The difference observed indicates stronger associations (smaller P values) occurred with passive surveying (Brooks, 2009).
Figure 4: Harp nets are not always fruitful, are labour intensive and have been known to damage bats caught by the netting. This net was set in a fly way for seven days, and despite confirming bat activity through acoustic survey techniques, the harp net caught nothing. (Photo credit: K Howton)
2.7 Public perception

Megabats (flying foxes) are often killed by farmers who employ illegal methodology in an attempt to stop them raiding fruit crops (Environmental Defenders Office, Unknown; Environmental Law Publishing, unknown). Often, non-targeted species are also killed, including microbats and nocturnal birds.

Bats, particularly flying foxes are often unwelcomed visitors in the urban landscape. Public perception of bats varies; however, evidence suggests that they are often viewed as destructive and diseased animals. Many councils in New South Wales, including Lismore, have call for their removal (Clarence Valley Council, 2008; Lismore City Council, 2007; Singleton Council, 2007, 2008). While most people recognise and can identify megabats on sight, many struggle to identify or even acknowledge the presence of microbats which are often mistaken as large moths. This can result in a bias against microbats.

2.8 Disease

Bats have been identified as natural reservoirs for a number of zoonotic diseases, often causing public panic and used to support bat removal campaigns. While emphasis is often on megabats, microbats have been associated with some of the more infamous diseases often misrepresented throughout common media.

2.8.1 Hendra

Hendra virus was first discovered in 1994 after Queensland horse trainer Mr Vic Rail and 14 of his horses died. The disease was initially associated with the deadly Ebola virus, but was later grouped with the Nipah virus which killed more than 100 people in Malaysia during 1998 - 1999. The two viruses, Hendra and Nipah form a new genus called Henipavirus (CSIRO, 2011).

According to the Department of Primary Industries (NSW) website; “There is no evidence of bat-to-human, human-to-human or human-to-horse spread of Hendra virus” (2012). Hendra is only transmitted to humans as a result of close contact with horses. Yet despite these facts, public hostility regarding bats and sensationalistic media persists (ABC Radio, 2011; ABC Television, 2009; Unknown, 2012).

2.8.2 Australian Bat Lyssavirus

In 1996, a Black Flying Fox, exhibiting atypical nervousness was found near Ballina, NSW, and 30 km from Lismore (Schultz et al., 1995). Subsequent tests on brain tissue returned a negative result for Hendra, but a positive result for rabies. Originally called the Ballina virus, it was later renamed to Australian Bat Lyssavirus (ABL).

Later the same year, a wildlife rehabilitator died of ABL (CSIRO, 2012; Schultz et al., 1995). Two variants of the disease are known to exist, and comparison of tissues extracted from micro and megabats to that of the human victim identified the source of her infection as originating from a microbat (Gould et al., 2002). A second wildlife carer died in 1998, but is suspected to have been infected two years earlier, prior to the release of the ABL vaccine (New South Wales Office of Environment and Heritage, 2012d).
ABL is of the same family (Rhabdoviridae) as the classical rabies virus. Studies on wild caught flying foxes have revealed that less than 1% of the population (95% confidence level) carry the disease (Department of Agriculture, 2007). The disease is transmitted through contamination of a flesh wound by the saliva of an infected bat alive or dead.

Affected bats are usually unable or unwilling to fly or care for themselves, exhibit depressed or aggressive behaviour. People in high risk categories, such as veterinary professionals or wildlife carers should be vaccinated against the disease (Simmons, 2005).

2.8.3 SARS

In the seven months from November 2002 to June 2003, 8098 people would contract the Severe Acute Respiratory Syndrome (SARS) virus resulting in 774 deaths globally. Originating in the People’s Republic of China, the disease spread to 33 countries on five continents (Wang et al., 2006).

The disease was thought to be contracted by humans from masked palm civets (Paguma larvate) – a medium sized animal commonly sold at live animal markets in China and in restaurants. Rats and raccoon dogs have also been implicated in the spread of the disease. Additional studies have found SARS antibodies in microbats in Africa and Hong Kong, identifying them as another possible vector for infection (O'Shae et al., 1980; Woo et al., 2006). Nevertheless, no direct transmission has been reported.

2.8.4 White-nose Syndrome

During 2006, White-nose syndrome (WNS) was first reported in hibernating bat colonies in New York State and has since been associated with decline in bat populations throughout North America (Brooks, 2011). The newly discovered, cold adapted fungus responsible for WNS is Geomyces destructans, which causes abnormal activities amongst hibernating bats resulting in the depletion of critical fat reserves. While this disease has not been reported amongst Australian bat species, the threat cannot be ignored.

2.9 Definition of problem

Microbats play an important role in urban and natural environments. They are numerous in taxa and distribution (Simmons, 2005), identifying them as a major contributor to regional mammal diversity (Basham et al., 2011). They have a high conservation status and may also be important indicators for the health of the environments in which they live (Jones et al., 2009).

