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Manual

Fauna Sensitive Transport Infrastructure Delivery Chapter 17: Species profile – Reptiles

June 2024

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1 Reptiles

1.1 Introduction

Approximately 500 species of native reptiles occur in Queensland, consisting of snakes, turtles, crocodilians, and lizards. Reptiles occur across the entire state and in every bioregion, including some areas highly impacted by human activity. Many Queensland species of reptile are endemic, meaning they only occur in Queensland, and some only occur in relatively small areas of the state. Approximately 75 species of reptiles within Queensland are threatened under the *Nature Conservation Act* 1992 (NC Act) and/or the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act).

1.1.1 Commonly encountered threatened species

Of the approximately 75 threatened reptile species in Queensland, only a small number are regularly encountered on road and rail projects (Table 1.1.1). For example, the threatened collared delma (*Delma torquata*) is a legless lizard that has been a focus on road and rail projects in South East Queensland. This is likely due to:

- Rapid expansion of infrastructure development in South East Queensland.
- The species ability to utilise relatively degraded habitats, including grazed paddocks and woodlands heavily infested with lantana (*Lantana camara*).

Table 1.1.1 – Threatened reptile species in Queensland likely to be encountered on transport projects

SCIENTIFIC NAME	COMMON NAME	DISTRIBUTION	HABITAT
SNAKES			
Furina dunmalli	Dunmall's snake	Occurs from near the Queensland border, throughout the Brigalow Belt region in the south-eastern interior of Queensland. It also occurs in the Nandewar bioregions as far south as Ashford in New South Wales.	Forests and woodlands on black alluvial cracking clay and clay loams dominated by brigalow (*Acacia harpophylla*).
Hemiaspis damelii	Grey snake	Distribution is continuous from southern New South Wales to South East Queensland. In Queensland the distribution is broad and dispersed with most records being along the Macintyre and Condamine Rivers and associated floodplains of the southern Brigalow Belt from Goondiwindi and Dalby, west to Glenmorgan, on the Darling Downs, and western Lockyer Valley.	Woodlands (typically brigalow and belah *Casuarina cristata*), usually on heavier, cracking clay soils, particularly in association with water bodies or in areas with small gullies and ditches (gilgais).

SCIENTIFIC NAME	COMMON NAME	DISTRIBUTION	HABITAT
Aspidites ramsayi	Woma python	Most of their populations reside within Western and Central Australia, within the Brigalow Belt, Channel Country, Mitchel Grass Downs, and Mulga Lands.	Desert dune fields on sandy plains, usually with hummock grasses, but also other arid woodlands and grasslands. They often inhabit rabbit burrows but may also use their head and neck to excavate shelters under hummock grasses or dense bushes.
LIZARDS			
Delma torquata	Collared delma	The species has been recorded within the Bunya Mountains, Blackdown Tablelands National Park, Expedition National Park within Central Queensland, Western Creek, near Millmerran and within the Toowoomba Range. Within South East Queensland it has been recorded within western suburbs of Brisbane including Kenmore, Pinjarra Hills, Anstead, Mt Crosby, Lake Manchester, and Karana Downs.	Eucalypt dominated woodland and open forest where it is associated with suitable micro-habitats (exposed rocky outcrops). The ground cover is predominantly native grasses, such as kangaroo grass (*Themeda triandra*), barbed-wire grass (Cymbopogon refractus) and other species of wiregrass (*Aristida sp*.).
Egernia rugosa	Yakka skink	Distribution extends from the coast to the hinterland of sub-humid to semi-arid eastern Queensland. A large area covers portions of the Brigalow Belt, Mulga Lands, South East Queensland, Einasleigh Uplands, Wet Tropics, and Cape York Peninsula.	Broad range of open forest, woodland, and low shrub land vegetation types, predominantly on firm but friable soils but are also known to occur less frequently in rocky environments.
Strophurus taenicauda	Golden-tailed gecko	Species range occurs within the Brigalow Belt regions.	Woodlands and forests typically dominated by Brigalow.
Tympanocryptis condaminensis	Condamine earless dragon	The species occurs in the eastern Darling Downs region of South East Queensland and within the Brigalow Belt South bioregion. They occur on the Condamine River floodplain within a location bounded by the Pirrinuan / Jimbour area in the north-west, Millmerran in the south-west, Clifton in the south-east and Toowoomba in the north-east.	Remnant native grasslands, croplands and roadside verges of the eastern Darling Downs. These grasslands occur on black cracking clays of the Condamine River floodplain.
Tympanocryptis wilsoni	Roma earless dragon	Distributed within the Brigalow Belt of Queensland.	Currently known to occur in grasslands on sloping terrains. Grasslands in the western Darling Downs (Roma Grasslands) are dominated by Mitchell grasses (*Astrebla sp*.)

