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Manual

Fauna Sensitive Transport Infrastructure Delivery Chapter 14: Species profile – Arboreals

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Queensland Government

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1 Introduction

Arboreal species require trees for all or part of their shelter, food, and movement requirements. Consequently, arboreal species are restricted to areas with trees, including rainforest, forest and woodland, and to a lesser extent, shrubby and grassy habitats which include scattered trees. In Queensland, there are arboreal and semi-arboreal mammals, reptiles, and amphibians.

There are at least 24 species of arboreal marsupials in Queensland, with the majority restricted to South East Queensland, the wet tropics and along the east coast. Eight species are threatened under the *Nature Conservation Act* 1992 (NC Act) and six species are listed under the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act). Arboreal marsupials that are commonly found on transport infrastructure projects are shown in Table 1.1.

There are approximately 54 species of arboreal frog in the *Hylidae* family and 18 semi-arboreal frog species in the *Microhylidae* family. Fifty-one arboreal and semi-arboreal frog species are considered threatened under the NC Act and 12 species are listed under the EPBC Act.

Lastly, there are around 219 species of reptile in South East Queensland and some of these species utilise arboreal habitats, including snakes, geckos, monitors, dragons, and some skinks.
Seventy species of reptile in Queensland are threatened under the NC Act and/or the EPBC Act and a large proportion of these are arboreal.

This chapter focuses primarily on arboreal marsupials (possums and gliders) and briefly summarises arboreal amphibians and reptiles. For further details on reptiles and amphibians refer to Chapter 17 and Chapter 18 respectively, and for details on tree kangaroos refer to Chapter 12. While koalas are arboreal, they are described in detail in Chapter 13.

1.1 Commonly encountered arboreal marsupials

Table 1.1 – Threatened arboreal fauna in Queensland likely to be encountered on transport infrastructure projects

SCIENTIFIC NAME	COMMON NAME	DISTRUBITION	HABITAT
Petauroides volans	Southern and central greater glider	Occurs in eastern Australia and has a broad distribution from Proserpine in Queensland, through to New South Wales and the Australian Capital Territory and Victoria.	Largely restricted to eucalypt forest and woodlands. Typically found in taller, montane, moist eucalypt forest with fertile soils. It favours areas with relatively old trees with an abundance of hollows. It also occurs in drier habitats in South East Queensland. It relies on various structural attributes of forest overstorey and forage quality. As a result, it's likely that only a proportion of forest in potential habitat is suitable for use.

SCIENTIFIC NAME	COMMON NAME	DISTRUBITION	HABITAT
Petauroides minor	Northern greater glider	Occurs in the north-eastern region of Australia, including within the Wet Tropics World Heritage Area. The species has a patchy distribution from Townsville, north towards the Windsor Tablelands.	Restricted predominantly to eucalypt forests and woodlands and is typically restricted to high elevation and wetter sites of open woodland to open forests. Relies on old trees with hollows and local population size is correlated with hollow abundance.
Petaurus australis australis	Yellow-bellied glider (southern)	Widespread but patchy distribution from south-eastern Queensland to south-eastern South Australia.	Occurs in eucalypt dominated woodlands and forests, including wet and dry sclerophyll forests. Forest age and floristics determine habitat suitability and this subspecies shows a preference for mature old growth forests that provide suitable trees for foraging and shelter. Forests that provide a high proportion of winter flowering and smooth-barked species are favoured.
Petaurus australis unnamed sp.	Yellow-bellied glider (northern-wet tropics)	Occurs in the Wet Tropics Bioregion of Queensland. Range is between Yamanie Creek catchment and Mt Windsor Tableland (100 kilometres north-west of Cairns).	Largely restricted to a narrow band of wet sclerophyll forest that is an ecotone between rainforest and drier woodland ecosystems. These habitats provide key sap feed trees, red mahogany (*Eucalyptus resinifera*), and den trees, flooded gum (*Eucalyptus grandis*).
Petaurus gracilis	Mahogany glider	Occurs in Northern Queensland between Ollera Creek (40 kilometres south of Ingham) and the Tully River near Tully (a north-south distribution distance of 120 kilometres).	Occurs in a narrow band of open wet sclerophyll woodlands, primarily at elevations below 100 metres. Their habitat requirements correlate with a variety of tree species from the family *Myrtaceae* and *Mimosaceae*, in addition to a reduced middle and upper canopy cover structure.