Effective management of biodiversity relies in part on an inventory of fauna present. Conservation of bats within the urban landscape requires an understanding of not only what species persist, but also what their habitat requirements are.

2.10 Aims and objectives

Southern Cross University’s (SCU) Sustainability Policy Advisory Committee has recognised the need for a Fauna and Flora Management Plan for its campuses as a high priority. This survey seeks to i) identify which species of Microchiropteran bats are present at Southern Cross University’s Lismore campus and within the wider Lismore local governance area and ii) identify which habitats they are utilising more frequently.
3 Methods

3.1 Site Description

The main campus for Southern Cross University is located at Lismore (Figure 5), New South Wales (28° 49’S., 152° 18’E), approximately 800 km from Sydney. The Lismore Local Government Area (LGA) has a population of 44,225 people, and 27,067 (61.2%) in the urban areas of Lismore (Lismore City Council, 2011).

Figure 5: Southern Cross University’s Lismore Campus is situated in Northern NSW, approximately 800 km north of Sydney.
3.1.1 Climate

The climate can be described as predominately subtropical, featuring warm humid summers and mild winters (Bureau of Meteorology, 2011). Mean temperatures range from 29.9°C (maximum) to 18.8°C (minimum) during January in summer and 19.9°C (maximum) to 6.5°C (minimum) during July in winter. Annual average rainfall is 1343 mm with January to March being the wettest months recorded, contributing 39% of the annual total (Bureau of Meteorology, 2011). This results in the region being known as one of the wettest areas in the state with a high amount of erosive rainfall (Bureau of Meteorology, 2011; Morand, 1994).

3.1.2 Geology

The influence of the Mount Warning Shield Volcano is evident in the low hilly landscape of the region and is typified in Lismore. The Tertiary Lamington Volcanics on which Lismore is situated originated as lava flows from an eruption approximately 20 million years ago and cover the majority of the sheet up to 200 m deep (Morand, 1994).

The basalt foundation with rhyolite and sedimentary rocks is known as Lismore Basalt, and has been enriched by non-volcanic material including gravels, sands, ancient soils and clays during periods of erosion (Morand, 1994).

3.1.3 Vegetation

The “Big Scrub” was the largest continual expanse of rainforest in Australia covering some 75,000 hectares of northern New South Wales, historically taking in the study site. Extensive clearing has reduced it to less than 1% of its original size (Lott et al., 1993; Specht et al., 2002). Some sites within the study area are within close proximity to remnants, existing on private property and public lands (Catterall et al., 2011; Specht et al., 2002).

Other sites feature post disturbance dry rainforest regrowth containing some big scrub species and exotic weed. Morand (2009) describes the vegetation in the area as closed dry sclerophyll forests with fragmented subtropical rainforests, however, much of the area is dominated by invasive weed species such as Small and Broad Leafed Privet (Ligustrum sinense and L. lucidum), Camphor Laurel (Cinnamomum camphora) and Lantana (Lantana camara).

Typical backyards represent much of the general urban landscape. Various native species have been deliberately planted and form part of the ornamental gardens evident at some sites. Roadways are often planted with dominant local tree species soften the hard urban edges.

3.1.4 Land Use

From 1890 until recent times, Lismore was an area of high primary productivity such as cedar getting, cattle grazing, macadamia farming, banana cultivation and sugar cane production. Evidence of this agricultural past remains in the current fragmented landscape. Land use conflicts in the region are increasing with the demands for continuing urban development. This trend is likely to continue as local populations are predicted to rise by up to 33% by 2021, making it one of the fastest growing regional areas in the state (Morand, 2009; NSW Department of Planning, 2010).
The Lismore campus of Southern Cross University covers 75 ha (Southern Cross University, 2011a) and is just 3 km from Lismore’s main business district. During the 2010 academic year, 2605 students studied internally at the campus (Southern Cross University, 2011b). Up to 3090 external students were registered during the same period and may have visited the campus for residential study periods. The Lismore campus employed 916 staff on a permanent basis during 2010 (Southern Cross University, 2011b).

3.2 Survey Site Selection

Southern Cross University owns approximately 158 ha of land in Lismore excluding the Vice Chancellor’s residence and conference centre, though only 75 ha are considered the active areas. This encompasses some 22 lots that are bordered by a mixture of privately owned residences, industrial sites and public lands (Appendix 8.1). Nine transects were surveyed within the active areas of the campus (Figure 6); three of each habitat category (see below).

Nine transects were surveyed within the wider Lismore community (Figure 7). Almost all of the sites were reported as being areas of known bat activity and were typical of the habitat categories they represent. One site of each habitat category was chosen at random by dropping a pen onto a map of Lismore LGA.

3.3 Habitat Categories

The survey contains three broad habitat categories, representing typical landscape elements and land use. The categories are: i) vegetated (>40% canopy cover), ii) near water (≤ 40m of a water body) and iii) urban (2 - 5 building ha⁻¹ including areas artificial lit with lights at night). For each habitat category, six replicates were sampled for analysis – three for each location source.

