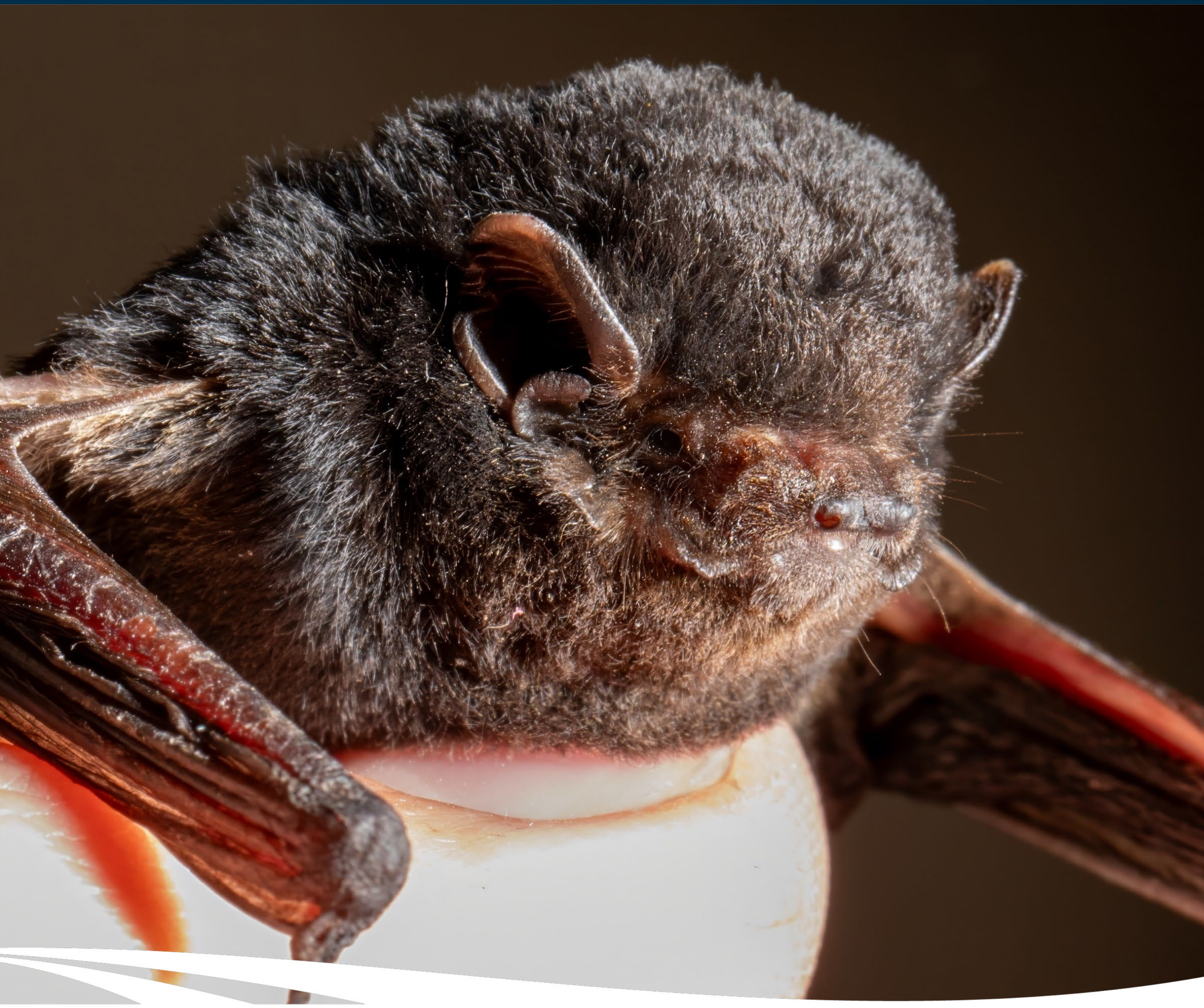

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Manual

Fauna Sensitive Transport Infrastructure Delivery
Chapter 11: Species profile – Microbats

June 2024

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1 Introduction

Microbats – also referred to as insectivorous bats – are placental mammals that are capable of sustained flight. Unlike flying-foxes (Chapter 10), microbats are small, in some cases weighing as little as four grams (less than a 10-cent piece). Microbats are cryptic and elusive, being mostly silent and nocturnal.

Australia is home to around 77 species of microbats from eight different families. In South East Queensland alone, there are approximately 36 microbat species representing most of the eight families. Of the 36 species, 12 are considered threatened under the *Environmental Protection and Biodiversity Conservation Act* 1999 (EPBC Act) and/or the *Nature Conservation Act* 1992 (NC Act) (Table 1.1).

1.1 Commonly encountered microbat species

Table 1.1 – Threatened microbat species in Queensland likely to be encountered on transport projects

SCIENTIFIC NAME	COMMON NAME	DISTRIBUTION	HABITAT
Chalinolobus dwyeri	Large-eared pied bat	Distribution is poorly known. Records from Shoalwater Bay, north of Rockhampton in the Brigalow Belt region, then south through to the vicinity of Ulladulla, around 300 kilometres east of Canberra. Thought to be far more restricted than its widespread range.	Roosting habitat includes sandstone cliffs and fertile woodland valley habitats. Records from South East Queensland suggest that rainforest and moist eucalypt forest habitats at high elevation are of importance to the species. Species require their roosting habitat to be adjacent to highly fertile habitats, particularly Box Gum woodlands or river / rainforest corridors for foraging.
Murina florium	Eastern tube-nosed bat	Eastern coast of Australia, from Cape York Peninsula, down south to Lismore in New South Wales North Coast region.	Tropical and subtropical rainforest, wet sclerophyll forest, vine forest, tropical woodland, and heathlands. Favour streamside environments with the above habitats.
Nyctophilus corbeni	Eastern long-eared bat	Scattered distribution mostly within the Murray-Darling Basin. Most common in box, ironbark, and cypress pine woodland.	Found in a variety of habitats including Eucalypt forests, mallee, open woodlands, savannahs, semi-evergreen vine thickets, dry sclerophyll forests, Callitris forest, and open forests with Poplar Box (*Eucalyptus populnea*), native pine, and/or grass trees. Generally roost under bark and in dry fissures of branches, while tree hollows are used for maternity sites.