Some of Queensland's more commonly encountered arboreal reptiles and amphibians include:

Agamidae "Dragons"

- Eastern bearded dragon (*Pogona barbata*)
- Central bearded dragon (*Pogona vitticeps*)
- Eastern water dragon (*Intellagama lesueurii*)

Varanidae “Monitors”

- Lace monitor (*Varanus varius*)
- Sand monitor (*Varanus gouldii*)
- Perentie (*Varanus giganteus*)

Snakes

- Green tree snake (*Dendrelaphis punctulata*)
- Brown tree snake (*Boiga irregularis*)
- Carpet python (*Morelia spilota*)

Amphibians

- Green tree frog (*Litoria caerulea*)
- Eastern sedge frog (*Litoria fallax*)
- Peron’s tree frog *(Litoria peronii*)
- Wallum sedge frog (*Litoria olongburensis*)

2 Ecology

2.1 Biology

Arboreal species are adapted to living in trees and rely on trees to varying degrees for survival, including:

- Tree hollows for denning, nesting, or raising young.
- Provision of food, including nectar and pollen from flowers, lerp from leaf-eating insects, tree sap, or other animals living in the tree, such as insects under the bark.
- A substrate for movement, including climbing or gliding from tree to tree.
- Shelter from predators and other threats.

Arboreal marsupials are classified into two distinct functional groups, being those that are capable of gliding (i.e. gliders) and those that are unable to glide and instead climb or jump short distances between gaps in the tree canopy (i.e. possums). Arboreal marsupials perform important ecological roles, including managing tree growth, pollination, seed dispersal and acting as a food source for predators, notably owls[1].

The diet of arboreal marsupials differs among species. Some are strict folivores and are almost solely reliant on a diet of leaves, such as the greater gliders and common ringtail possum (*Pseudocheirus peregrinus*). Others feed on nectar, pollen, and tree sap (e.g. yellow-bellied glider, mahogany glider, sugar glider (*Petaurus breviceps*), and squirrel glider (*Petaurus norfolcensis*), while others comprise a more varied diet, such as the common brushtail possum (*Trichosurus vulpecula*)[2].

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[1] (Smith 1980, Pavey et al. 1994, Pavey 1995, Cooke et al. 1997, Schulz 1997)
[2] (Henry and Craig 1984, Henry and Suckling 1984, Hume et al. 1984, MacLennan 1984, Pahl 1984, Quin et al. 1996, Jackson 2001)

Figure 2.1(a) – Central greater glider (Petauroides volans)

Source: © Matt Head

Figure 2.1(b) – Squirrel glider (Petaurus norfolcensis)

Source: © Matt Head

The most common groups of reptiles to utilise trees include geckoes, dragons, monitors, tree snakes, and pythons, and they occupy a wide range of habitats from sclerophyll forests to arid areas. Green-tree snakes and brown-tree snakes are also arboreal, however, are much more cryptic and are less often encountered on roads compared to pythons. Depending on their body size, arboreal reptiles may shelter in small cracks or under bark (e.g. geckoes) or in tree hollows (e.g. monitors) and feed on a range of prey from insects to possums and gliders. For more information about reptiles, refer to Chapter 17.

Tree frogs (*Hylidae*) have sticky circular toe pads that enable them to climb vegetation and other structures. Tree frogs occupy a variety of habitats including shrubs, sedges, trees, and grasses, with taller vegetation used as vantage points to catch food, escape from terrestrial predators, and display for mates. Frogs from the *Microhylidae* family are semi-arboreal and spend their time between terrestrial and arboreal habitats. For more information about amphibians, refer to Chapter 18.

2.2 Behaviour

Arboreal marsupials vary widely in their movement abilities and home range sizes. Some species have quite large area requirements, such as yellow-bellied gliders near Ravenshoe in north Queensland which have home ranges of 25–120 ha[3] and male striped possums (*Dactylopsila trivirgata*) on Cape York which have home ranges of 100–150 ha[4]. In contrast, the eastern pygmy possum (*Cercartetus nanus*), which occurs in South East Queensland near the New South Wales border, has a home range of approximately one ha, and the feathertail glider home range is approximately two ha[5]. Gliders have been observed dispersing and moving across open habitats without trees by coming to the ground[6], however, they are vulnerable to predation and wildlife-vehicle collision (WVC) while doing so.