3.4 Survey Timing

This survey was conducted during the bat maternity season, between November 2012 and January 2013, when the period of resource requirements was at its peak (Ford et al., 2005; Threlfall et al., 2011). No sampling took place within five days either side of a full moon, which is known to interrupt normal bat and insect behaviors (Ford et al., 2005; Threlfall et al., 2012a; Threlfall et al., 2011). Additionally, surveys were postponed if wind or rain was forecasted or experienced as inclement weather is known to reduce bat activities (Basham et al., 2011; Ford et al., 2005; Threlfall et al., 2011).
3.5 Survey Technique

Each transect (18) measured 200m in length and was sampled on two separate occasions. One transect of each habitat category was surveyed from within Lismore and SCU on each survey night. Surveys commenced at sunset or when bat activity was first noted and continue for up to three hours.

Bat echolocations (commonly referred to as calls) were recorded onto a CF storage card using an Anabat II Bat Detector (Titley Scientific, Brisbane) (Corben, 2000). The detector was swept back and forth in an attempt to capture entire call sequences (Ford et al., 2005; Brooks, 2009). Active sampling was undertaken for 15 minutes on each transect (Ford et al., 2005; Brooks, 2009) and involved walking along cleared walkways and paths that may be used as fly ways (Law & Dickman, 1998; Threlfall et al., 2011).

3.6 Call Identification

The recorded bat calls were downloaded from the Anabat and were inspected using the Analook software (Corben, 2011). Only entire call sequences (often called a pass or call) (Figure 8) containing at least three pulses of similar frequency were used for identification. Species identification was based on observed pulse characteristics observed using the identification guide “Bat Calls of New South Wales: Region based guide to the echolocation calls of microchiropteran bats” (Pennay et al., 2004). Where ambiguity in identification existed, the call was not used in the results (Figure 9, Figure 10). Where two different species were recorded on the one file, only species that could be positively identified were used for the results (Figure 11).

Thirteen files (Appendix 8.2) were sent to two consultants, Ray Williams and Amy Rowles from Ecotone Ecological Consultants Pty Ltd for comment (Appendix 8.2). The files were highly ambiguous in terms of species identification, hence, not initially included in the results. This was done to i) assess the rate of successful identifications by the author and to ii) possibly expand the survey results in terms of identified species.
Figure 6: The transects at Southern Cross University were chosen based on personal knowledge of bat activities. One transect per habitat type (Urban, Near Water, Vegetated) was chosen solely on random. Three replicates per habitat type were sampled twice.
Figure 7: The transects within the Lismore Local Government Area were chosen based on personal knowledge of bat activities. One transect per habitat type (Urban, Near Water, Vegetated) was chosen solely on random. SCU grounds can be seen in the bottom right corner of the map.
Figure 8: When a call is analysed, many characteristics are looked at. Only a full call sequence of more than three pulses can be analysed. This call of a Little Bentwing Bat (*Miniopterus australis*) is a long sequence and identification is highly likely based on this call.

Figure 9: Occasionally species calls are similar and a certain amount of overlap is common. Where ambiguity exists, the call identification was not reported in the results section. In this example, the call could be of an Eastern Freetail Bat (*Mormopterus norfolkensis*) or the unidentified *Mormopterus sp 2*.
Figure 10: Calls come in a range of call lengths, frequencies and tone variations. This call is possibly of a Greater Broad-Nosed Bat (*Scoteanax rueppelli*) or an Eastern False Pipistrelle (*Falsistrellus tasmaniensis*). It is displayed here to highlight the contrast between the calls of different species.

Figure 11: Occasionally, two individual bats can be identified from the one file recording. In this example, a Little Bentwing Bat (*Miniopterus australis*) (right) begins to call the instance that the Gould’s Wattled Bat (*Chalinolobus gouldii*) finishes.
4 Results

The survey resulted in more than 125 files containing bat calls. Seventy six (56%) were adequate for purposes of species identification. Nine species were positively identified, including four species listed as Vulnerable in New South Wales.

Records from the broader Lismore LGA accounted for 86% (n = 65) of all records obtained during this survey. Vegetated transects accounted 65% (n = 49) of the data while 32% (n = 24) and 3% (n = 3) were attributed to the near water transects and urban transects respectively.

Only eleven records representing six species were positively identified at SCU. They were *C. gouldii*, *F. tasmaniensis*, *Mormopterus sp 2*, *N. geoffroyi*, *S. rueppellii* and *S. orion*. With the exception of *F. tasmaniensis* and *S. orion*, all records were from vegetated transects representing 72% (n = 8) of the data from SCU. The *F. tasmaniensis* and *S. orion* records (n = 3) was sourced from a near water transect. No records were confirmed on any urban transects at SCU.