2 Ecology

2.1 Biology

Queensland contains some of Australia's largest and smallest reptiles, from the lace monitor (*Varanus varius*) which can grow up to 2.1 metres and preys on large arboreal mammals like possums and gliders, to the dwarf litter-skink (*Pygmaeascincus timlowi*) which is 2.9 centimetres in length and feeds on small invertebrates. Interestingly, the diet of some reptiles, including bearded dragons (*Pogona sp.*) and some skinks (*Egernia sp.*), changes from insectivorous to herbivorous over their lifetime[1].

Most reptiles are not limited by the availability of water because their scaly skin minimises water loss from the body and their ability to conserve water enables them to live throughout Queensland. Most reptiles lay shelled eggs which reduces their dependency on water sources for reproduction and subsequently increases the variety of environments in which they can reproduce. For example, some species of geckos lay hard shelled eggs which allows them to reproduce and thrive in even the harshest conditions. Most reptiles in Queensland lay eggs in burrows, leaf litter and organic matter, logs, and trees (i.e. within hollows, stumps, and exfoliating bark)[2]. A small number of reptile species give birth to live young.

Unlike reptiles in North America and Europe, Queensland's reptiles do not hibernate. However, they do undergo a mild form of hibernation called brumation during winter / dry season, which consists of reduced activity, lower body, temperature and slower heart and respiratory rates[3]. Most species take advantage of occasional warm days during winter and come out of brumation to feed and move around. During brumation, reptiles basking on the road will likely be slower to move away from oncoming traffic and are more difficult to detect as they shelter within burrows and logs.

2.2 Behaviour

Reptiles are more active in warmer weather, which in Queensland normally coincides with spring and summer months or the wet season (October – March). Reptile activity is species specific but can be generalised as per Table 2.2[4].

Table 2.2 – Generalised reptile activity

REPTILE GROUP	ACTIVITY	DESCRIPTION
Dragons, monitors (goannas), and skinks	Diurnal and crepuscular	• Diurnal—mainly active during daylight hours. • Crepuscular—active during twilight hours (morning and afternoon). • Nocturnal—generally active during the night.
Geckoes	Nocturnal	
Snakes, turtles, and crocodilians	Diurnal, nocturnal, and crepuscular	

Unlike northern hemisphere reptiles, most Australian species do not migrate along specific pathways to breeding sites and their movements can appear random. Consequently, mitigating transport infrastructure impacts to reptiles can be complex. This is compounded by the cryptic nature of many

[1] (Wotherspoon and Burgin 2016)
[2] (Rowland and Farrell 2019)
[3] (Mayer 2022)
[4] (Cogger 2018)

reptiles and their ability to utilise nearly all habitat types and habitat features including some very specific ones, such as black soil cracks, exfoliating bark of small shrubs, leaf litter, disused structures, and rubbish[5].

A large proportion of geckos, for example, spend most of their lives within trees and shrubs, sheltering and foraging underneath bark and within crevices – their sticky toes enabling them to climb and grip onto most surfaces. Dragons and monitors are also excellent climbers, and they use their strong limbs and claws to grip a variety of surfaces. Trees, shrubs, and other tall objects (e.g. fence posts) provide shelter from predators, foraging opportunities and improved access to ultraviolet (UV) light. Monitors also bask within trees at a variety of heights and will retreat up high within the tree if threatened.

Figure 2.2(a) – Northern leaf-tailed gecko (*Saltuarius cornutus*)

Source: © Matt Head

Figure 2.2(b) – Golden-tailed gecko (*Strophurus taenicauda*)

Source: © James Sparshott

[5] (Cogger 2018)

Reptiles typically have defined territories or home ranges, which can vary in size among species. Legless lizards, for example, are relatively sedentary and have small home ranges while lace monitors can have home ranges that are 65 to 100 ha in size[6]. The impacts of transport infrastructure will thus vary among species based on the size of the area they occupy and their ability to move across the landscape.

Reptiles are ectothermic, which means they are unable to produce metabolic heat and are therefore dependent on their surrounding environment to maintain body temperature. Subsequently, many reptiles can be found basking on the road and railway ballast to absorb heat, increasing their risk of wildlife-vehicle collisions (WVC). For example, the eastern water dragon (*Intellagama lesueurii),* eastern bearded dragon (*Pogona barbata*), and blue-tongue lizards (*Tiliqua sp.)* are commonly encountered on roads while basking and consequently have high rates of injury and mortality from WVC[7].