Possums and gliders are nocturnal and spend most of their time during the day in a ‘den’ either in a tree hollow, fallen log, rock cavity, or termite mound. Some species, such as the common ringtail possum, can build their own nest within tree branches, called a drey, as well as use tree hollows. Most possum species are solitary and generally only come together during the breeding season. Many use a range of vocalisations to communicate or defend a territory from other individuals. In contrast, some glider species are highly social and live in large groups, sometimes up to approximately 10 individuals[7]. Gliders are typically territorial and there is minimal overlap of adjacent social groups. Most species of possum and glider have one to two young per litter, with up to two litters per year, resulting in relatively slow rates of population growth.

Trees are important nesting sites for many reptiles. Monitors will often lay eggs in termite mounds in trees and geckoes can lay their eggs under peeling bark. Trees are also utilised for movement. Arboreal reptiles are at high risk of WVC when they come to ground to move across gaps in tree cover or when basking on roads (Chapter 17).

2.3 Habitat

Arboreal species are largely restricted to rainforest, forest and woodland habitats, and some species also occupy shrubby habitats and grassy areas with scattered trees. The most possums and gliders occur in South East Queensland, along the eastern and western slopes of the Great Dividing Range and in the Wet Tropics. Some species, such as common brushtail possums and common ringtail possums, have adapted well to urbanisation and persist within many cities and towns[8]. Gliders, phascogales, and antechinus can persist in narrow strips of vegetation along transport infrastructure corridors provided they support high quality vegetation (i.e. large trees with hollows, shrubby understorey) and are well connected[9].

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[3] (Goldingay and Quin 2004)
[4] (Handasyde 2008)
[5] (Ward and Turner 2008, Ward and Woodside 2008)
[6] (Suckling 1984)
[7] (Goldingay and Jackson 2004)
[8] (e.g. Statham and Statham 1997, van der Ree 2004)
[9] (van der Ree et al. 2001, van der Ree and Bennett 2003, van der Ree et al. 2003)

A key determinant of habitat quality for most species of possums and gliders is the availability of numerous suitably sized tree hollows. Tree hollows provide critical shelter and denning opportunities, with some species using many hollows over time. Tree hollows, particularly large ones, can take more than 100 years to develop[10] and the loss of tree hollows is a key threat to hollow-dependent species in Queensland and nationally. The decline in tree hollows is due to a myriad of factors, including habitat clearing, timber harvesting, wildfires, fuel reduction burns, and clearing in urban areas to reduce risk of tree failure.

Figure 2.3 – Squirrel glider in artificial hollow

Source: © Matt Head

3 Direct impacts

Trees are a critical resource for arboreal species and the clearing of trees and shrubs for transport infrastructure corridors results in a loss of habitat and the creation of gaps that many arboreal species are unable or unwilling to cross. The impacts of transport infrastructure on arboreal species depends largely on their primary mode of locomotion and their willingness to come to the ground to move across gaps. Some species, such as the common brushtail possum, frequently move across the ground while others, such as the larger gliders (e.g. yellow-bellied glider, greater gliders), are almost entirely arboreal and when they do come to the ground are clumsy and at high risk of predation and WVC. Additionally, species which avoid coming to the ground are at greatest risk of barrier effects from transport infrastructure when gaps in tree canopy are wider than the distance they can jump or glide.

3.1 Wildlife-vehicle collision

The rate of injury and mortality of arboreal fauna due to WVC varies significantly among species due to their ecology and movement habits, with species that travel on the ground more likely to be

[10] (Gibbons and Lindenmayer 2002)

impacted compared to gliders. For example, the common brushtail possum and common ringtail possum often feature prominently in WVC surveys because they frequently come to the ground to move around[11].

In contrast, gliders are rarely recorded in WVC surveys, which is probably a reflection of relatively lower rates of WVC as well as the difficulty associated with collecting reliable injury and mortality data due to their small size and likelihood of them landing on road verges after collision. In addition, rates of WVC are likely to be underestimates because all species will be subject to removal by scavengers and damage from passing vehicles. Nevertheless, WVC with gliders does occur. One study reported that a squirrel glider was found more than 500 kilometres from where it was fitted with a radio collar, which the authors presumed was due to it being attached to the front of a vehicle after collision and being transported[12].