Six individual species were confirmed in the Lismore LGA. They were *C. gouldii*, *F. tasmaniensis*, *M. australis*, *M. norfolkensis*, *Vespadelus vulturnus* and the yet to be classified *Scotorepens species*. The trend at SCU was duplicated on Lismore LGA transects where 63% (n = 41) of data pertained to vegetated transects, 32% (n = 21) to near water and 5% (n = 3) urban transects.

Only one species, *M. australis* was identified in all three habitat categories. Four species, (*C. gouldii, Mormopterus sp 2, N. geoffroyi* and *S. rueppellii*) were identified on only one habitat type while three species (*F. tasmaniensis, M. norfolkensis, Scotorepens species* (undescribed taxa) were identified on two.

Two species, *F. tasmaniensis* and *Scotorepens species* (undescribed taxa) were identified both at SCU and the broader Lismore LGA. All other records pertained to only one survey location.

4.1 Consultation results

Of the 13 files analysed, the consultants agreed with the author’s assessment at a species level 38.5% (n = 5), at a genus level 23% (n = 3) and disagreement with the authors assessment 38.5% (n = 5) overall. The complete species list (Table 1) identifies the nine species previously noted, and two broader genus identifications.
Table 1: Active acoustic survey of microbats was conducted from November 2012 to January 2013 in Lismore, NSW. The study focused on three broad habitat types; vegetated (>40% canopy), urban (2 - 5 building ha\(^{-1}\)) and near water (≤ 40m of a water body). Nine species were identified, including four Vulnerable species in New South Wales.

<table>
<thead>
<tr>
<th>Species</th>
<th>Vegetated</th>
<th>Urban</th>
<th>Near Water</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LIS</td>
<td>SCU</td>
<td>LIS</td>
<td>SCU</td>
</tr>
<tr>
<td>Gould’s Wattled Bat <em>Chalinolobus gouldii</em></td>
<td>2</td>
<td>1</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Eastern False Pipistrelle <em>Falsistrellus tasmaniensis</em></td>
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<td></td>
<td></td>
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<td>Little Bentwing Bat <em>Miniopterus australis</em></td>
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<td>1</td>
<td>10</td>
<td>46</td>
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<tr>
<td>Eastern Freetail Bat <em>Mormopterus norfolkensis</em></td>
<td>2</td>
<td>1</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Mormopterus sp 2</td>
<td>1</td>
<td>1</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Lesser Longeared Bat <em>Nyctophilus geoffroyi</em></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Nyctophilus species</td>
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<td></td>
<td></td>
<td></td>
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<td>Greater Broad-Nosed Bat <em>Scoteanax rueppellii</em></td>
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<td></td>
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<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>41</strong></td>
<td><strong>8</strong></td>
<td><strong>3</strong></td>
<td><strong>21</strong></td>
</tr>
</tbody>
</table>

5 Discussion

The study illustrated that increases in urban density resulted in a decrease in species richness and abundance. Fewer microbats were detected on urban transects. In contrast, bats were more abundant on vegetated and near water transects that contained vegetation. This suggests the retention of vegetated areas (both of natural forests and replanted “green” areas) within the urban landscape may be important for this bat assemblage. This is consistent with other studies (Basham et al., 2011; Hourigan et al., 2010; Threlfall et al., 2011).

Species richness was equivalent at SCU to that in the broader Lismore LGA (6 spp), however, abundance was notably lower at SCU. Species richness and abundance were lower on urban transects compared to the other two habitat categories at SCU and Lismore LGA. This contrast between urban and other forested habitats is consistent with
other studies (Avila-Flores, 2003; Hourigan, 2001), and should be noted during management planning.

There was a noticeable difference in identified records among the near water transects; 22 records were identified within the Lismore LGA compared to just 1 at SCU. While it is possible that site selection may be responsible for some of this disparity, it is unlikely to be the only cause. Further investigations of the water requirements for microbats and their prey would be needed to put this result into context.

Hourigan et al. (2010) noted, “Most previous studies of bat assemblages in urban landscapes have found that they are dominated by one or two highly active or abundant species, which typically account for more than 50% of bat records”. That is certainly true for the current study where one species, *M. australis*, accounted for 61% of the data presented. A possible explanation for this may be a close proximity to a maternity colony of *M. australis*.

### 5.1 Conservation value

With the pressures of habitat loss and fragmentation, disease, fire and inadequate representation in the public reserves system, it is a necessity that conservation of biodiversity also occur on private lands. As conservation efforts increase, effective management of areas with biodiversity values is vital and rely in part on an inventory of the fauna present.

Four species with state conservation status were identified throughout the current study. *Falsistrellus tasmaniensis, M. australis, M. norfolkensis,* and *S. rueppellii* are all listed as Vulnerable in the state of New South Wales (New South Wales Government, 2013). *Scoteanax rueppellii* has also been identified nationally as Near Threatened. These species represent 44% of the data. The identification of these threatened species is important for both policy makers and environmental managers. The protection of the key environmental factors essential for their survival should be considered in any conservation policies.