SCIENTIFIC NAME	COMMON NAME	DISTRIBUTION	HABITAT
Saccolaimus saccolaimus nudicluniatus	Bare-rumped sheathtail bat	North Queensland, with specimens collected from Babinda Creek and Gowrie Creek near Cardwell. Occasional individuals collected from a narrow coastal region between Ayr and Cooktown, and one isolated specimen from north of Coen in Cape York Peninsula.	Occurs mostly within lowland areas in range of woodland, forest, and open environments. Confirmed roosting locations have been from deep tree hollows of Poplar Gum (*Eucalyptus platyphylla*), Darwin Woollybutt (*Eucalyptus miniate*), and Darwin Stringybark (*Eucalyptus tetrodonta*).
Taphozous australis	Coastal sheathtail bat	Occurs within a narrow coastal zone from Shoalwater Bay, just north of Rockhampton, through to Cape York Peninsula. Range extends no more than one kilometre inland from this coastal band.	Forages above the canopy in areas of coastal dune scrubland, melaleuca swamps, open eucalypt forests, grasslands, coastal heathland, monsoon forests and mangroves on lowlands and foothills. Typically prefers sea caves and rocky clefts to roost. Also known to roost in disused mines, boulder piles, rock fissures, concrete bunkers, and occasionally in buildings.
Hipposideros cervinus	Fawn leaf-nosed bat	Found in Cape York Peninsula region. It has been recorded in Kutini-Payamu (Iron Range) National Park, Ngalba Bulal National Park, Oyala Thumotand National Park, and Kulla (McIlwraith) National Park.	Roosts in caves and abandoned mines, occasionally in sheds and buildings. Forages in a variety of habitats including rainforest, gallery forest along waterways, and open savannah woodlands.
Hipposideros diadema reginae	Diadem leaf-nosed bat	Subspecies endemic to Queensland, ranging from Cape York Peninsula south to Townsville and inland from Cairns to Chillagoe.	Roosts in caves and disused mines, preferring ones with large chambers, high domed ceilings, and multiple entrances. Preferred microclimate conditions include a temperature between 25–26.5°C and 65–80% humidity (Churchill 2008). Occurs in a range of habitat types including lowland rainforest, Melaleuca forests, Eucalypt woodland, deciduous vine thickets, and open woodland, where suitable roosts occur throughout.
Hipposideros semoni	Semon's leaf-nosed bat	Broadscale distribution for the species includes coastal Queensland from Cape York Peninsula to just south of Cooktown. Southern limit of the distribution is unclear, although calls have been recorded on the Mount Windsor Tableland.	Found in tropical rainforest, monsoon forest, wet sclerophyll forest, and open savannah woodland. Daytime roosts include tree hollows, old buildings, road culverts, and shallow caves amongst granite boulders or in fissures.

SCIENTIFIC NAME	COMMON NAME	DISTRIBUTION	HABITAT
Hipposideros stenotis	Northern leaf-nosed bat	Only records in Queensland are from Mount Isa in the Mount Isa Inlier region.	Forages in tall open forests, open eucalypt woodlands, flood plains, and spinifex hills. Roosts in sandstone caves, boulder piles, and disused mines.
Rhinolophus robertsi	Greater large-eared horseshoe bat	Occurs in the Cape York Peninsula region from Iron Range south towards to Townsville in the Wet Tropics and west to the karst regions of Chillagoe and Mitchell-Palmer. The southern limit has not been clarified and may be present south of Townsville at Mount Elliot and Cape Cleveland.	Found in lowland rainforest, along gallery forest-line creeks within open eucalypt Forest, melaleuca forests with a rainforest understorey, open savannah woodland, and tall riparian woodlands of melaleuca, forest red gum, and Moreton Bay ash. Roosting habitat includes caves and underground mines located in rainforest and open eucalypt forest and woodland. The species has also been observed roosting in culverts, tunnels, and old rail infrastructure. It's suspected the species may also use basal hollows of large trees, dense vegetation, and areas beneath creek banks.
Rhinonicteris aurantia	Orange leaf-nosed bat	Occurs across the top end of Australia, from the Kimberley region in Western Australia through to north-west Queensland, with colonies near Camooweal and at Lawn Hill Gorge.	Forages in several habitats including grassland, open woodland, savannah woodland, and spinifex covered hills. Species roosts in caves and mines that are hot and very humid.
Macroderma gigas	Ghost bat	Found in Northern Australia with a scattered distribution across Western Australia, Northern Territory, and Queensland.	Roosts in caves, old mine tunnels, rockpiles, deep crevices, and cracks in rocks. Recorded foraging in a variety of habitats including rainforest, monsoon, and vine scrub in the tropics as well as open woodlands and arid areas.

2 Ecology

2.1 Biology

Microbats are a vital component of the Australian environment and perform numerous ecosystem services including insect control and pollination. For example, some species of microbats eat large quantities of insects – some consuming up to three quarters of their body weight in insects each night. Importantly, microbats consume mosquitoes, flies, locusts, and moths that present health risks to humans and can damage crops and native vegetation. Because they feed primarily on insects, microbats are susceptible to changes in the abundance and health of insects and are often considered bioindicators of ecosystem health.

Microbat diet varies among species. While most are largely insectivorous, some will also prey on vertebrates, and some occasionally feed on fruit, pollen, and nectar[1]. The large-footed myotis (*Myotis macropus*) will catch and eat small fish while the ghost bat (*Macroderma gigas*) eats small birds, small mammals, other microbats, frogs, and geckos. Some microbats have specialised insect-specific diets, such as the eastern horseshoe bat (*Rhinolophus megaphyllus*) whose primary food source are moths, and the yellow-bellied sheathtail bat (*Saccolaimus flaviventris*), which feeds mainly on beetles, crickets, grasshoppers, leafhoppers, and wasps.

Microbats forage in different ways depending on their body size and wing shape, which affects how fast they can fly, how manoeuvrable they are, and thus where they feed. Some species will forage within forest canopies, and these species generally fly more slowly and are more agile to manoeuvre through vegetation and trees. Other species will feed above the canopy or further above in open air and these species are generally fast flyers who feed on higher flying insects. Each species of microbat also has a particular way of catching their prey, with some using their tails to 'cup' their prey, while others will ambush prey by rapidly grabbing them from a branch or from out of vegetation. Some species will 'glean' (pluck) prey off foliage or off the ground. Other species use passive listening, which is where they listen to the noise of their prey to detect and hunt them.

2.2 Behaviour

Microbats are nocturnal and spend their nights travelling and foraging for food. They are a cryptic group of species and are generally very quiet in flight. Many microbat species live in large colonies and will roost together as large groups. Other species breed, mate, or give birth alone or in small groups. The yellow-bellied sheathtail bat, for example, roosts in mixed-sex colonies in tree hollows with a maximum size of ~30 individuals[2]. Conversely, the little bent-winged bat (*Miniopterus australis*) will congregate in the breeding season in maternity colonies of up 200 individuals, however colony sizes are smaller at other times of the year[3]. In contrast, the little pied wattled bat (*Chalinolobus picatus*) generally roosts alone in tree hollows, caves, and buildings, and will typically stay in the same area for their lifetime[4].