Figure 3.1 – Example of WVC on the Hume Highway Victoria that is difficult to detect during standard surveys

Source: © Kylie Soanes, University of Melbourne.

It is critical to note that while rates of mortality of some species are seemingly low (e.g. gliders) and others are relatively high (e.g common brushtail possum), it is necessary to consider rates of mortality as a percentage of the adjacent population and calculate the population-level effect of the rate of mortality. Importantly, a species with low population size or low rates of population growth may be more severely impacted by low rates of WVC than species with higher rates of WVC mortality and larger population sizes.

3.2 Barrier effects

The severity of the barrier effect on arboreal animals is related to interacting factors of:

- Animal behaviour, including ability to glide and glide distance, willingness to cross gaps, ability and willingness to come to the ground, and response to traffic.
- Width of the transport infrastructure and size of the gap between trees.
- Traffic volume or train frequency.

The size of the gap in canopy cover is highly relevant for gliders and has been well studied for many species across eastern Australia. Gliders have a species-specific glide distance that is based on body

[11] (Taylor and Goldingay 2004, Giffney et al. 2009, Russell et al. 2009, Visintin et al. 2017, Rendall et al. 2021)
[12] (Soanes et al. 2016)

size and launch height[13], and significant barrier effects will occur when the gap size exceeds their safe glide distance. 'Safe' glides are defined as glides when the entire glide is at least two metres above the maximum height of vehicles (i.e. trucks).

Some of the significant early work on squirrel gliders was conducted along the Hume Freeway in northern Victoria and southern New South Wales. These studies showed that wide roads that exceeded the species glide capability was a barrier to movement and gene flow[14]. In addition, a small-scale radiotracking study of six mahogany gliders in north east Queensland found that a 36 metre wide road and a 31 metre wide powerline easement impeded, but did not fully prevent, movement[15]. This 'filter' effect of gaps may be related to glide capabilities of males vs females, juveniles vs adults, and even differences in risk-taking among individuals[16]. In other words, gaps which exceed the safe glide distance for gliders is a significant impact to movement.

There is now reliable information on gap-crossing and glide capability of many glider species that can be used to assess the likely barrier effect of a project and to inform design for mitigation[17].

Case study 14.1 – The effect of gap-size and traffic volume on road-crossing by squirrel gliders

The impact of road width and traffic volume on the frequency of road-crossing by squirrel gliders was investigated along the Hume Freeway in northern Victoria [18]. A total of 58 squirrel gliders were fitted with radiocollars at eight sites – three freeway sites with no trees in the centre median, three freeway sites with trees in the centre median, and two control sites at narrow secondary roads (a, b, c in Figure 3.2(a)). Radiotracking was undertaken between December 2005 and November 2006 and sufficient data was collected from 49 gliders for analysis. Fewer than half of the gliders (23 of 47) were detected crossing any roads. The proportion of animals crossing the narrow secondary road (77% of individuals) was similar to that at the freeway with trees in the median (67%). However, just 6% of individuals crossed the freeway at sites without trees in the median. This study showed that very large gaps (e.g. 60–70 metres) were a barrier to movement, but the same overall distances were traversed when the gap-sizes were more than halved by having trees in the median. The study also showed that it wasn't traffic volume that was causing the barrier effect, because traffic volume was the same at all the study sites.