2.3 Habitat

Reptiles occur Australia wide and inhabit almost every habitat type. Within Queensland, species diversity is generally highest in biodiversity hotspots such as South East Queensland and the Wet Tropic bioregions. However, due to their ability to utilise a wide diversity of habitat, many reptile species, including threatened species such as the golden tail gecko *Strophurus taenicauda*, Allan's lerista and the collared delma, can be found in less diverse and more modified habitats[8].

Many reptiles have a narrow geographic distribution and live in very specific habitats. Subsequently, the loss, fragmentation, and degradation of even relatively small areas can have a significant impact on such species. The collared delma (*Delma torquate*), Figure 2.3, is a small legless lizard found in South East Queensland. It is a relatively sedentary species that has a small home range (<1 ha) and may even rely on the same rock for shelter[9].

Figure 2.3 – Collared delma

Source: © James Sparshott

[6] (Lei and Booth 2018, Pascoe et al. 2019)
[7] (Koenig et al. 2002)
[8] (Cogger 2018)
[9] (Ryan 2006)

Additionally, they can be incredibly cryptic, making some species difficult to detect and monitor. For example, Allan's lerista (*Lerista allanae*), a small burrowing skink with reduced limbs, is only known to occur in the root systems of grass tussocks on black soils within undulating basalt, shale, and sandstone plains. Historical land clearing and grazing have resulted in this species being listed under the EPBC Act and the NC Act. Their extremely fragmented habitat is distributed within a small area of the Brigalow Belt North Bioregion and is now largely contained within road reserves located in the Central District, Central Highlands District, the Mackay District, and Northern District[10].

3 Direct impacts

3.1 Wildlife-vehicle collisions

The rates of reptile-vehicle collisions are underestimated because most reptiles are small, difficult to detect with conventional WVC survey techniques (e.g. vehicle-based surveys), are likely to be scavenged by predators, and rarely result in human injury and are thus not included in crash statistics. However, numerous surveys that have attempted to account for this bias have shown that reptile-vehicle collision rates are often high and invariably lead to high rates of reptile mortality[11]. For example, a survey in Taiwan using citizen science found that snakes had the highest proportion of road mortality observations out of all major taxonomic groups (i.e. bats, turtles, lizards, mammals, amphibians, and snakes). From 2011 to 2018, 11,238 snake road mortalities throughout Taiwan were recorded[12]. The small size of snakes (and other reptiles) and being active at night reduces their detectability to drivers which, when combined with basking on roads, likely contributes to their high rates of road mortality.

Some drivers deliberately attempt to run snakes and other species (e.g. cane toads) over[13], suggesting that some WVC rates are higher than what might be expected. Therefore, any estimates of reptile road mortality should be used as a guide and interpreted cautiously, as they are almost certainly a significant underestimate of the true rate of WVC.

Turtles frequently move overland and across roads to locate nesting grounds and more suitable habitat, with such movements often more likely to occur immediately after rain[14]. This behaviour can lead to high rates of mortality due to WVC[15]. For example, a total of 124 turtle deaths, consisting of broad-shelled snake-necked turtle (*Chelodina expansa*), eastern snake-necked turtle (*Chelodina longicollis*) and Murray River turtle (*Emdura macquarii*) were recorded on roads along the Murray River by citizen scientists from 2014 to 2017. The majority of these deaths were adults, hence road mortality is likely a major cause of the alarming decline of even common turtle species in the Murray River[16].

Some species, such as the frillneck lizard (*Chlamydosaurus kingii*) appear to prefer living near to roads because the open roadside habitats provides them with higher levels of visibility[17]. In addition,

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10 (DCCEEW 2021)
11 (Chyn et al. 2019)
12 (Chyn et al. 2019)
13 (Beckmann and Shine 2012)
14 (Santori et al. 2018)
15 (Gibbs and Shriver 2002, Aresco 2005)
16 (Santori et al. 2018)
17 (Griffiths 1999)

their use of road surfaces for basking or to access other resources (e.g. water from rainfall after extended dry periods) may also increase their susceptibility to WVC. Transport infrastructure corridors can also be habitat for many reptiles which can increase the risk of WVC. Open vegetation allows for ease of basking and can sometimes provide suitable nesting sites due to appropriate ground temperature and well drained gravely soils[18]. This use of transport infrastructure corridors as habitat may increase the risk of WVC, especially during breeding and hatching seasons when reptiles typically travel longer distances than other times of year and for species that don't avoid roads.

An additional source of potential mortality is entrapment between railway tracks for small species of reptiles that enter the tracks at level crossings and are then unable to climb over the tracks. Eastern box turtles (*Terrapene carolina*) have been found trapped between railway tracks in the eastern United States of America, where they can overheat due to sun exposure and heat from tracks and ballast, resulting in mortality[19]. Similar impacts have been observed in India[20] and probably also occur in Australia.

