Observations on the roost characteristics of the East-coast Free-tailed Bat *Mormopterus norfolkensis* in two different regions of New South Wales

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ABSTRACT

The protection of day roosts is critical to the conservation of threatened insectivorous bat species. However, little is known about the roosting ecology of many species and this is particularly the case for Australian hollow-roosting species, such as East-coast Free-tailed Bat *Mormopterus norfolkensis*. We undertook targeted surveys to capture *M. norfolkensis* and investigate the factors that influence roost selection. However, we were only able to capture and radio-track six individuals in two different regions of New South Wales (three in the Hunter Valley and three at Urbenville). We found that *M. norfolkensis* roosted in tree hollows in a range of tree species, including Grey Box *Eucalyptus moluccana* and Spotted Gum *Corymbia maculata* in the Hunter Valley and Flooded Gum *E. grandis* and red gum *E. amplifolia / tereticornis* in Urbenville. Additionally, a telegraph pole was used as a roost by a small colony of eight bats in Urbenville. As we experienced very low trap success and were only able to track bats for a brief period, roost preference is yet to be thoroughly investigated.

Key words: Chiroptera; *Mormopterus norfolkensis;* radio-telemetry; roost use; rare; threatened species; hollow-dependent fauna; conservation; rural landscape; tree hollow; scattered trees

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Introduction

There is a paucity of information available on the ecology of Australian insectivorous bat species. The least well known of these tend to be high-flying, hollow-roosting species that are not often captured and many are listed as threatened under state and federal legislation. Bats depend on day roosts to fulfil a number of life-cycle functions and a lack of roosts may limit their distribution and the size of populations (Churchill 2008; Kunz and Lumsden 2006). At present, conservation management strategies can only be directed towards a select few hollow-roosting species that have been adequately studied (Law and Anderson 2000; Lumsden, Bennett *et al.* 2002; Lunney *et al.* 1988; Threlfall *et al.* 2013; Webala *et al.* 2010). Furthermore, compensatory habitat strategies require roost selection information to ensure that offsets contain suitable roosting habitat for threatened bat species.

One hollow-roosting insectivorous bat of which little is known is the East-coast Free-tailed Bat *Mormopterus norfolkensis* (Figure 1). It occurs along the east coast of Australia and is listed as Vulnerable under the New South Wales (NSW) *Threatened Species Conservation Act 1995* and as Vulnerable C1 under the International Union for Conservation of Nature (IUCN) red list (IUCN 2009). While the species has been anecdotally recorded from natural and artificial roosts when these habitats come into conflict with humans (i.e. during tree felling operations and in buildings), there is no empirical evidence to quantify what type of roosts are most suitable.

Figure 1. An adult male *Mormopterus norfolkensis* captured and radio-tracked (M2) in the Hunter Valley, NSW. Photo, M. Jones.

We conducted targeted surveys to capture *M. norfolkensis* for radio-tracking studies to investigate what factors influence roost selection. However, due to the small number of individuals captured, we revised our aims to simply document and discuss the characteristics of roosts that were used by *M. norfolkensis*.

Methods

Pokolbin - Lovedale study area, Hunter Valley

Pokolbin and Lovedale are located in the Hunter Valley, NSW, 45 km inland from the port of Newcastle on the east coast of Australia (Figure 2). The predominant land-uses in this rural locality are viticulture and cattle grazing, with some tourist facilities also occurring. Much of the surrounding area has been cleared for agriculture, with remnant vegetation existing mainly as scattered paddock trees and narrow linear patches along roads and creek-lines. Dominant tree species are Spotted Gum *Corymbia maculata*, Narrow-leaved Ironbark *Eucalyptus crebra* and Red Ironbark *E. fibrosa*, with Grey Box *E. moluccana* also occurring. Large forest reserves exist approximately 6 km to the west in the sandstone escarpment of the Broken Back Ranges (Pokolbin State Forest) and to the east in more disturbed low elevation remnants (Werakata National Park). While the floodplains of the Hunter River consist of relatively rich alluvial soils, the study area occurs on the fringe of the floodplain more than 10 km away from the Hunter River and so it is also influenced by the poor soil quality associated with the sandstone escarpments. Smaller areas of freshwater wetland, Swamp Oak *Casuarina glauca* and River Oak *C. cunninghamiana* forests once occurred in riparian habitats and some disturbed remnants remain. Additionally, many large farm dams occur in low-lying areas across the study area to irrigate vineyards and to provide water to stock. In the Hunter region, *M. norfolkensis* is distributed much further west than anywhere else in NSW (The Office of Environment and Heritage 2011), as the mountains of the Great Dividing Range are relatively low and gentle at the broad Hunter Valley (Peake 2006). The Pokolbin - Lovedale study area is located in the centre of the east-west distribution of *M. norfolkensis* in the Hunter region.