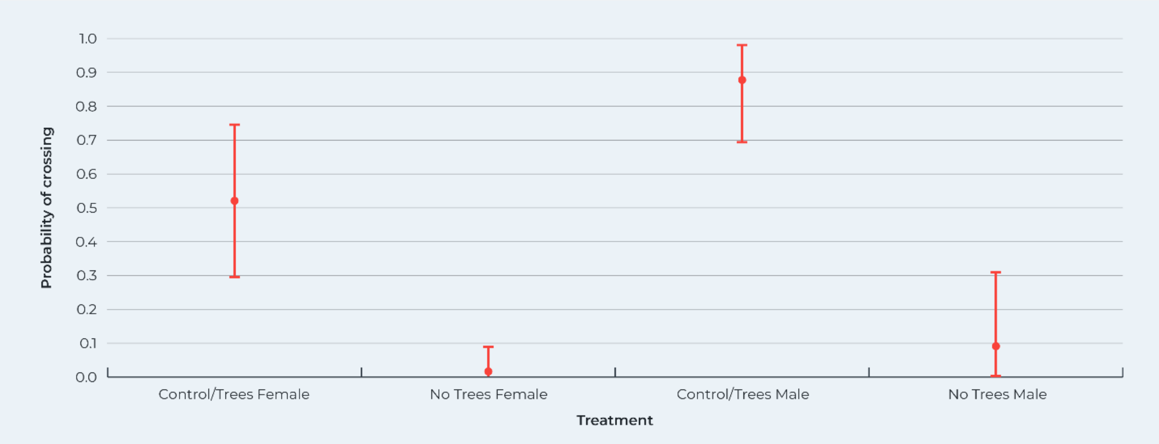
[13] (Jackson 1999)
[14] (van der Ree 2006, van der Ree et al. 2010, Soanes et al. 2013, Soanes et al. 2018)
[15] (Asari et al. 2010)
[16] (van der Ree 2006, Asari et al. 2010, van der Ree et al. 2010)
[17] (Jackson 1999, van der Ree et al. 2003, Flaherty et al. 2008, Goldingay and Taylor 2009, Goldingay 2014)
[18] (van der Ree et al. 2010)

Figure 3.2(a) – Aerial photograph of the three types of sites along the Hume Freeway in northern Victoria where squirrel gliders were radiotracked

Source: van der Ree et al., 2010

Sites in Figure 3.2(a) were intersections between (a) the Hume Freeway and a secondary road with trees present in the centre median of the freeway, (b) the Hume Freeway and a secondary road with no trees present in the centre median of the freeway, and (c) two secondary roads away from the Hume Freeway.

Figure 3.2(b) – Mean predicted probability (± credible interval) that resident squirrel gliders will make a partial, i.e. verge to median or median to verge, or complete crossing at different site types



Source: van der Ree et al. (2010).

There was no significant difference in the likelihood that an individual will cross a secondary road or the dual-roadway Hume Freeway with trees in the median, and these are pooled (denoted as Control / Trees). No trees are sites at the Hume Freeway without trees in the median.

3.3 Habitat loss and modification

The loss of wooded vegetation is a threat to the survival of arboreal species because they are reliant on trees for survival. The loss of trees is particularly problematic in already highly cleared landscapes, such as agricultural, urban, and residential areas, where canopy cover and thus the availability of foraging and hollow bearing trees has already been significantly reduced. It is important to realise that mature non-native trees can provide important resources (including foraging, shelter, and movement) and their removal can impact arboreal species.

The widening of existing transport infrastructure often requires the removal of vegetation, and this can significantly impact the narrow strips of habitat on transport infrastructure corridors, potentially reducing habitat and movement opportunities for arboreal species. Similarly, the removal of roadside trees to satisfy safety standards can result in significant loss of habitat and the creation of barriers to movement, both along and across the transport infrastructure. Additionally, transport infrastructure corridors may support mature and hollow-bearing trees and the loss of these result in significant reductions in habitat quality for arboreal species, including foraging resources (e.g. flowers, peeling bark) and shelter (e.g. hollows).

3.4 Noise, light, and other pollution

There have been no studies of the effects of traffic noise and limited studies on the effects of artificial light at night (ALAN) on arboreal fauna. However, one study of captive sugar gliders found reduced foraging time under light levels analogous to street lighting[19]. A field study of small mammals (including bandicoots, small macropods, and possums) in Victoria found that some species were less active on nights with higher ambient light levels and more active on nights with cloud cover, which has been attributed to an increased risk of predation[20]. Therefore, it is likely that some arboreal species may avoid or be less active in areas with high levels of ALAN.

Similarly, there have been no studies of the impacts of chemical pollution on arboreal species. However, dust and chemicals on vegetation, especially along dirt roads, will be ingested by species that eat leaves and flowers. This may have direct health impacts, as well as result in increased rates of tooth wear, potentially reducing longevity.