Most species of microbat breed during the warmer months of the year and give birth to single young (pups) once per year. The majority give birth in groups called 'maternity' groups, where females congregate sometimes numbering in the many hundreds or thousands of individuals, and sometimes in groups as small as two or three. Some species will commute hundreds of kilometres to special maternity sites. Maternity roosts are critical for microbat conservation.

Microbat species have high energy requirements due to their small size and many will use torpor to conserve energy. Torpor is a controlled reduction in body temperature and metabolic rate and is used by microbats during periods of cold stress and when food supply is limited. Torpor usage in microbats is highly variable[5]. For example, microbat species that live in cooler climates within Australian will use torpor more frequently and for longer periods during the day. Conversely, species that live in tropical and subtropical climates will use torpor less and torpor may only be used by species who roost in

[1] (Churchill 2008)
[2] (Rhodes and Hall 1997)
[3] (Hoye and Hall 2023)
[4] (Ford et al. 2023)
[5] (Geiser and Stawski 2011)

more open environments, compared to those who roost within caves[6]. The duration of torpor periods also varies among species and locations. For example, some temperate-zone microbat species including *Nyctophilus* spp. and *Chalinolobus* spp. enter an extended period of torpor that can last up to two weeks. The lesser long-eared bat (*Nyctophilus geoffroyi*) will go into torpor for up to around 40 hours, even during cooler days in summer[7].

Microbats navigate using echolocation, which is the use of high-frequency sound waves to locate objects such as prey, trees, buildings, and other obstacles. Microbats continually scan their environment while flying and use the reflected sound pulses to determine flight paths, manoeuvre around objects, and locate prey. The call characteristics of most species are unique, and analysis of calls can be used to identify species occurrence and activity levels.

2.3 Habitat

Microbats forage in a wide array of habitats across all of Queensland. Foraging preferences vary among species, with some preferring open spaces including agricultural lands, open waterways, or parklands in urban landscapes[8], while others feed within denser vegetation such as rainforest, mangroves, woodlands and shrublands.

Microbats sleep during the day in roosts, and they can roost in a range of different locations including caves, rock crevices, mine shafts, rock and boulder piles, culverts, bridges, bark crevices, tree hollows, and buildings. Some microbat species switch roosts frequently – even daily, while others occupy the same roost for weeks or months at certain times of the year[9] and sometimes with complex patterns of use[10]. Roost site selection has consequences for the survival of microbat populations and is influenced by a range of factors including thermoregulation, parasite avoidance, proximity to foraging resources, roost availability, and abundance[11].

While the type of roost can vary among species, it must provide a specific microclimatic (i.e. temperature, humidity) and other (e.g. cavity size, accessibility, ability to restrict access to predators) conditions to be suitable. Roosts also need to be strategically located – often close to foraging habitat and within proximity to other roosts. Due to these requirements, roost sites are often a limited resource in the landscape and are not abundant in many modified landscapes[12].

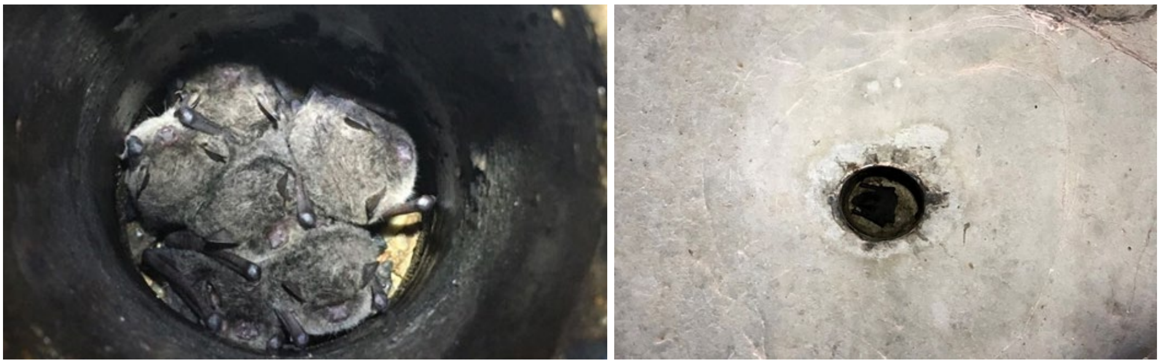
Land use changes resulting from urban and residential development, mining, forestry conditions, and agriculture are reducing the number and quality of natural roosts used by microbats. However, some species will use built structures such as culverts, bridges, tunnels, mine shafts, and buildings[13]. For example, the large-footed myotis will roost in concrete culverts as both maternity roosts and day roosts provided microhabitat features such as crevices and gaps are available[14]. The species can use

[6] (Turbill et al. 2003)
[7] (Stawski et al. 2008)
[8] (Finch et al. 2020)
[9] (Dixon and Huxley 1989, Willis and Brigham 2004, Rhodes 2007, Lumsden et al. 2020)
[10] (Rhodes 2007, Godinho et al. 2015)
[11] (Kunz and Lumsden 2003)
[12] (Gorecki et al. 2019)
[13] (Detweiler and Bernard 2023)
[14] (Gorecki et al. 2019)

natural roosts such as tree hollows and artificial roosts such as culverts and bridges[15], although high fidelity (100%) to artificial roosts has been recorded[16].

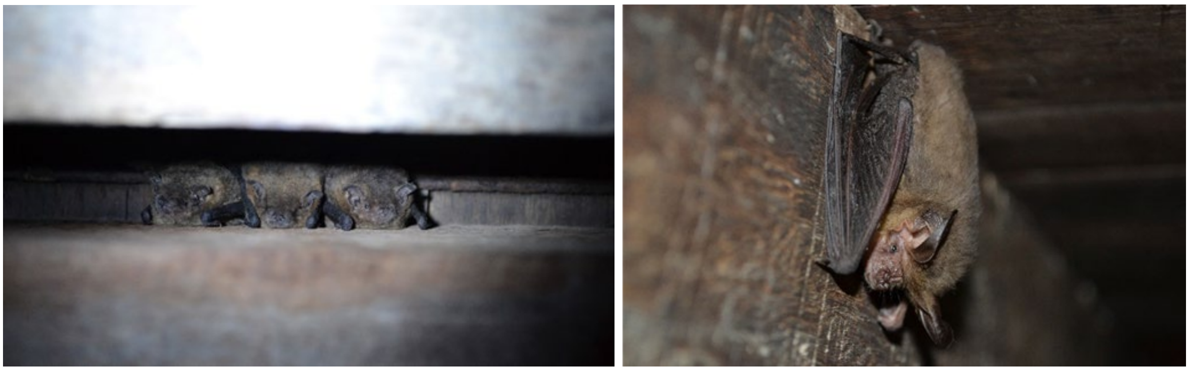
Roost sites in transport infrastructure for microbats can include lift-holes in culverts, expansion joints, girders, and parapets on concrete bridges and timber decking, split stringers, secondary stringers, cross girders, truss, and support beams on timber bridges, as well as mud nests built by wasps and birds (Examples of microbat roosts in Figure 2.3(a) – Figure 2.3(d)).