We selected Pokolbin and Lovedale as our primary study area as it was conducive to radio-tracking (it had a good road network, line of site and reasonable private property access) and most importantly high (but patchy) levels of *M. norfolkensis* activity (its distinctive echolocation call identified from bat call recordings collected during a systematic study; McConville *et al.* in press). This rural landscape was vastly different to forested reserves and large remnant patches that have been traditionally targeted for trapping of insectivorous bats, which have been largely unsuccessful in capturing *M. norfolkensis* (e.g. NSW National Parks and Wildlife Service 1998).

Urbenville study area

The Urbenville study area was located in far northern NSW, close to the Queensland border and approximately 93 km inland (Figure 2). The study area is part of a long term research project investigating the habitat value of paddock trees and eucalypt plantations in agricultural areas of NSW, where high *M. norfolkensis* activity had been recorded (Law *et al.* 2000) and one male had been radio-tracked (B. Law unpublished data). Urbenville is located at the western extent of *M. norfolkensis* distribution in northern NSW (The Office of Environment and Heritage 2011). Urbenville is a small rural community where the predominant land-uses are agriculture on the fertile alluvial flats and forestry on the surrounding volcanic ranges. The agricultural areas were characterised by undulating hills with small flats along creeks. The remnant vegetation consisted mainly of large old paddock trees such as Broad-leaved Apple *Angophora subvelutina*, Small-fruited Grey Gum *E. propinqua*, Pink Bloodwood *C. intermedia* and Tallowwood *E. microcorys*. Grey Ironbark *Eucalyptus sideroploia* dominated drier topography such as ridge-tops and Cabbage Gum *Eucalyptus amplifolia* occurred in riparian zones. Yabbra State Forest occurs in the high relief eastern portion of the study area and consists of dry sclerophyll forests on the elevated slopes grading to wet sclerophyll forest and rainforest in the gullies. Since 2000, some of the agricultural areas adjoining existing forest areas have been converted to eucalypt plantation comprising Blackbutt *E. pilularis*, Dunn's White Gum *E. dunnii* and *C. maculata*.

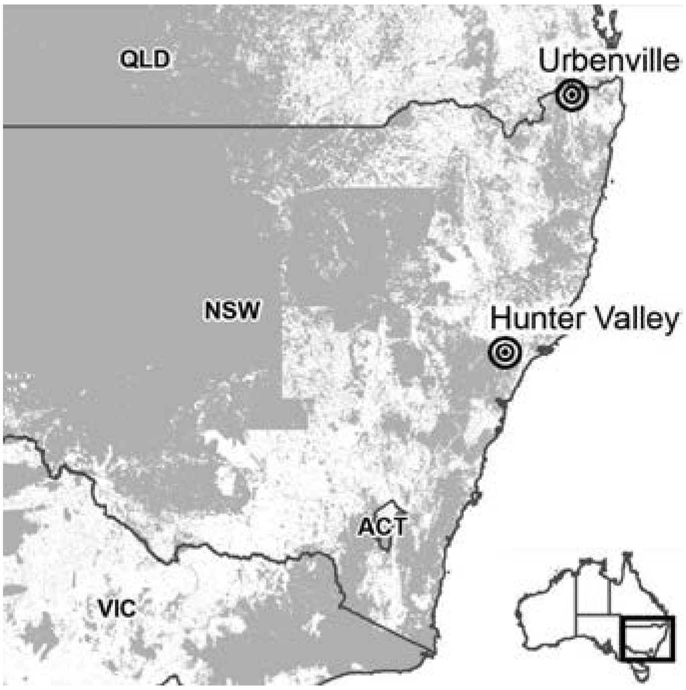

Figure 2. Hunter Valley and Urbenville study area locations (black circles) and native vegetation cover (grey shading).

Investigative trapping was undertaken at two other locations in NSW, Coolongolook and Paterson. However, *M. norfolkensis* was not captured and these sites are not discussed here further.