4 Avoidance and minimisation

Avoid areas of woodland, forest, and scattered trees wherever possible. Where transport infrastructure must pass through wooded habitats, minimise width of the infrastructure as much as possible. The objective is to keep the trees as close together as possible, ideally maintaining canopy connectivity above the transport infrastructure, as shown in Figure 4(a). Where canopy connectivity is not feasible, the gap should be minimized, because canopy bridges and glider poles are more effective and cheaper the shorter the gap they need to span.

When widening or duplicating transport infrastructure, consider placing the new carriageway in already cleared land, thereby reducing the extent of tree removal.

Rather than remove roadside trees that are a hazard to motorists, consider reviewing speed limits or installing guard rail, and select types of guard rail which requires the minimum possible deflection zone (e.g. W-beam requires smaller clear-zones than wire rope), as exemplified in Figure 4(b).

Large trees and hollow-bearing trees are critical habitats for arboreal species because they provide important shelter and denning opportunities, as well as key connectivity elements. Projects should seek to avoid the removal of large trees and hollow-bearing trees as much as possible through route

[19] (Barber-Meyer 2007)
[20] (Linley et al. 2021)

planning and micro-siting. Canopy bridges and glider poles that are constructed near these large trees will likely result in higher rates of use by arboreal species.

Figure 4(a) – Some canopy connectivity above the Eungella Dam Road Queensland

Source: Transport and Main Roads image library

Figure 4(b) – Large trees behind guard rails along Strathpine – Samford Road, Draper, Queensland

Source: Transport and Main Roads DVR 2023

5 Mitigation

5.1 Wildlife crossing structures

The most effective approach to maintaining connectivity for arboreal species is to avoid creating gaps in the canopy. Numerous studies in Australia and internationally have shown that arboreal species can traverse clearings at ground-level provided the canopy remains intact (for non-gliding species) and is within a safe (i.e. above traffic height) gliding distance for gliders [21]. Canopy connectivity can be restored but it will likely take many decades for trees to grow and there is no guarantee of successful growth.

There have been many studies of the use of canopy bridges and glider poles by arboreal marsupials, with most studies showing high rates of success and use at many of the structures (Table 5.1). This evidence demonstrates that canopy bridges and glider poles can effectively restore connectivity for many species of arboreal marsupials.

Despite strong evidence of use by a wide range of arboreal species, there are still numerous challenges and data gaps:

- Further work is required for greater gliders, smaller arboreal species (e.g. feathertail glider and pygmy possum), as well as all the arboreal and semi-arboreal frogs and reptiles.
- As adept climbers, there are challenges in funnelling arboreal species to the crossing structures and keeping them off the transport infrastructure to prevent WVC. The preferred approach is to install multiple crossing structures and install them in their preferred habitat or movement pathways.
- Predation of species on canopy bridges and glider poles is often cited as a concern, however there is minimal evidence to support these claims. In one study with 13,488 crossings of canopy bridges, only one predation attempt was detected on camera, and it was unsuccessful[22]. Nevertheless, predator shields on the top of poles and refuge pipes on poles and bridges should be included as a simple, low-cost precautions.
- There has been comparatively little evaluation of the use of vegetated land bridges by arboreal species and more is required. This lack of study is probably because most evaluations took place before cost-effective cameras were available and it takes many years for trees to mature and be utilised. Intuitively, connected canopy on a vegetated land bridge should function similarly to connected canopy elsewhere and provide effective connectivity for arboreal species, however further research is required.

There is now reliable information on the gap-crossing and glide capability of many glider species that can be used to assess the likely barrier effect of a project and to inform the design for mitigation[23]. Further details of the design, spacing, heights, and placement of crossing structures for arboreal species are provided in Chapter 6.