Figure 2.3(a) – Microbat roosts in lift holes



Source: © Vanessa Gorecki, WSP.

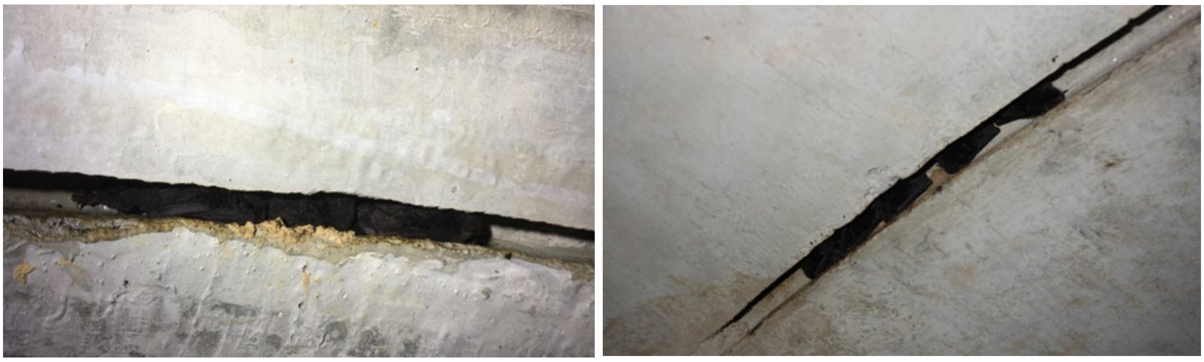
Figure 2.3(b) – Microbat roosts in beams under bridges



Source: © Andrew Taylor.

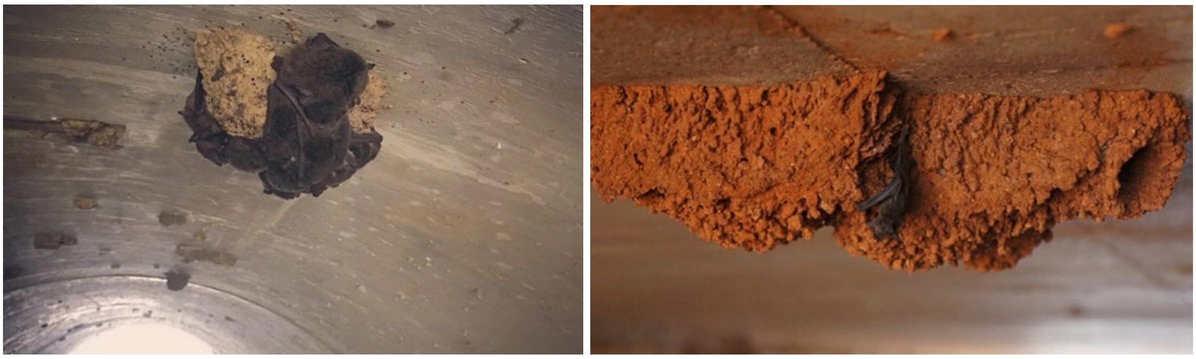
[15] (Campbell 2009)
[16] (Gonsalves and Law 2017)

Figure 2.3(c) – Microbat roosts in seals in culverts



Source: © Vanessa Gorecki, WSP.

Figure 2.3(d) – Microbat roosts in mud nests built by wasps and birds



Source: (Left) © Vanessa Gorecki, WSP and (right) © Lara Daddow.

While all roost sites are important, those supporting maternity colonies are critical to the survival of microbats as they are sites where females congregate to raise young[17]. These roosts may only be used by microbats at certain times of the year and they often differ in size or structure to roosts used at other times. Therefore, any disturbance or destruction of maternity roosts, even when not occupied, may affect the survival and reproductive output of some species. Additionally, winter roost disturbance can impact on reproductive success and survival rates of bats if they are aroused from torpor and are forced to increase their metabolic rate and use energy stores prematurely. This can subsequently effect their health, hinder reproduction or in severe cases, may result in death.

[17] (Neubaum 2017)

3 Direct impacts

3.1 Wildlife-vehicle collision

It is often assumed that microbats are not subjected to high rates of wildlife-vehicle collision (WVC) because they are rarely or never detected in standard WVC surveys in Australia[18]. However, this is most likely a significant underestimate because microbat-vehicle collisions are difficult to detect, and most surveys are not designed to detect microbats[19] because:

- Surveys are not done at first light, after which time any carcasses will be destroyed by passing vehicles.
- Surveys are done in a moving vehicle at speeds that reduce the detectability of microbat carcasses.
- Surveys do not search the verges, where microbats may be thrown after collision.

However, surveys conducted overseas, particularly in Central and Eastern Europe, demonstrate that microbats can be killed at relatively high rates and many families and species of microbats are impacted[20]. Importantly, multiple reviews of the impacts of roads and traffic on microbats concluded that rates of WVC were higher:

- Near roosts.
- For species which forage lower to the ground.
- In areas of higher traffic volume.
- For species with large home ranges that would encounter roads more frequently.
- For young individuals who are still learning to fly.
- For males of some species.
- Where foraging habitat occurs along or across transport infrastructure corridors on major highways.

These reviews have conservatively concluded that mortality of bats from WVC may be high enough to lead to the population decline of some species[21].

3.2 Barrier effects

There is an incorrect assumption that transport infrastructure is not a barrier to the movement of microbats because they are capable of sustained flight and are willing to fly across cleared areas. However, the flying abilities and willingness to fly in open areas varies significantly among species. There is an increasing body of evidence that some species of microbats – particularly less mobile and forest-interior species – will avoid travelling across linear clearings and that transport infrastructure

[18] (e.g. Taylor and Goldingay 2004, Burgin and Brainwood 2008, Rendall et al. 2021)
[19] (Abbott et al. 2015, Ramalho and Aguiar 2020)
[20] (Lesiński et al. 2011, Fensome and Mathews 2016, Ramalho and Aguiar 2020, Huang et al. 2021)
[21] (Fensome and Mathews 2016, Frick et al. 2020, Ramalho and Aguiar 2020)

may hinder their movement[22]. These effects were evident for even relatively small clearings of less than five metres[23], through to six-lane motorways[24].

The effect of roads on microbat movement – in particular their avoidance of crossing high-volume multi-lane roads – is also well demonstrated by their preferred use of vegetated overpasses to cross such roads. Research on the movement of microbats at Compton Road in Brisbane showed much higher rates of microbat activity above the vegetated land bridge than the adjacent forest[25]. Studies in Victoria show similar results where some species of microbats preferred to fly under road bridges rather than cross above the road itself[26].