In a recent publication, controversial biologist Flannery (2012) stated that Christmas Island Pipistrelle (*Pipistrellus murrayi*) had become extinct during August 2009. When officially announced, it will be the first mammal extinction in Australia in 60 years; however, the species is still listed as Critically Endangered. Flannery states that two decades earlier, the population of this species had been considered healthy; however, the ecosystem conservation approach of management had failed to recognise a species in trouble, and ultimately, its extinction. It serves to highlight how quickly population stability can change in microbat communities and emphasises the need to address species management in addition to ecosystem conservation.
5.2 Ambiguity in Call Identification

The consultancy results highlight the need for a cautious approach in identifying bat species via acoustic surveying technique. The call characteristics of several overlapping species make positive identification difficult. The consultants’ style of reporting is of a i) species level identification with a definite, probable or possible confidence level, ii) genus level identification or to list an “either” option of several species where such overlapping ambiguity exists.

This presents issues in terms of management. Although call characteristics may be similar between species, niche requirements differ widely. An example comes from a consultancy survey conducted one year prior to the current study (summer 2011 – 2012) (Taylor, 2011). The files were sent for professional analysis. The consultation report (Appendix 8.4) labelled one call thus; “Scotorepens orion or Scoteanax rueppellii or Falsistrellus tasmaniensis”. To highlight the differences between these three species, a summary follows:

- *Scotorepens orion* roosts alone in hollow trees 7 m above the ground, however nursing females have been found sharing maternal colonies. It is found in a variety of habitats from wet forests and rainforests to low open woodlands. It has a distribution from Brisbane to Melbourne, with an additional population in Northern Queensland. It is an endemic species. Nothing is known about the foraging habits of this species (Churchill, 1998).

- *Scoteanax rueppellii* prefers moist forests east of the greater dividing range from Cairns to Sydney. It is only found at lower altitudes (<500 m). It has been known to prey on other bat species and large moths and beetles. Roosts in tree hollows (Churchill, 1998).

- *Falsistrellus tasmaniensis* prefer a wet habitat with trees in excess of 20m. They prefer to roost in colonies within hollow trunks. It has a known distribution from Brisbane to Tasmania. They have been known to travel 12 km from roost site to foraging grounds. Their diet consists of mainly beetles (75%), with some moths and bugs (Churchill, 1998).

The addition of an “either” category as the consultants have in this example would introduce more data into survey results. All three of these species would require management for tree hollows, which are noticeably lacking within the current study area. Notwithstanding, two of the species are listed as Vulnerable within NSW, and key management decisions and funding requirements may rely on more definitive identification.
5.3 Survey Constraints

The properties of SCU provide adequate habitat for microbats, however, some sites provided no data during this survey. Sites where microbats were detected during a previous test of methods (Appendix 8.5) did not produce results during the current study (Blackthorn, 2011). Microbats had been observed at some sites over recent years, however, were not recorded during this survey.

This variability may indicate that essential environmental elements (such as tree hollows) were absent during this time, or that changes within the environment have deterred bat activities in areas previously noted for such. As discussed above, changes in microbat communities in terms of richness and abundance may play an important role as bio indicators of ecological health. While reporting on such changes are beyond the scope of this report, over time sampling would quantify these results and would be valuable for management decisions.

Surveys were cancelled on over half of the scheduled nights due to sudden changes in weather. Resulting time restrictions required for replicate surveys to be cancelled, limiting the data available for analysis for this report. Certain obvious sites (such as the Big Scrub Remnant at SCU) were not surveyed due to design constraints. Surveying such sites and expanding habitat types surveyed may have provided additional information, valuable for directing management decisions.

5.4 Survey observations

This study followed the methodology described in the literature; however, the author noted that bat sightings were reduced considerably an hour after twilight. Presumably, the bats had left their roosting sites and had flown to their foraging grounds, which were not included in the current study.

Additionally, temporal studies may be more productive in identifying habitat use. This would best be achieved by adopting passive survey techniques, leaving the Anabat detector in situ overnight. While there are inherent risks associated with this practice, the author feels it would produce valuable data that is being missed by active survey techniques.

5.5 Limitations

Surveys were cancelled on over half of the scheduled nights due to sudden changes in weather. Resulting time restrictions required for replicate surveys to be cancelled, limiting the data available for analysis for this report.

Certain obvious sites (such as the Big Scrub Remnant at SCU) were not surveyed due to design constraints. Surveying such sites may have provided additional information, valuable for directing management decisions.
5.6 Recommendations

The retention of vegetated areas is likely to encourage a greater array of bat fauna than highly urbanised areas. The design of urban areas could incorporate a higher level of ornate gardens and forested areas surrounding buildings and structures.

The results revealed from this study should serve as a starting place for conservation efforts. Additional surveys are necessary to confirm and expand upon the results listed within.