Trapping

We undertook a targeted trapping survey in November - December 2008 using harp traps, mist nets and trip lines in the Hunter Valley to capture *M. norfolkensis* for radio-tracking. As the morphological and anecdotal evidence suggests that *M. norfolkensis* is an open-adapted species (Churchill 2008; Hoye *et al.* 2008; Rhodes 2002), we located trapping sites in forests with an open structure or in semi-cleared agricultural areas. We placed traps along tracks in forested reserves (Werakata National Park) and we also set harp traps near paddock trees or groups of paddock trees in private rural properties. Some of these harp traps (three traps for a total survey effort of 18 harp trap nights) were hoisted up under overhanging branches of trees to a height of approximately 6 m high to target higher-flying bats both along forest tracks and near paddock trees. We set trip-lines and monofilament mist nets at small dams to capture bats as they flew low to drink. We also set mist nets on 4 m poles near paddock trees or forest edges where we thought bats might be regularly travelling.

At Urbenville, trapping was undertaken in November 2009 as part of a larger study on wildlife succession in eucalypt plantations (B. Law unpublished data). Harp traps were positioned to take advantage of flyways along tracks in the 11 year old eucalypt plantation, especially along elevated narrow ridges and near water-bodies to target *M. norfolkensis* and Greater Broad-nosed Bat *Scoteanax rueppellii* for radio-tracking studies (B. Law unpublished data). One harp trap was hoisted up under an overhanging branch to approximately 6 m height to target higher-flying bats such as *M. norfolkensis* for two nights.

Radio-tracking

Transmitters (Titley Scientific, LT4-337, ~0.4 g, single stage with 30 cm whip antennae) were positioned mid-dorsally below the scapulae and fixed in place using surgical glue (VetBond, 3M, St Paul, MN; Figure 3). Bats were released after transmitter attachment before dawn or within two hours of dusk if they were held during the day. Searches for radio-tagged bats were conducted during the day by vehicle and by foot along accessible tracks within the study area with regular targeted searches conducted at high vantage points. Once a signal was obtained, directional antennae were used to track bats to their roosts by homing in on the signal (White and Garrot 1990) until the roost or roost tree was identified. We recorded the following at each roost: type of roost (e.g. tree hollow, dead limb, under bark); roost height; entrance diameter of roost; tree species; tree height; diameter at breast height over bark (DBH); senescence level (of increasing senescence categories from 1 - 8, following Gibbons *et al.* 2000); projected foliage cover of the canopy (PFC); distance to nearest tree; distance to nearest hollow-bearing tree; and distance to water.

Roosts were stag-watched, where possible, for 30 mins prior and one hour after dusk, with bats counted and the roost location confirmed. A bat detector (Anabat SD1, Titley Electronics, Balina, Australia) was carried during stag-watching to record bat echolocation calls and to assist in identifying the bat species present. Stag-watching was not conducted within the wet sclerophyll forest at Urbenville as the height of the emergent roost trees and the dense rainforest canopy meant that it was highly unlikely that we would be able to observe bats exiting.

Figure 3. Photograph showing the attachment of a radio transmitter (LT4337, Titley Scientific) to an adult male *Mormopterus norfolkensis* (M2), in the Hunter Valley, NSW. Photo. M. Jones.

Searches were also undertaken for bats at night using directional antennae from vehicles to confirm that bats had not lost transmitters (for those roosts that were not able to be stag-watched) and to determine where they were foraging. Bats were followed via vehicle as they moved about the landscape, with distances estimated from signal strength, calibrated from occasions when the bats crossed our path. Due to the small overall number of roosts and data points recorded at night, data were not statistically analysed.