Studies have also shown that roads can disrupt the daily commuting movements between roosts and foraging areas[27]. In Europe, commuting bats will follow hedgerows and other linear strips of wooded vegetation across cleared farmland. Some Australian species may follow similar landscape features (e.g. wooded road reserves), although research is limited. When these commuting pathways get disrupted by new roads and railways, the movement of microbats can be affected[28].

It is unclear if the barrier or filter effect is due to the actual clearing, gap in canopy cover, traffic noise, lighting, and/or other disturbance factors, or a combination of these factors[29] (Sections 3.3 and 3.4). The barrier effect is exacerbated when individuals attempting to cross are killed through WVC.

3.3 Habitat loss and modification

Studies have shown that the abundance and diversity of microbats in urban and agricultural areas is related to the amount and quality of habitat including tree cover[30], presence of healthy water bodies[31], and the abundance and quality of roost sites[32]. Hence, the loss and degradation of both foraging and roosting habitat are key threats to microbat populations[33]. The impacts of habitat loss and degradation from transport projects are especially problematic in areas that are already highly cleared or modified, including urban and agricultural landscapes. Projects that result in a loss of habitat or a reduction in the suitability or quality of that habitat can have significant impacts on microbats.

For simplicity, it is useful to consider impacts to foraging habitat and roosting habitat separately, however it is important to remember that both must be considered during impact assessments.

3.3.1 Foraging habitat

Microbats forage where insects are most active, which mostly includes the space around tree canopies to riparian areas and wetlands. The reduction of trees and other woody vegetation, and the draining of wetlands, waterways, and boggy areas has a detrimental impact on the number and diversity of microbats that can occur there due to a reduction in foraging resources. Even isolated

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[22] (Berthinussen and Altringham 2012b, Abbott et al. 2015)
[23] (Bennett and Zurcher 2013)
[24] (Berthinussen and Altringham 2012b)
[25] (McGregor et al. 2017)
[26] (Bhardwaj et al. 2017)
[27] (Bennett and Zurcher 2013)
[28] (Ramalho and Aguiar 2020)
[29] (Abbott et al. 2015)
[30] (Lumsden and Bennett 2005, Caryl et al. 2015)
[31] (Straka et al. 2016, Straka et al. 2020)
[32] (Gorecki et al. 2019)
[33] (Frick et al. 2020)

trees, such as scattered trees in paddocks, are important foraging habitats for microbats[34] and should be considered for protection. Likewise, the loss of individual trees can reduce the availability of foraging resources for microbats in modified landscapes where structural diversity is limited.

3.3.2 Roosting habitat

Transport projects can impact microbat roosts in the following ways:

- The clearing of large trees with hollows – including dead and living trees – that microbats use as roosts[35].
- The removal of smaller trees and trees without hollows that microbats also use for roosting, such as under peeling bark or under palm fronds[36].
- Removal and/or replacement of bridges and culverts that microbats use as roosts, or repair of specific features (e.g. lift holes, cracks, and joins) used as roosts by microbats[37].

3.4 Noise and light pollution

Traffic noise can interfere with microbat echolocation and their ability to hear other microbats, their prey, and predators. Studies using simulated traffic noise in flight enclosures found that the hunting efficiency of microbats was reduced when traffic noise was played[38]. Habitat near roads with high traffic volumes is likely to be similarly noisy and reduce foraging success compared to areas near roads with lower traffic volumes and areas without traffic.

Echolocation is also likely to be affected by traffic noise if the noise is sufficiently loud and if the frequency of the noise overlaps with the frequency of a species call. For example, traffic noise was found to be a significant factor that reduced road-crossings and increased the instances of microbats turning away from roads during flight[39]. This effect is likely to reduce foraging success, dispersal, and gene flow, however this has not been explicitly studied.

Artificial light at night (ALAN) can also affect the movements, breeding, foraging, torpor, and social behaviour of microbats and their insect prey[40]. For example, some species of microbats (typically faster-flying species which generally forage in open spaces) are drawn to streetlights and the insects they attract, while others (typically slow- and low-flying species) avoid such areas due to the increased lighting levels. Importantly, species that are attracted to streetlights may also be more vulnerable to WVC[41]. In addition, ALAN may also delay microbat roost emergence (the act of leaving a roost at dusk), resulting in reduced foraging time. This might be of significance during summer when periods of night time are shorter.

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[34] (Lumsden and Bennett 2005)
[35] (Lumsden et al. 2002b, Lumsden et al. 2002a, Campbell et al. 2005)
[36] (Law and Anderson 2000)
[37] (Gorecki et al. 2019)
[38] (Siemers and Schaub 2011)
[39] (Bennett and Zurcher 2013)
[40] (Stone et al. 2015a)
[41] (Huang et al. 2021)

The benefit that some species of microbat obtain through their ability and willingness to forage around streetlights is relatively minor compared to the negative response experienced by most microbat species[42]. Negative impacts from ALAN can include:

- Disruption to movement and commuting due to avoidance of lit areas[43].
- Reduced foraging success in areas with ALAN and increased energetic costs to avoiding lit areas[44].
- Reduction in area of habitat available for use because lit areas are avoided[45].
- Increased risk of WVC when microbats are forced to cross roads above traffic due to avoiding lit bridge underpasses and culverts[46].

A study on rail impacts to bats in an operational rail corridor found that microbat activity was reduced by 30–50% each time a train passed, with the effect lasting for up to two minutes[47]. The net effect of this impact is related to the number of trains, with cumulative loss of foraging opportunity increasing as the number of passing trains increases. This demonstrates that passing trains reduced the total amount of microbat foraging time, which can impact reproductive success and survival rates.

The impacts of ALAN on insects, an important component of microbat diet, are described in Chapter 20.

3.5 Road- and railway-effect zone

Distance from transport infrastructure appears to be a significant factor influencing microbat activity, an impact known as the road- and railway-effect zone (REZ) (Chapter 4). The specific factor or combination of factors (e.g. lighting, noise, disturbance, mortality etc.) causing the effect zone is complex, and it is significant for many species of microbats. The size of the REZ varies among species and landscape context, and was found to be approximately 123 metres in central Victoria[48], approximately 300 metres in the USA[49] and 1600 metres in Cumbria in the UK[50].

The REZ is a direct impact to microbat habitat availability, particularly in greenfield areas.

4 Indirect impacts

The indirect impacts of transportation on microbats have not been well documented and are difficult to identify, especially because the direct impacts are still being investigated. Given the current level of understanding, the focus should be on quantifying, avoiding, minimising, and mitigating direct impacts whilst also seeking to better understand and manage indirect impacts.