A general species abundance disparity was noted at SCU compared to Lismore LGA. The lack of tree hollows at SCU is potentially the limiting environmental factor. The provision of artificial tree hollows and over time sampling could correct this situation.

6 Conclusion

Microbats are important indicators for biodiversity health within all ecosystems, including highly urbanised and fragmented habitats. This results in their internationally high conservation value (Jones et al., 2009).

Conservation and management decisions are driven in part by census results of the targeted fauna. Data regarding populations and distribution of microbats is still lacking at Southern Cross University, making management decisions difficult. Timely conservation efforts are required from all levels of government, private organisations and the general public.

The present study listed two objectives; to i) identify which species are present at Southern Cross University’s Lismore campus and within the wider Lismore local governance area and ii) identify which habitats they are utilising more frequently. The results of this study fulfilled both objectives.

This study identified nine species of microbats over the entire census. Species richness was equivalent at both SCU and in the broader Lismore LGA (6 spp). Vegetated transects were accounted to 65% (n = 49) of the data while 32% (n = 24) and 3% (n = 3) were attributed to the near water and urban transects respectively. Records from the broader Lismore LGA accounted for 86% (n = 65) of all records obtained during this survey, despite the identification of some similar habitats at SCU.

The retention of vegetated areas within the urban landscape, therefore, is important to bat communities. Additionally, tree hollows could be a limiting environmental factor at SCU which accounts for the disparity of abundance data between the two locations. The value and importance of these findings can only be realised through repeated and expanded habitat searches.
7 References


40


8 Appendix

8.1 Map of the Land Assets owned by Southern Cross University.

Figure 12: A map indicating the land assets owned by Southern Cross University map (1:3000 scale). Source: (Newton Denny Chapelle Consulting Surveyors and Planning, 2009)
8.2 Consultancy Files

Figure 13: Identified as ID1, this was the first call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors' assessment was “Possibly Mormopterus norfolkensis or Chalinolobus gouldii”. Amy Rowles assessment was “More likely Mormopterus sp2 or poss Chalinolobus gouldii” while Ray Williams’s assessment was “I agree most likely Mormopterus sp2 with feeding buzz”.

45
Figure 14: Identified as ID2, this was the second call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Possibly *Nyctophilus geoffroyi*”. Amy Rowles assessment was “*Nyctophilus sp*”. Ray Williams assessment was “Agree but too shot to ID”.
Figure 15: Identified as ID3, this was the third call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Likely Scotorepens sp1 or possibly Scotorepens orion”. Amy Rowles did not comment. Ray Williams’s assessment was “Frequency a little too high for Scotorepens orion. Could be Scotorepens greyii or Scotorepens sp1 if NE NSW”.
Figure 16: Identified as ID4, this was the fourth call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Possibly Nyctophilus geoffroyi”. Amy Rowles assessment was “Not Nyctophilus”. Ray Williams’s assessment was “Possibly Scotorepens orion or Scotoeanax rueppellii”.
Figure 17: Identified as ID5, this was the fifth call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Possibly Scotenax rueppellii or possibly Scotorepens Orion”. Amy Rowles did not comment. Ray Williams’s assessment was “Agree”.

Figure 18: Identified as ID6, this was the sixth call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Possibly Mormopterus norfolkensis or Mormopterus sp2”. Amy Rowles assessment was “More likely to be Mormopterus sp2”. Ray Williams’s assessment was “Mormopterus sp2”.
Figure 19: Identified as ID7, this was the seventh call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Unknown, but possibly *Vespadelus darlingtoni*”. Amy Rowles assessment was “Possibly *Miniopterus schreidersii oceanensis*”. Ray Williams’s assessment was “not identifiable”.
Figure 20: Identified as ID8, this was the eighth call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “*Vespadelus troughtoni* or possibly *Vespadelus vulturnus*”. Amy Rowles did not comment. Ray Williams’s assessment was “Probably *Vespadelus vulturnus*”.
Figure 21: Identified as ID9, this was the ninth call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors' assessment was “Possibly *Scoteanax rueppellii*”. Amy Rowles assessment was “*Mormopterus sp2* or *Mormopterus norfolkenensis* or *Chalinolobus gouldii*”. Ray Williams assessment was “Probably *Mormopterus sp2* with feeding buzz unless two species”.
Figure 22: Identified as ID10, this was the tenth call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Likely Falsistrellus tasmaniensis”. Amy Rowles assessment was “wouldn’t say likely”. Ray Williams’s assessment was “more likely Scotorepens Orion”.
Figure 23: Identified as ID11, this was the eleventh call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors' assessment was “Scoteanax rueppellii or Scotorepens Orion”. Amy Rowles assessment was “Chalinolobus gouldii”. Ray Williams assessment was “Most likely Chalinolobus gouldii”.
Figure 24: Identified as ID12, this was the twelfth call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Possibly Mormopterus sp2 and Miniopterus australis”. Amy Rowles assessment was “Mormopterus norfolkensis possibly”. Ray Williams assessment was “a bit too high for Mormopterus sp2 probably Mormopterus norfolkensis but not typical”.
Figure 25: Identified as ID13, this was the last call to be analysed by Ecotone Ecological Consultants Pty Ltd. The authors’ assessment was “Falsistrellus tasmaniensis”. Amy Rowles did not comment. Ray Williams’s assessment was “Falsistrellus tasmaniensis or Scotorepens Orion. Could also be Scoteanax rueppellii except freq a bit high”.
8.3 Consultancy Results