Results

Low capture rates were found for *M. norfolkensis* in the Hunter Valley with a total of 240 harp trap nights, 18.75 mist net hours and 3.9 trip-lining hours undertaken during the six weeks of study. This resulted in a trap success of 1.25 *M. norfolkensis* individuals per 100 harp trap nights. Survey effort was not even or stratified across the study area, with successful locations subjected to more trapping effort. For example, we repeatedly trapped the site where the first *M. norfolkensis* (M2) was captured to try to capture more individuals, with a total of 21 harp trap nights undertaken at this one site. This approach was successful in capturing another *M. norfolkensis* individual (M4) towards the end of the Hunter Valley study period, resulting in a higher trap success rate of 9.5 *M. norfolkensis* per 100 harp trap nights at this one site. At Urbenville, a total of 30 harp trap nights, four mist net hours and three trip-lining hours were undertaken in 2009, resulting in a capture rate of 13.3 *M. norfolkensis* per 100 harp trap nights. It should be noted that considerably more survey effort has been undertaken prior to this study within the Urbenville study area since 1997 with only one *M. norfolkensis* captured (B. Law, unpublished data). Mist nets and trip-lines were unsuccessful at capturing *M. norfolkensis* in both study areas. Most transmitters were removed by bats quickly during the study, with most bats tracked for only one day (Table 1; Table 2).

Hunter Valley

A total of three *M. norfolkensis*, two males and one non-breeding female, were tracked to three different roosts in the Pokolbin - Lovedale study area, November - December 2008. Two bats (M2 and M4) were captured in a harp trap placed next to a linear roadside remnant and one (M3) was captured in a small patch of paddock trees in a grazing pasture within 640 m of the other successful trap (Figure 4). One roost was identified for each of the bats, with the two males tracked for two days each and the female for only one day (Table 1). Two *E. moluccana* and one *C. maculata* were used as roosts in the Hunter Valley with small colony sizes of 1 - 2 bats recorded (Table 1). Bats moved less than 2 km from capture site to roost and often the bats roosted close to where they were trapped (Figure 4).

Table 1. Hunter Valley *Mormopterus norfolkensis* roost details. DBH – diameter at breast height; HBT = hollow-bearing tree; H = tree hollow; A = Artificial; NA = not observed. Senescence category is a 1 – 8 scale of increasing senescence following Gibbons et al. 2000

Roost ID	Bat ID	Sex	Reproductive status	Tree Species	Tree DBH (cm)	Roost Type	Senescence category	Roost tree Height (m)	Roost Height (m)	Entrance diameter of roost (cm)	Distance to nearest tree (m)	Distance to nearest HBT (m)	Distance to water (m)	PFC	Colony Count	Distance trap to roost (m)	No. consecutive nights used
M2.1	M2	Male	Testes enlarged	Grey Box *Eucalyptus moluccana*	72	H	1	15	4	2	2	3	99	25	NA	5	2
M3.1	M3	Male	Testes enlarged	Spotted Gum *Corymbia maculata*	106	H	2	25	6	30	6	6	93	20	2	1975	2
M4.1	M4	Female	Non-breeding regressed nipples	Grey Box *Eucalyptus moluccana*	66	H	1	15	3	2	3	10	42	15	1	270	1

Table 2: Urbenville *Mormopterus norfolkensis* roost details. DBH – diameter at breast height; HBT = hollow-bearing tree; H = tree hollow; A = Artificial; NA = not observed. Senescence category is a 1 – 8 scale following Gibbons et al. 2000

Roost ID	Bat ID	Sex	Reproductive status	Tree Species	Tree DBH (cm)	Roost Type	Senescence category	Roost tree Height (m)	Roost Height (m)	Entrance diameter of roost (cm)	Distance to nearest tree (m)	Distance to nearest HBT (m)	Distance to water (m)	PFC	Colony Count	Distance trap to roost (m)	No. consecutive nights used
MU1.1	MU1	Female	Pregnant	Telegraph pole	40	A	NA	NA	8	NA	8	25	50	0	8	1280	1
MU2.1	MU2	Female	Non-breeding, nipples regressed	Flooded Gum *Eucalyptus grandis*	115	NA	1	45	NA	NA	1	25	50	75	NA	4891	2
MU2.2	MU2	Female	Non-breeding, nipples regressed	Flooded Gum *Eucalyptus grandis*	108	NA	1	40	NA	NA	5	5	50	70	NA	5013	3
MU3.1	MU3	Female	Lactating	Red Gum *Eucalyptus tereticornis / amplifolia*	78	NA	2		NA	NA	7	7	100	10	NA	3270	1