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[42] (Abbott et al. 2015, Stone et al. 2015a)
[43] (Stone et al. 2009, Zeale et al. 2018)
[44] (Zeale et al. 2018, Hooker et al. 2022)
[45] (Threlfall et al. 2013)
[46] (Bhardwaj et al. 2020)
[47] (Jerem and Mathews 2021)
[48] (Bhardwaj et al. 2021)
[49] (Kitzes and Merenlender 2014)
[50] (Berthinussen and Altringham 2012b)

5 Avoidance and minimisation

Transport projects should first seek to avoid and minimise impacts to microbats and their habitats, wherever possible, including:

- Not destroying, disturbing, or modifying microbat roosts, such as tree hollows, caves, culverts, and bridges.
- Not clearing or disturbing foraging habitat.
- Avoiding crossing waterways where microbats forage, roost, and commute.
- Minimising the width of clearing to reduce barrier effects, especially where the project dissects commuting pathways such as riparian corridors and wooded road reserves in cleared landscapes.
- Retaining the specific culvert, bridge, or structural elements (e.g. lift holes, cracks etc.) used by microbats as roosts when repairs are required.
- Minimising ALAN and avoiding the spill of light into foraging areas, roosts, and commuting pathways.

6 Mitigation

6.1 Wildlife crossing structures

Efforts to mitigate the barrier effect of transport infrastructure on microbats have increased significantly in the past few years, especially in Europe and the United Kingdom[51]. Underpasses and overpasses appear to provide safe passage for many species of bats[52], however they need specific designs and features (Chapter 6) and careful placement to maximise effectiveness. Canopy connectivity may assist the movement of high-flying bats, however there is no evidence that other designs such as hop-overs and gantries (Section 6.2) are effective.

There is still uncertainty about the proportion of microbats in a population or area that will use underpasses and overpasses. Optimal underpasses for microbats are[53]:

- Connected to the adjacent microbat habitat (i.e. along pre-construction flight paths or linear landscape features that microbats follow).
- High enough to allow the microbats to pass without changing flight height or direction (at least three metres high for clutter-adapted species and approximately six metres high for edge-adapted species).
- Are not cluttered with too much vegetation, structures, or obstacles.
- Do not contain lighting.

Vegetated land bridges are also likely effective connectivity structures for microbats when they provide continuous forest cover across transport infrastructure. Studies on the use of the Compton Road land bridge in Brisbane detected 11 species or species groups of microbats flying above the bridge over a

[51] (Abbott et al. 2015)
[52] (Bach et al. 2004, Boonman 2011, Abbott et al. 2012, Berthinussen and Altringham 2012a, Bhardwaj et al. 2017, Laforge et al. 2019, Martínez-Medina et al. 2022)
[53] (Abbott et al. 2015)

seven-month period[54]. Importantly, this study found that microbat activity was higher on the land bridge compared to the adjoining forest, suggesting that the land bridge was attracting bats to cross at that location. Unfortunately, surveys were not conducted in the middle of Compton Road away from the land bridge to provide a direct comparison, but the results (microbat activity levels) suggest that the land bridge has facilitated the safe crossing of many species of microbats. As vegetation on land bridges mature, the insect abundance should increase, and bats are likely to use these areas for foraging as well.

It is not possible to install fencing for bats to funnel them to underpasses or overpasses, and thus crossing structures should be installed in optimal locations, such as:

- Original commuting pathways or routes that were present prior to road construction[55].
- Along riparian habitats.
- Where flyways, such as vegetated corridors or wooded road reserves, cross the transport infrastructure.

Underpasses and overpasses can also be used by microbats as roosting and foraging sites. As described in Section 2.3, many species will roost in the lift holes, cracks, and gaps in culverts and bridge structures.

To improve the suitability of underpasses and overpasses, noise and light walls may be required to reduce the effects of noise and ALAN on the approaches to crossing structures and on the edges of land bridges. Other lighting reduction measures are detailed in Section 6.4.

As a general rule, lighting should never be installed within underpasses intended for microbats, as this has been shown to reduce rates of microbat activity[56]. For example, research in central Victoria found that there was a decrease in the number of species using lit underpasses compared to when they were unlit[57]. Microbat species would instead fly over lit underpass structures or chose not to cross at all. This increased the risk of WVC and affected habitat connectivity and movement. Interestingly, two species were attracted to the lit culverts, Gould’s wattled bat (*Chalinolobus gouldii*) and the white-striped freetail bat (*Austronomus australis*). However these are relatively common species, and the rarer and more specialised species avoided the lit culverts.

6.2 Gantries and hop-overs

Gantries or ‘hop-overs’ have been proposed as structures which microbats can follow while using echolocation and are promoted as relatively inexpensive for microbat connectivity. There are several different designs – such as an array of steel cables or overhead steel gantries – similar to those used for signage across multi-lane roads. There has been one study that indicated the recorded flying height of microbats was higher after the installation of one steel gantry in France[58]. However, most studies and reviews have demonstrated they are not effective[59] and are unlikely to be beneficial[60].

[54] (McGregor et al. 2017)
[55] (Berthinussen and Altringham 2012a, Claireau et al. 2019)
[56] (Bhardwaj et al. 2020)
[57] (Bhardwaj et al. 2020)
[58] (Claireau et al. 2021)
[59] (Berthinussen and Altringham 2012a, Claireau et al. 2019)
[60] (Abbott et al. 2015, Berthinussen et al. 2021)

Based on the current evidence-base, Transport and Main Roads do not support the use of gantries and hop-overs for microbat connectivity.

6.3 Artificial roosts

Some species of microbats will roost and/or breed in a wide variety of artificial structures, including microhabitat features within transport infrastructure such as lift holes and crevices as shown in Figures Figure 2.3(a) – Figure 2.3(d). In many cleared or modified landscapes, the roosting opportunities provided by existing transport infrastructure may represent important roosting habitat for microbats[61]. In these areas, specific designs of bridges and culverts that provide roosting habitat for microbats should be considered for both upgrade projects and new projects. Increasing the availability and quality of roosts will improve biodiversity conservation outcomes. This is particularly important on projects which are modifying or destroying roosts in existing bridges and culverts through upgrades, replacements, and repairs, but can be considered on all projects. Importantly, improving habitat with artificial roosts even when not required as a condition of approval presents valuable opportunities to meet sustainability outcomes on projects and should be considered. Some feasible approaches to creating roosts in bridges and culverts include:

- Leaving lift holes in pipe culverts unfilled.
- Intentional installation of roost structures into the design of culverts and bridges.
- Use of vertical beams on bridges.
- Concrete roof slabs with in-built grooves and crevices (mimicking a cave).
- Installation of alternative roosts adjacent to the structure.

Where projects are modifying or destroying an existing roost the replacement roost must be installed prior to the disturbance of the original roost. If possible, installation of replacement roosts should be completed months in advance of the expected disturbance.