3.2 Barrier effects

Research on the barrier effect of transport infrastructure on Australian reptiles is limited. However, inferences can be taken from studies conducted overseas. For example, western fence lizards (*Sceloporus occidentalis*) in the USA completely avoided highways with high traffic volume or consistent traffic flow. Therefore, such roads act as a complete barrier to their movement. In contrast, dirt roads and secondary roads with low traffic volume were only partial barriers as western fence lizards would often cross dirt roads as part of their normal movement and had erratic and irregular movement along the edge of secondary roads[21].

Blanding's turtle (*Emydoidea blandingii*) and eastern massasauga rattlesnake (*Sistrurus catenatus*) in North America both avoided crossing roads, however snakes were more likely than turtles to cross all road types[22]. Interestingly, eastern snake-necked turtles were found living in wetlands around Melbourne with higher density of roads surrounding them, suggesting that roads may be acting as a barrier to them being able to move among water bodies[23].

Reptile species that avoid roads will have low rates of WVC and more severe barrier effects. Road avoidance can fragment populations and impact the long-term persistence of meta-populations though lack of recruitment. For example, one study found common blue tongue skink (*Tiliqia scincoides*) consistently avoided crossing busy urban roads, particularly females who did not need to roam across large areas to reproduce. Instead, they moved through corridors of thick vegetation along fence lines[24].

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[18] (Santori et al. 2018, Paterson et al. 2019)
[19] (Kornilev et al. 2006)
[20] (Dorsey et al. 2015)
[21] (Brehme et al. 2013)
[22] (Paterson et al. 2019)
[23] (Hamer et al. 2016)
[24] (Koenig et al. 2001)

Figure 3.2 – Blue tongue skink

Source: © James Sparshott

The specific factors that influence transport infrastructure avoidance behaviour by reptiles is not well understood. Likely causes of avoidance relate to increased risk of predation when in open areas, traffic noise, and vibration and visual disturbance from trains and cars[25]. The effects of reduced movement are discussed further in Chapter 4.

3.3 Habitat loss and modification

Loss of habitat combined with habitat modification is a global threat to reptiles[26], including many species in Queensland. For example, the yakka skink (*Egernia rugosa*) and Allan's lerista are threatened as a direct result of land clearing within the Brigalow Belt[27].

Infrastructure projects such as the Toowoomba Second Range Crossing and Cooper's Gap Wind Farm have resulted in the removal of threatened species habitat, including the collared delma. Habitat loss from transport infrastructure reduces population size because there is less habitat available. In addition, the process of clearing can cause injury and mortality if not done carefully or at the right time of year (Chapter 7). For example, the collared delma is incredibly cryptic and difficult to locate despite high survey effort, and thus the true cost of habitat loss for the species is difficult to quantify.

[25] (Koenig et al. 2001, Brehme et al. 2013, Paterson et al. 2019)
[26] (Gibbons et al. 2000, Geyle et al. 2021)
[27] (Mine 2013, Geyle et al. 2021)

3.4 Noise, vibration and light pollution

Impacts due to light pollution on reptiles are understudied, with the exception of marine turtles[28]. Increases in coastal development and associated artificial beachfront lighting has disrupted the behaviour and survival of sea turtles[29] by:

- Repelling females from nesting grounds because nesting females actively avoid artificially lit beaches and favour the darkest areas for nesting[30].
- Disrupting the seaward orientation of hatchling turtles after emerging. Light pollution disorientates hatchlings, who move towards the lights on land rather than the ocean, severely lowering their survival[31].

Conversely, there are some positive effects of artificial light at night (ALAN) for reptiles, such as feeding on invertebrates attracted to lights. This can result in increased growth and reproductive output of reptile species, as seen in the green anole (*Anolis carolinensis*) in North America[32].

Artificial light has also been implicated in the spread of invasive species in Australia, such as the Asian house gecko (*Hemidactylus frenatus*) which forages around lights where insect abundance is greater. Subsequently, native species are less willing to forage within these ‘light traps’[33]. Further research on the impacts of ALAN on reptiles is urgently required.

The impacts of traffic noise and vibration on reptiles is also understudied[34] however it has been attributed to road avoidance behaviour in North American lizards[35]. The extent to which reptile species native to Queensland rely on aural cues for reproduction or other important behaviour is unknown. Nevertheless, high impact construction noise may cause temporary or permanent hearing loss in reptiles and vibration may limit their ability to detect prey.