[21] (van der Ree et al. 2010)
[22] (Soanes et al. 2017)
[23] (Jackson 1999, van der Ree et al. 2003, Flaherty et al. 2008, Goldingay and Taylor 2009, Goldingay 2014)

Table 5.1 – Summary of literature detailing the use of crossing structures above linear infrastructure by arboreal species. Note that all studies are on roads, except southern greater glider, which is on a cleared pipeline easement

SPECIES	LOCATION	REFERENCE
Canopy bridges		
Squirrel glider	North east New South Wales; northern Victoria	(Goldingay et al. 2013, Soanes et al. 2013, Soanes et al. 2015, Soanes et al. 2018)
Brush-tailed phascogale	Northern Victoria	(Soanes et al. 2015)
Common / eastern ringtail possums	Perth, Western Australia; northern Victoria; north east New South Wales	(Goldingay et al. 2013, Yokochi and Bencini 2015, Goldingay and Taylor 2017)
Green ringtail possum	Wet Tropics	(Weston et al. 2011)
Lemuroid ringtail possum	Wet Tropics	(Weston et al. 2011)
Herbert river ringtail possum	Wet Tropics	(Weston et al. 2011)
Striped possum	Wet Tropics	(Weston et al. 2011)
Common brushtail possum	Northern Victoria; north east New South Wales	(Goldingay et al. 2013, Soanes et al. 2015)
Mountain brushtail possum	Central Victoria	(Mitchell et al. 2023)
Coppery brushtail possum	Wet Tropics	(Weston et al. 2011)
Sugar / Krefft's glider	North east New South Wales; central and northern Victoria	(Soanes et al. 2015, Goldingay and Taylor 2017, Goldingay et al. 2018, Mitchell et al. 2023)
Leadbeater's possum	Central Victoria	(Mitchell et al. 2023); van der Ree unpub. data;
Brown antechinus	Central Victoria	(Mitchell et al. 2023)
Feathertail glider	North east New South Wales; Central Victoria	(Goldingay et al. 2013, Mitchell et al. 2023)
Fawn-footed melomys	Wet Tropics	(Weston et al. 2011)
Giant white-tailed rat	Wet Tropics	(Weston et al. 2011)
Goanna	Northern Victoria	(Soanes and van der Ree 2009)

SPECIES	LOCATION	REFERENCE
Glider Poles		
Squirrel glider	Northern Victoria; north east New South Wales	(Taylor and Goldingay 2013, Goldingay and Taylor 2017, Goldingay et al. 2018)
Sugar / Krefft's gliders	Northern Victoria; north east New South Wales	(Goldingay and Taylor 2017, Goldingay et al. 2018)
Mahogany glider[1]	North east Queensland	(Asari et al. 2010)
Yellow-bellied glider	North east New South Wales	(Goldingay et al. 2018, Taylor and Rohweder 2020)
Southern greater glider[2]	Central Victoria	Kelly Dalton, GHD, pers comm.
Feathertail glider	North east New South Wales	(Goldingay et al. 2018)
Vegetated land bridges[3]		
Squirrel glider	Brisbane	(Taylor and Goldingay 2012)
Sugar / Krefft's / squirrel glider	Hair detected on glider poles on two canopy bridges in Brisbane	(Taylor and Goldingay 2012)
Possums (scats detected)	Brisbane	(Bond and Jones 2008)

[1] One mahogany glider was observed using a 15-metre-tall timber power pole as a launch platform to cross a road.

[2] This study was conducted across a cleared underground pipeline easement.

[3] Vegetated land bridges enable movement via trees or glider poles and/or canopy bridges installed on the land bridge. Most monitoring of arboreal species using vegetated land bridges occurred while trees were still relatively small and prior to the accessibility of cheap cameras for monitoring. Hence records likely underestimate actual use.

5.2 Habitat restoration and replacement hollows

The restoration of habitat is a key approach to mitigating the local impacts of transport infrastructure projects on arboreal species. Habitat restoration is a medium to long-term strategy for arboreal species, and should focus on the following:

- Strategic revegetation to link existing vegetation towards crossing structures, such as glider poles and canopy bridges.
- Strategic revegetation along transport infrastructure to restore natural canopy connectivity over time.
- Tree planting around glider poles and canopy bridges to increase direct connections to crossing structures.
- Strategic revegetation in adjacent areas to create or restore linkages and corridors across the landscape.

There is a tension between creating habitat along transport infrastructure and the potential increased risk of WVC. Unfortunately, there has been no research to quantify the relative effect of roadside plantings on rates of WVC and improvements in fauna connectivity. As a general rule, plantings on the verges of high-speed and high-volume roads for arboreal fauna should be focused on restoring connectivity to specific crossing locations or zones, rather than broadscale creation of habitat along roadsides. The risk of increased WVC along railways and smaller roads is much lower than major roads because the gap sizes are typically smaller and fewer cars and trains means lower exposure to risk.