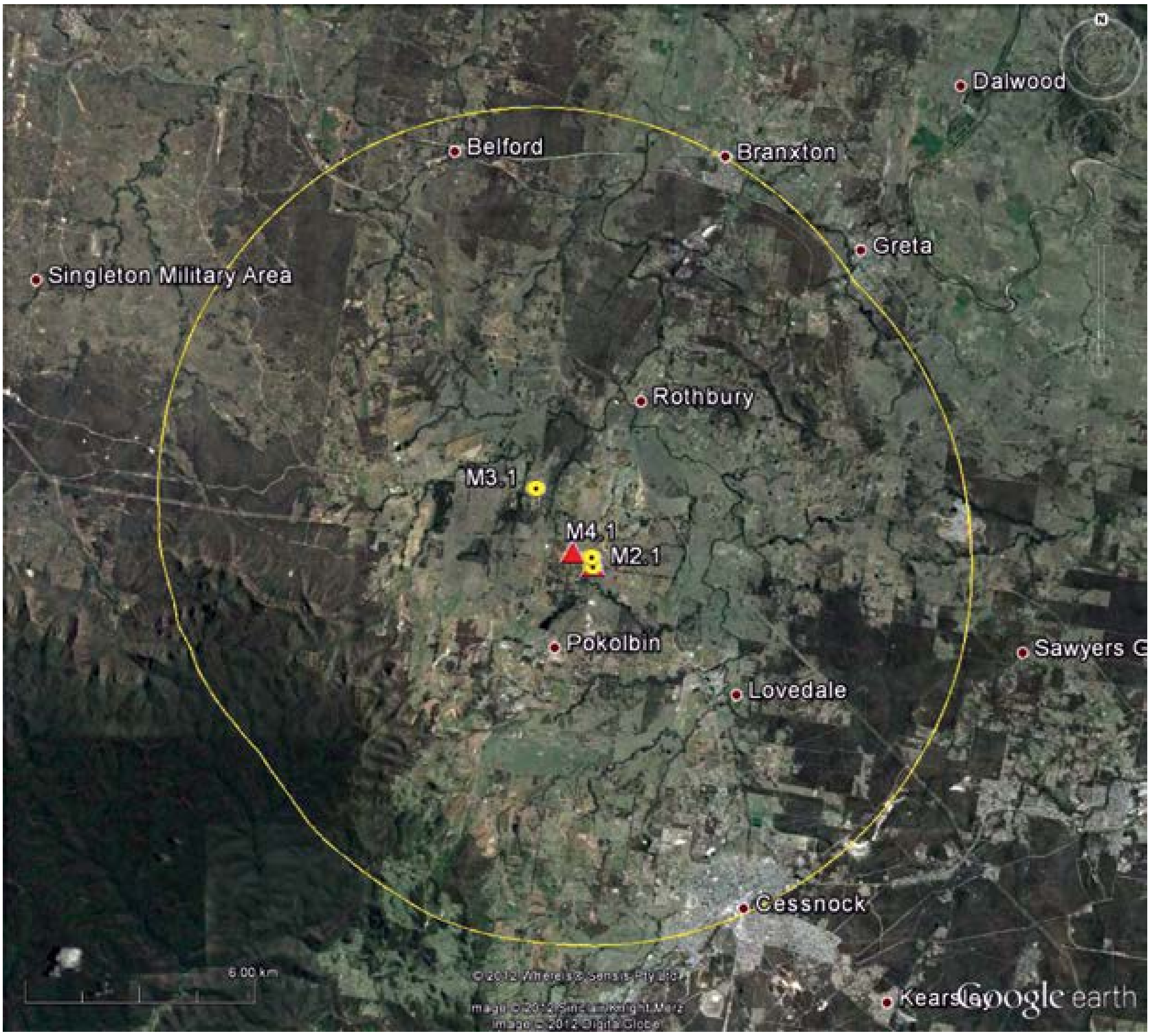

Figure 4. Hunter Valley *Mormopterus norfolkensis* roost (yellow circle) and successful trap (red triangle) locations. A 10 km radius surrounding the trap and roost locations (yellow line) is shown to illustrate the maximum distance likely to be travelled by radio-tracked bats. Mapped using Google earth (version 6.2.2.6613).

One male (M2) was tracked over three nights (including the night of release) for a total of 1.5 hours between 2030 - 2400 h and during this time it stayed relatively close (maximum distance of 1.5 km) to its roost in a *E. moluccana* (M2.1; Figure 5; Table 1). M2 roosted in a small dead branch with a small hollow in the end (approximately 2 cm diameter) and the tree was located < 2 m from the edge of a road in a linear roadside remnant (Figure 5). Adjacent to the roost tree was a large, unfenced block with regenerating eucalypts and shrubs, with holiday cabins with a mown understorey and scattered trees occurring on the opposite side of the road to the roost. M2 appeared to travel along a small power line easement and also spent time in an open woodland remnant with very little understorey and the low-density holiday cabins. Large dams and remnant riparian vegetation were also present within the general area surrounding the roost.