Table 2: Thirteen files were sent to Ecotone Ecological Consultants Pty Ltd for comment by consultants Ray Williams and Amy Rowles. The results identified a correct assessment by the author at a species level 38.5%, at a genus level 23% and disagreed 38.5% of the overall assessments. Confidence levels used were: Likely (almost certain), Probably (not quite certain) and Possibly (quite unsure).

<table>
<thead>
<tr>
<th>ID</th>
<th>Authors assessment</th>
<th>Amy Rowles Assessment</th>
<th>Ray Williams Assessment</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Possibly <em>Mormopterus norfolkensis</em> or <em>Chalinolobus gouldii</em></td>
<td>More likely <em>Mormopterus sp2</em> or poss <em>Chalinolobus gouldii</em></td>
<td>I agree most likely <em>Mormopterus sp2</em> with feeding buzz</td>
<td>AGREE at GENUS level</td>
</tr>
<tr>
<td>2</td>
<td>Possibly <em>Nyctophilus geoffroyi</em></td>
<td><em>Nyctophilus sp</em></td>
<td>Agree but too shot to ID</td>
<td>AGREE at GENUS level</td>
</tr>
<tr>
<td>3</td>
<td>Likely <em>Scotorepens sp1</em> or possibly <em>Scotorepens orion</em></td>
<td>Frequency a little too high for <em>Scotorepens orion</em>. Could be <em>Scotorepens greyii</em> or <em>Scotorepens sp1</em> if NE NSW</td>
<td>AGREE at SPECIES level</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Possibly <em>Nyctophilus geoffroyi</em></td>
<td>Not <em>Nyctophilus</em></td>
<td>Possibly <em>Scotorepens orion</em> or <em>Scotoeanax rueppellii</em></td>
<td>INCORRECT assessment</td>
</tr>
<tr>
<td>5</td>
<td>Possibly <em>Scotoeanax rueppellii</em> or possibly <em>Scotorepens orion</em></td>
<td></td>
<td>Agree</td>
<td>AGREE at SPECIES level</td>
</tr>
<tr>
<td>6</td>
<td>Possibly <em>Mormopterus norfolkensis</em> or <em>Mormopterus sp2</em></td>
<td>More likely to be <em>Mormopterus sp2</em></td>
<td><em>Mormopterus sp2</em></td>
<td>AGREE at SPECIES level</td>
</tr>
<tr>
<td></td>
<td>Unknown, but possibly Vespadelus darlingtoni</td>
<td>Possibly <em>Miniopterus schreibersii oceanensis</em></td>
<td>not identifiable</td>
<td>INCORRECT assessment</td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>-----------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>8</td>
<td><em>Vespadelus</em>roughtoni or possibly <em>Vespadelus vulturnus</em></td>
<td>Probably <em>Vespadelus vulturnus</em></td>
<td>AGREE at SPECIES level</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Possibly <em>Scoteanax rueppellii</em></td>
<td><em>Mormopterus sp2</em> or <em>Mormopterus norfolkensis</em> or <em>Chalinolobus gouldii</em></td>
<td>Probably <em>Mormopterus sp2</em> with feeding buzz unless two species</td>
<td>INCORRECT assessment</td>
</tr>
<tr>
<td>10</td>
<td>Likely <em>Falsistrellus tasmaniensis</em></td>
<td>wouldn’t say likely</td>
<td>more likely <em>Scotorepens Orion</em></td>
<td>INCORRECT assessment</td>
</tr>
<tr>
<td>11</td>
<td><em>Scoteanax rueppellii</em> or <em>Scotorepens Orion</em></td>
<td><em>Chalinolobus gouldii</em></td>
<td>Most likely <em>Chalinolobus gouldii</em></td>
<td>INCORRECT assessment</td>
</tr>
<tr>
<td>12</td>
<td>Possibly <em>Mormopterus sp2</em> and <em>Miniopterus australis</em></td>
<td><em>Mormopterus norfolkensis</em> possibly</td>
<td>a bit too high for <em>Mormopterus sp2</em> probably <em>Mormopterus norfolkensis</em> but not typical</td>
<td>AGREE at GENUS level</td>
</tr>
<tr>
<td>13</td>
<td><em>Falsistrellus tasmaniensis</em></td>
<td><em>Falsistrellus tasmaniensis</em> or <em>Scotorepens Orion</em>. Could also be <em>Scoteanax rueppellii</em> except freq a bit high</td>
<td>AGREE at SPECIES level</td>
<td></td>
</tr>
</tbody>
</table>
8.4 Consultancy Report: Brendan Taylor

This consultancy report was generated by Amy Rowles of Ecotone Ecological Consultants Pty Ltd. The data used for analysis was obtained by active acoustic survey at Southern Cross University’s Crawford property during October 2011. The survey was conducted by Brendan Taylor and Ross Goldingay through private consultation. It is used in the current study to highlight the differences and variances in call analysis.