The loss of large trees with hollows can be mitigated through the installation of replacement hollows. Tree hollows lost during projects have typically been replaced with timber nest boxes, however these have recently been criticised for their poor insulation capacity, use by invasive species, and high rates of decay and collapse[24]. Nevertheless, numerous arboreal species have been observed using nest boxes, including for breeding, over periods of at least 10 years, indicating that replacement hollows can have an important role in mitigating the loss of large old trees with hollows[25]. A wide range of new approaches to replace natural hollows are currently being trialled, including:

- Hollows carved into standing trees using chainsaws, drills, or other tools.
- Hollow logs that are salvaged during clearing and hung in trees.
- Enhanced nest boxes, including 3D printed boxes, moulded plastic, etc.
- Hollows for species that require very large hollows or hollows positioned higher in the canopy.

The effectiveness of these alternatives to nest boxes is still being quantified, and where tree hollows are being removed, projects should consider replacement hollows in an experimental approach. For example, a project required to install 100 hollows could install 25 hollows of four different types and monitor their use and condition over time. Further details and guidance to implement such an experiment that tests the effectiveness of mitigation and meets conditions of approval are provided in Chapter 4. More information on replacement hollows is provided in Chapter 6.

5.3 Noise and light mitigation

There have been no studies investigating the effectiveness of noise and light mitigation on arboreal animals. Despite this lack of clear evidence, reductions in lighting are likely to improve the rate of crossing structure use because it reduces the risk of predation by owls and wildlife are more active during low light conditions[26]. Streetlights are likely to have a similar effect and it is best practice to avoid installing streetlighting near canopy bridges, glider poles, land bridges, and areas with canopy connectivity.

6 Construction

The primary impact of construction is the injury and mortality of arboreal species that often occurs when trees are being cleared. A critical first step is to have an inventory of the total number of hollow-bearing trees at the site and an understanding of the abundance of arboreal animals so the clearing can be well-planned and executed (Chapter 7). Care should be taken to identify hollow-bearing trees, as some hollows are not visible from the ground and a conservative approach should be taken.

[24] (Lindenmayer et al. 2015, Griffiths et al. 2017, Griffiths et al. 2018)
[25] (Goldingay et al. 2015, Goldingay et al. 2020)
[26] (Barber-Meyer 2007, Linley et al. 2021)

The incidences of injury and mortality can be minimised by inspecting hollows and ensuring they are empty before felling the trees. Inspections can occur many days prior to clearing and empty hollows can be blocked to prevent re-entry after inspection, a process known as habitat reduction.

Staged clearing can also be undertaken, where non-hollow bearing trees are removed a day or two prior to the hollow-bearing trees, and the disturbance will encourage arboreal animals in the hollow-bearing trees to vacate the area.

Trees with hollows that are unable to be inspected and/or blocked should be felled in pieces, with hollow sections lowered to the ground by arborists or machinery. The hollow sections should then be inspected, and all species relocated according to the fauna salvage and relocation plan (Chapter 7). Fauna should be safely relocated to areas of suitable habitat near the project, ideally within their existing home range. If there are insufficient existing hollows in the relocation areas additional replacement hollows (e.g. nest boxes, carved hollows – Section 5.2) should be installed in the weeks to months prior to clearing occurring.

Experienced fauna spotter / catchers should be engaged to assess and map the hollow-bearing trees, undertake habitat reduction, supervise tree clearing, and relocate any impacted fauna.

7 Maintenance and operation

The removal of trees along transport infrastructure corridors for maintenance and safety reasons is highlighted in Chapter 8. Alternatives to tree removal should be considered wherever possible.

Trees growing next to glider poles and canopy bridges should be allowed to grow as close as possible to the structures, provided they don’t impact on its structural integrity. From an ecological perspective, the structures are likely to be more effective as tree height and canopy cover increases. Trees growing on vegetated land bridges should similarly be allowed to grow, with trees on the edge of the bridge inspected periodically by an arborist to assess health and risk of failure. Trees that pose an unsatisfactory risk should be pruned to a lower height rather than completely removed, and any gaps in canopy cover should be replanted as soon as possible.

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