Another male (M3) was tracked over two nights (including the night of release) for a total of 2.25 hours between 2130 - 2330 h, to a maximum distance of 2 km from the roost. This individual appeared to traverse open paddocks, used for cattle grazing, quite quickly after release and then moved back and forth over a linear-shaped area approximately 120 ha in size that contained remnant riparian vegetation

Figure 5. *Mormopterus norfolkensis* roost (M2.1), Grey Box *Eucalyptus moluccana,* Hunter Valley, NSW. Roost location in a small branch indicated by arrow. Photo, A. McConville

and paddock trees. M3 roosted for two consecutive days in a large *C. maculata* paddock tree on a rural residential property, approximately 70 m from a house (M3.1; Figure 6; Table 1). The roost entrance was an elongated fissure on the trunk, approximately 30 cm long and up to 15 cm wide, with a westerly aspect (Figure 6; Table 1). The general area surrounding the roost had little understorey (grazing and mowing), with patches of young eucalypts, scattered old paddock trees and some ornamental shrubs.

The non-breeding female bat (M4) was tracked on the night of release from 2100 - 2330 h and from 0330 - 0450 h. Early in the night, after initially travelling approximately 2 km, M4 spent over one hour moving around a remnant open woodland patch approximately 11 ha in size that was located 0.5 km from the capture site. Before dawn the next morning, M4 was located 1.3 km from the capture site and then was recorded moving progressively closer to the roost during the next hour. M4 was tracked until it was found to be stationary within the roost (M4.1; Figure 7; Table 1) at 0450 h, 39 minutes before civil twilight. However, on return later that morning the signal was not able to be relocated, despite searching the surrounding road network thoroughly. The roost (M4.1) was stag-watched with a bat detector on dusk and two *M. norfolkensis* (identified by call) were observed to exit. We concluded that the transmitter was likely to have ceased operating while the bat was inside the roost.

Figure 6. *Mormopterus norfolkensis* roost (M3.1), vertical crack in trunk, Spotted Gum *Corymbia maculata,* Hunter Valley, NSW. Approximate location of roost shown by arrow. Photo, A. McConville

Figure 7. *Mormopterus norfolkensis* roost tree (M4.1), Grey Box *Eucalyptus moluccana,* Hunter Valley, NSW. Photo, A. McConville

Urbenville

Three *M. norfolkensis* were radio-tracked at Urbenville during November 2009 (one non-breeding female, one lactating female and one pregnant female, Table 2). Another lactating female was captured towards the end of the study, but it was not radio-tracked. The bats were all captured in a single harp trap which was placed along a ridge-top track in the young eucalypt plantation (Figure 8). The non-breeding bat (MU2) was tracked for five consecutive days with two roosts located and the other bats were tracked for one day only before their transmitters were removed. A total of four roost trees were identified (Figure 8), two of these being maternity roosts. However, only one of the roost entrances was confirmed.

The non-breeding female (MU2) roosted in two different trees in a rainforest gully with tall (40 - 45 m) emergent *E. grandis* for a total of five days (Figure 8; Figure 9). Whilst the actual roost locations in the trees were not confirmed, they were estimated to be high based on signal strength and triangulation. Whilst the PFC of the canopy in the rainforest gully was estimated to be 75 %, the PFC of the emergent layer where the bats were thought to be roosting was just 20 % being more similar to a woodland structure when above the dense rainforest canopy.

The pregnant female (MU1) roosted in a telegraph pole located in full sun (MU1.1; Figure 8) in a small, partially cleared paddock near a creek. The colony, of eight individuals, exited the telegraph pole from under the metal cap between 1950 - 2000 h, with MU1 emerging at 2000 h which was 43 mins after sunset and 18 mins after civil twilight. However, it is unknown if the bats were roosting