<table>
<thead>
<tr>
<th>Date</th>
<th>Species Description</th>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Confidence Level</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/10/11</td>
<td>Gould’s wattle bat</td>
<td><em>Chalinolobus gouldi</em></td>
<td></td>
<td>√</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Little Bent-wing Bat</td>
<td><em>Miniopterus australis</em></td>
<td></td>
<td>√</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eastern broad-nosed bat or Greater broad-nosed bat or Eastern False Pipistrelle (less likely)</td>
<td><em>Scoloporus orien</em> or <em>Sorex auratus</em> or <em>Pipistrellus tasmaniensis</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>White-striped freetail bat</td>
<td><em>Tadarida australis</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>East Coast Freetail Bat</td>
<td><em>Mormopterus australis</em></td>
<td></td>
<td></td>
<td>Poor call</td>
</tr>
</tbody>
</table>

12/10/11 No identifiable calls recorded.

Analysis completed on the 25th October 2011 by:

Amy Rowles
Ecologist

ECOTONE ECOLOGICAL CONSULTANTS Pty Ltd

Call libraries and keys consulted during analysis:
- Personal experience analysing calls and collection of reference calls in NSW.
8.5 Consultancy Report: Rhianna Blackthorn

This consultancy report was generated by Amy Rowles of Ecotone Ecological Consultants Pty Ltd. The data used for analysis was obtained by active acoustic survey at Southern Cross University’s main business areas during November to December 2011. The survey was conducted by the author during a test of methodology survey. It is used in the current study to highlight temporal result variances.

### Calls Analysed for Lismore 30/11/11?– (Rhianna Blackthorn)

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Confidence level (number of passes)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gould’s wattled bat</td>
<td>Chalinolobus gouldi</td>
<td>✓</td>
<td>301859.30, 301859.36, 301901.52, 301904.54, 301905.10</td>
</tr>
<tr>
<td>2</td>
<td>Gould’s wattled bat</td>
<td>Chalinolobus gouldi</td>
<td>✓</td>
<td>301918.30</td>
</tr>
<tr>
<td>3</td>
<td>Eastern freetail bat</td>
<td>Mormopterus mormopterus</td>
<td>✓</td>
<td>301930.38, 301933.03</td>
</tr>
<tr>
<td></td>
<td>Eastern broad-nosed bat</td>
<td>Saccopteryx bilineata</td>
<td>✓</td>
<td>301931.38, 301933.53, 301931.23, 301931.38, 301931.53, 301932.28, 301932.48, 301933.03 (most likely orion, but there is some potential for the calls to belong to other bats that call at the same frequency with a similar shape call)</td>
</tr>
<tr>
<td></td>
<td>East Coast Freetail Bat</td>
<td>Mormopterus mormopterus</td>
<td>✓</td>
<td>301931.38</td>
</tr>
<tr>
<td></td>
<td>or Eastern freetail bat</td>
<td>Mormopterus norfoliensis or Mormopterus ridibundus (Adams et al., 1988); or Chalinolobus gouldi</td>
<td>✓</td>
<td>301931.38</td>
</tr>
<tr>
<td></td>
<td>Long-eared bat</td>
<td>Nyctophilus sp.</td>
<td>✓</td>
<td>301931.38, 301935.55, 301939.36 (be more likely to be part of a another species call)</td>
</tr>
<tr>
<td></td>
<td>Little bent-wing Bat</td>
<td>Miniopterus australis</td>
<td>✓</td>
<td>301936.31</td>
</tr>
<tr>
<td>4</td>
<td>Gould’s wattled bat</td>
<td>Chalinolobus gouldi</td>
<td>✓</td>
<td>301936.31</td>
</tr>
<tr>
<td></td>
<td>Little bent-wing Bat</td>
<td>Miniopterus australis</td>
<td>✓</td>
<td>050000.42, 050002.25, 050000.10</td>
</tr>
</tbody>
</table>

Note: D—definitive, Pr—probable, Po—possible, either. Bold—threatened species. All other files contained calls that were poor quality or not enough pulses to identify.

*Analysis completed on the 19th December 2011 by:*

**Amy Rowles**  
Ecologist

**ECOTONE ECOLOGICAL CONSULTANTS Pty Ltd**

e-mail: rarowles@biopond.com.au