In urban areas, the provision of permanent artificial roosts provides multiple benefits including nature-based solutions for green infrastructure and nature-based tourism opportunities. The largest bridge roost is found in Austin, Texas USA, where gaps were provided between the concrete beams under the road deck for Mexican free-tailed bats (*Tadarida brasiliensis*). There are on average 100,000 bats roosting in the bridge year-round, and this number increases to 1.5 million bats in summer. The summer microbat emergence attracts tourists who invest in private microbat watching locations at restaurants, boat cruises and kayak cruises, and the fiscal impact of the bridge roost is an estimated $8 million[62]. The economic benefit of microbat-related tourism resulted in several bridge roosts being provided across Texas. Public microbat viewing opportunities are available at 17 roosts, attracting 242,000 visitors each year and an estimated $6.5 million in consumer surplus[63].

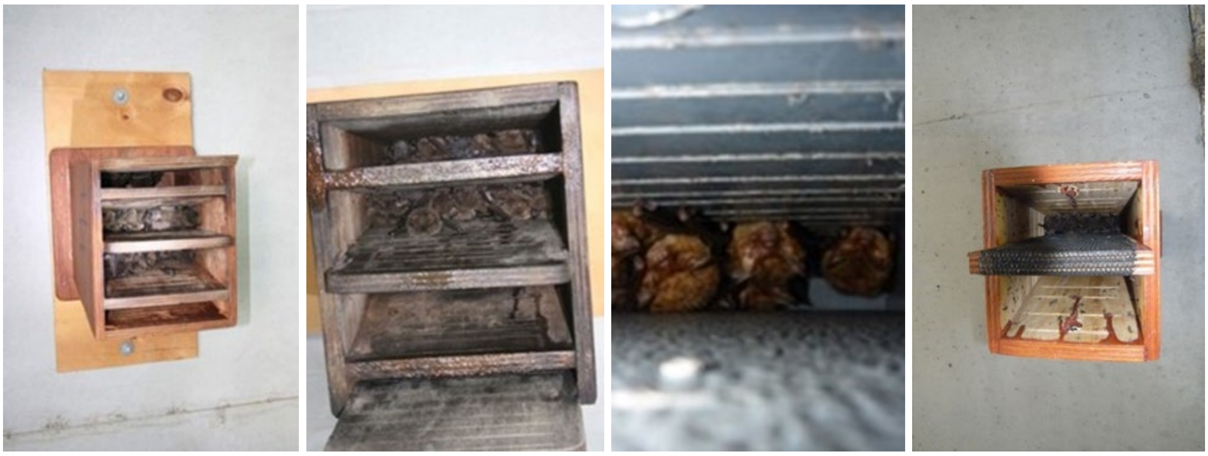
Different species display different preferences for naturally occurring roosts (e.g. tree hollows, caves etc.) while some will use artificial roosts (e.g. microbat boxes, culverts, bridges, mine shafts, and bridge structures). Many species of microbats will use microbat boxes and use varies seasonally[64]. Research in Brisbane concluded that microbat boxes in proximity (less than 50 metres) to each other

[61] (Gorecki et al. 2019)
[62] (Ryser and Popovici 1999)
[63] (Bagstad and Wiederholt 2013)
[64] (Rhodes and Jones 2011)

were used more often than isolated boxes[65]. Microbat box choice is influenced by a variety of factors including landscape variables, natural hollow abundance, box design, climate, and microclimate within the box itself[66]. There remains uncertainty about the specific design of preferred structure types, placement, number required, etc. for hollow dependent species, and there is ongoing research on hollow preferences by microbats in Australia. The design and placement of installed microbat boxes will differ for each project in response to the type of species and habitat being impacted (Figure 6.3(a)). Maintenance is required to ensure boxes continue to provide habitat for bats and are not occupied by pests such as wasps and bees[67].

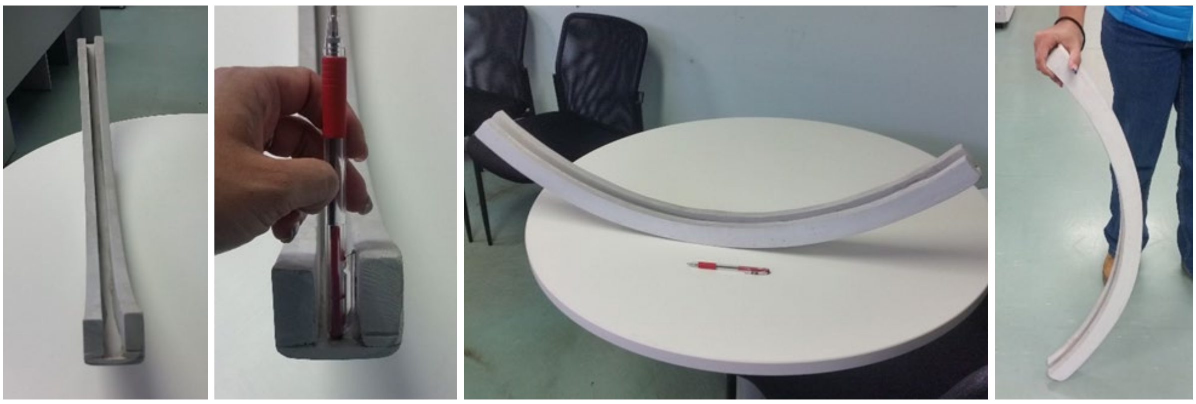
Cave- and crevice-roosting microbats are the most commonly encountered species of microbats roosting in transport infrastructure and there is little known about habitat preference and artificial roost selection. Further research and experimentation is urgently required and this topic would lend itself to experimental mitigation (Chapter 3).

Figure 6.3(a) – Examples of different microbat box designs installed on transport infrastructure projects



Source: © Alan Franks, Hollow Log Homes.

Figure 6.3(b) – Concrete wedge for retrofit in circular culverts to provide artificial roosts



Source: Transport and Main Roads

[65] (Rhodes and Jones 2011)
[66] (Rhodes and Jones 2011)
[67] (Rhodes and Jones 2011)

Structures that have been designed to provide roosting and breeding habitat for microbats should be added to the Transport and Main Roads ECHO Asset Management Database (Chapter 8). The potential impacts of any proposed works on those assets must be assessed in accordance with the relevant environmental assessment procedure (Chapter 5) and be carefully monitored, evaluated, and reported (Chapter 3).

Case Study 11.1 – Intentional creation of roosting opportunities for microbats in bridges and culverts[68]

Many species of microbats roost in a variety of cracks, joints and holes in culverts and bridges, and these artificial roosts provide important sheltering opportunities in landscapes where natural hollows may be limited. The upgrade and replacement of these culverts and bridges can result in the loss of roosts, with potential reductions in microbat populations. However, the replacement of structures can also be seen as an opportunity to increase roosting opportunities for bats if the structures are designed and constructed to provide roosting habitat.