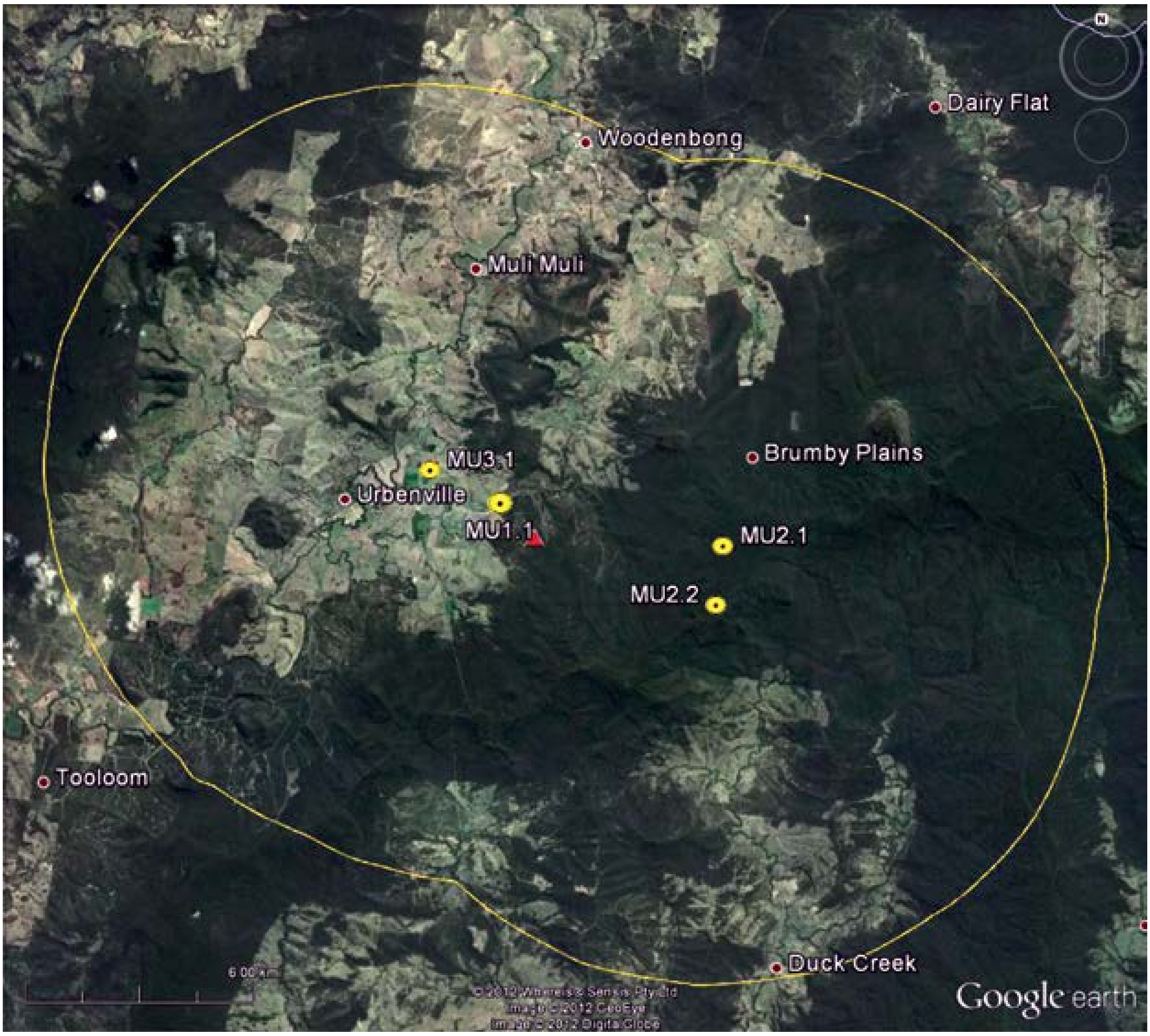

Figure 8. Urbenville *Mormopterus norfolkensis* roost (yellow circle) and successful trap (red triangle) locations. A 10 km radius of the trap and roost locations is shown (yellow line) to illustrate the maximum distance likely to be travelled by radio-tracked bats. Mapped using Google earth (version 6.2.2.6613).

Figure 9. Rainforest gully in which a non-breeding female *Mormopterus norfolkensis* (MU2) roosted in two different *Eucalyptus grandis* Flooded Gum for a total of five days, near Urbenville, NSW. Photo, B. Law.

directly under the hot metal cap or whether they were within a more protected central cavity. The maximum temperature recorded at the nearest weather station was 25.1 °C (Tabulam station, Bureau of Meteorology) and it is likely to have been much hotter under the exposed metal cap compared to the surrounding available hollows.

The lactating female (MU3) roosted in a patch of remnant red gum (either Forest Red Gum *E. tereticornis or E. amplifolia*) paddock trees (Figure 8; Figure 10). However, the exact roost location was unable to be determined during stag-watching as the transmitter appeared to stop functioning prior to bats exiting. We are reasonably confident that the transmitter malfunctioned as searches for MU3 that same night and subsequent days and nights failed to locate any signal.

At Urbenville, searches were made for tracked bats from 2100 - 2400 h each night. Signals were more intermittent than during the Hunter Valley component of the study, probably due to poor signal reception resulting from undulating terrain and relatively dense eucalypt plantations at Urbenville, compared with the open pasture

Figure 10. Patch of remnant red gum paddock trees (either Forest Red Gum *E. tereticornis* or Cabbage Gum *E. amplifolia*) where a lactating female *Mormopterus norfolkensis* (MU3) roosted near Urbenville, NSW. Photo, B. Law.

in the Hunter Valley. However, we did record the non-breeding female (MU2) from within the plantation forest each night and activity appeared to be focused along a small alluvial flat approximately 500 m from the trap site. We recorded this bat in this area for 1.25 hours on one night and for 20 mins on the following night before we left to search for other bats. This area had scattered remnant trees along an ephemeral creek-line and an open alluvial flat which was bordered upslope by eucalypt plantation. The maximum distance that *M. norfolkensis* was recorded travelling at Urbenville was 5 km from capture site to the rainforest gully roost (Table 2; Figure 8).

Discussion

This is the first published study to investigate roost use by *M. norfolkensis* and whilst we planned to have a greater sample sizes, we were only able to capture seven individuals and track six of them for a very short period. Our study confirms the difficultly of capturing rare open-adapted insectivorous bats, even in areas where the species has been regularly recorded using bat detectors. As such, *M. norfolkensis* roost preference remains to be revealed and future studies need to carefully consider ways to increase sample sizes.

Despite these sample size limitations we did make some new discoveries, recording roosts in some unexpected locations. The rainforest gully that a non-breeding female roosted in at Urbenville was unforseen. We anticipated that the dense vegetation within the gully would have precluded open-adapted bat species from using the area. However, it is possible that *M. norfolkensis* did not fly below the rainforest canopy, but used the airspace above where a more open structure amongst the emergent trees occurred. Additionally, whilst *M. norfolkensis* has been reported roosting under telegraph pole caps previously (Churchill 2008; Hoye *et al.* 2008), it was surprising to find this at Urbenville. Despite the agricultural and forestry history of the Urbenville study area there were many hollow-bearing trees persisting as paddock trees or embedded within the plantation (see Law *et al.* 2000) and indeed there were 5 - 10 large hollow-bearing trees within 50 m of the telegraph pole. It is possible that the exposed telegraph pole offered some thermoregulatory benefit to roosting bats compared with the nearby hollows and further research into use of these artificial structures would be valuable. Extensive dusk stag-watches of paddock trees over a 12 year period at Urbenville, aided by bat detectors, have failed to observe any *M. norfolkensis* roosts, although it is possible that roosts of individual bats were missed (Law *et al.* 2000; B. Law unpublished data). When these observations are considered with the results from this radio-tracking study, it appears that *M. norfolkensis* roosts in small colonies.

We also recorded *M. norfolkensis* travelling relatively short distances (maximum 2 km) in the Hunter Valley for an open-adapted species. Bats were tracked travelling greater distances (maximum 5 km) in Urbenville and this is consistent with previous radio-tracking at Urbenville in May 2002, where a male *M. norfolkensis* was tracked 6 km from its roost in an isolated *E. tereticornis* to foraging areas around a cemetery on the outskirts of town (B. Law, unpublished data). However, this was still less than what we expected based on other Australian *Mormopterus* species. For example, the South-eastern Free-tailed Bat *Mormopterus* species 4 has been reported travelling 12 km from a roost to forage (Lumsden *et al.* 2008). However, this is not to say that *M. norfolkensis* does not travel large distances on occasion, or regularly in other regions.

Finally, in the Hunter Valley, our study illustrates that in landscapes where much of the native vegetation has been removed, roadside reserves can be important roosting habitat for threatened insectivorous bat species.

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