A large number of timber bridges and culverts were damaged by the 2019-2020 bushfires and subsequent floods across eastern Australia and the NSW Department of Climate Change, Energy, Environment and Water undertook a trial to replace them with culverts that included pre-fabricated roosting opportunities. A single culvert with three types of roosts on the culvert ceiling was installed in June 2022 along a small creek in New England National Park in north east NSW as a proof of concept trial. The culvert included three types of pre-cast structures: multiple rows of U- or V-shaped concrete channels approximately 150 mm deep and 20 mm wide and one natural rock formation (Figure 6.3(c)).

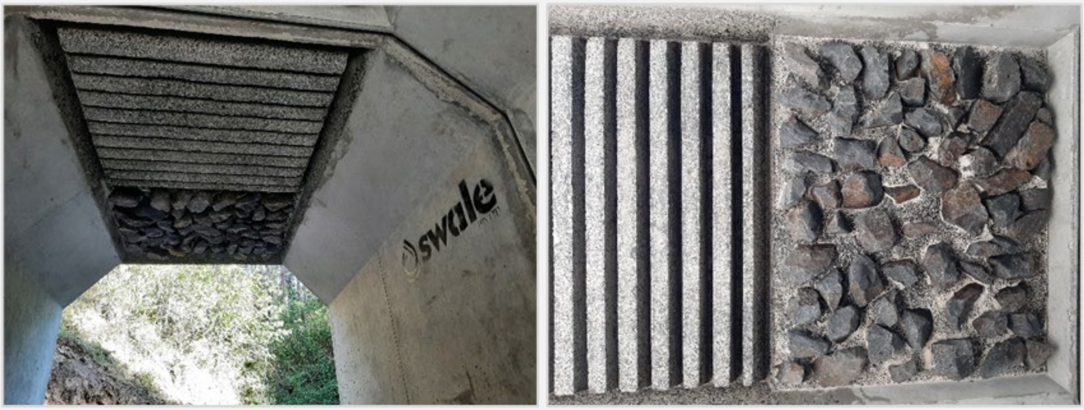
Seven months after installation (February 2023), three southern myotis (*Myotis Macropus*) were found roosting inside the U-shaped channels of the culvert. One year later, eight southern myotis, comprising a group of four, two and two individuals, were observed roosting in the U-shaped channels. While preliminary, the results suggest a preference for U-shaped channels as all bats were observed in these, approximately half of the U-shaped channels had guano in them and while guano was found on the ground under both channel types, there was more under the U-shaped channels. No bats or guano was observed within or under the natural rock formation. It is unknown if the culvert that was replaced was being used as a roost by microbats.

Importantly, the culvert with precast roosts is not prohibitively expensive (~$2000 more than a standard culvert in 2021) and are certainly cheaper than the cost to offset the cost of losing southern myotis habitat under the NSW legislation.

The study provides a proof-of-concept that the pre-cast roosts in concrete culverts can provide suitable habitat for microbats and further trials are urgently needed to refine preferences, confirm long-term use and suitability to support reproductive activity.

[68] Artificial Bat Habitat in Bridges and Culverts, NSW DCCEEW, Alicia Scanlon Pers. Comm.

Figure 6.3(c) – The ceiling of a trial culvert with three different types of pre-cast roosting habitat for microbats



Source: © Alicia Scanlon, NSW Department of Climate Change, Energy, the Environment and Water

6.4 Light management

Whenever street lighting is required and cannot be avoided (Section 3.4), the following mitigation measures to reduce the impacts of ALAN should be considered and adopted where possible:

- Only install lighting where it is required for user safety.
- Use the lowest intensity lighting possible.
- Use sensors or timers to only provide lighting when required, such as when pedestrians or motorists are present.
- Keep lights as close to the ground as possible to direct light to areas that require lighting.
- Use shielding of light fixtures to minimise light spill into sensitive areas, for example, crossing structures and entrances to crossing structures.
- Use 'warmer' colours of lighting rather than 'blue-white' colours[69].

It is important to note that recent studies have found that different species of microbats vary in their response to different types of lighting. Further trials are urgently needed to test and identify lighting types with the least impact on microbats[70]. It is likely that for some species, any level of ALAN will have an adverse impact on them[71].

7 Construction

7.1 Codes of practise and guidelines

There are requirements under the NC Act to protect fauna, fauna habitat, and fauna breeding places when these locations may be impacted. A Species Management Program (SMP) is required when a project tampers with the breeding places of threatened fauna. An animal breeding place is defined under section 335 of the Nature Conservation (Animals) Regulation 2020. Microbats are colonial

[69] (Gaston et al. 2012)
[70] (Stone et al. 2015b)
[71] (Stone et al. 2015a)

breeders due to the requirement for these species to form colonies during the breeding season. Therefore their broader populations are at greater risk from the impacts of events at a single location.

Tampering with breeding places of colonial breeders requires a high risk SMP. Microbat breeding places are any roost where young are raised and an SMP must be completed when a project tampers with a roost. Maternity roosts can be confirmed by searching for pregnant or lactating females and pups. In addition, knowing where and when different species breed can help to distinguish between maternity and non-maternity roosts.

The SMP is designed to assess the threats to microbat breeding places from planned activities and identify management actions such as avoidance and minimisation to protect the breeding place. The SMP will include monitoring and reporting requirements to ensure the continued conservation of the site and species, and to ensure expected outcomes are being delivered.

If a project is covered by a SMP the details of the SMP will be included in contract documentation.

7.2 Timing of construction activities

The timing of construction is critical to avoiding and minimising impacts to microbats. Clearing roosts should be undertaken:

- Outside of the breeding season (breeding season usually commences in spring until the end of summer) when females and/or their young may congregate in maternity roosts.
- Outside of any periods in colder areas when bats may go into torpor.

Appendix D in the TfNSW Microbat Management Guidelines[72] provide a useful starting point to plan the timing of works in relation to the breeding and/or potential presence of threatened microbats. It is important that these timing restrictions are used as a guideline only and projects must take into account the species of microbats in the area and any regional differences. More information about the timing of clearing and creation of alternate roosts are provided in Chapter 7.

7.3 Minimisation of health risks

Microbats in Australia can carry Australian Bat Lyssavirus (ABL), which is similar to rabies and can be fatal if an unvaccinated person becomes infected. Infection occurs when bitten or scratched by an infected microbat or flying-fox. Contact or exposures to bat faeces, urine, or blood does not pose a risk of exposure to ABL. Transport and Main Roads' 'work-related infections and parasitic disease procedure' outlines the requirements and recommendations to manage ABL for Transport and Main Roads staff and contractors. Please contact TMR_environment@tmr.qld.gov.au for a copy.

8 Maintenance and operation

The main threats of operation and maintenance activities on microbats are associated with:

- The modification or removal of roosts in large trees with hollows in transport corridors.
- The repair of culverts and bridges that are providing roosting opportunities.

[72] Microbat Management Guidelines (Transport for NSW)

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