4 Indirect impacts

4.1 Habitat degradation due to weed invasion

The greatest indirect impact of transport infrastructure on reptiles is likely the degradation of habitat through weed invasion. The construction and operations of transport infrastructure can facilitate the dispersal of weeds through earthworks, soil transportation, improper weed hygiene, and transfer of weeds by vehicles[36].

Weed invasion is particularly problematic for sensitive species of reptiles that rely on specific vegetation and/or structural conditions, such as the listed Roma earless dragon (*Tympanocryptis wilsoni*) and the Condamine earless dragon (*Tympanocryptis condaminensis*). These two species occupy remnant grassland patches containing deep complex black soil cracks that are often found

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[28] (Perry et al. 2008, Robertson et al. 2016, Price et al. 2018)
[29] (Robertson et al. 2016, Price et al. 2018)
[30] (Price et al. 2018)
[31] (Price et al. 2018)
[32] (Perry and Fisher 2006, Thawley and Kolbe 2020)
[33] (Zozaya et al. 2015)
[34] (Sordello et al. 2020)
[35] (Brehme et al. 2013)
[36] (Pickering and Mount 2010)

within road reserves[37]. Weed invasion is a threat to these species[38] because they can change the soil structure and severely reduce the availability of refuge sites. Woody weeds such as Lantana and invasive pasture grasses such as buffel grass (*Cenchrus ciliaris*) can infest roadside areas, effectively shading out critical refuge sites[39].

5 Avoidance and minimisation

Avoiding critical habitat is the most effective method of reducing transport infrastructure impacts on reptiles. Critical habitat for reptiles can include specific habitat elements, such as small patches of high-quality cracking soils, or larger areas of habitat. The ability to effectively avoid reptile habitat is possible with a thorough understanding of their habitat requirements. For example, the endangered pygmy blue tongue (*Tiliqua adelaidensis)* in South Australia is one of Australia's most studied reptiles and while rates of WVC are rare, there was concern that increased traffic associated with development could threaten the species[40]. Having a detailed understanding of the species' fine-scale habitat use allowed the South Australian Stony Gap Windfarm to avoid all habitat for the species as required under federal approval conditions for the project. Greater understanding of Queensland's threatened reptiles will allow similar results to be achieved.

Infrastructure projects which encounter reptiles, particularly species which are cryptic or poorly understood, such as the Dunmall's snake (*Furina dunmalli*), should consider consulting with experts to ensure impacts are fully understood and that avoidance, mitigation, and offsetting actions are appropriate.

6 Mitigation

6.1 Wildlife crossing structures

6.1.1 Overpasses

The most effective overpasses for most reptiles are land bridges because they can provide a continuous habitat up to and over the road or railway. Land bridges should include habitat for the target reptiles as well as 'furniture' (i.e. logs, rocks, and artificial habitat structures) that provide shelter and protection from predators. Surveys of reptiles between 2005 and 2010 on the Compton Road land bridge in Queensland found that the overpass had a higher species diversity of reptiles than the adjacent forested areas[41]. Importantly, the persistent presence of reptiles increased as the vegetation matured, suggesting that the overpass acted as an extension of the surrounding urban forests.

Lace monitors have been recorded on one rope ladder over the Hume Freeway in northern Victoria on one occasion[42] but no other reptiles have been reported using them. The current design of canopy bridges are likely too exposed for arboreal reptiles to use, and are thus not recommended as a measure to mitigate barrier effects on reptiles.

37 (Starr 2009)
38 (Melville et al. 2019)
39 (Melville et al. 2019)
40 (Clive and Bull 2018)
41 (McGregor et al. 2015)
42 (Soanes and van der Ree 2009)

6.1.2 Underpasses

No underpasses have been specifically installed for reptiles in Australia.

The optimal underpass for reptiles would include open span bridges and viaducts because the ground layer is more natural than the concrete base of culverts. In addition, the size of the cleared gap is typically less than for culverts, thereby reducing the size of the clearing to be crossed.

Numerous studies of underpasses in Australia and overseas has shown that locally abundant and/or generalist reptile species will use dedicated wildlife culverts and drainage culverts. For example, the lace monitor was a frequent user of several box-culvert underpasses near Grafton and Port Macquarie, New South Wales[43]. Elsewhere, common species of reptiles regularly used large concrete culverts under the Madrid-Seville High Speed Railway in Spain[44]. The successful crossings in Spain were concentrated in areas with border habitat (i.e. the intermediate area between two distinct habitat types, such as farmland and scrubland) and both lizards and snakes were seen basking at the entrances and inside culverts.

A novel approach used in Europe and North America are 'slotted culverts' which have open tops that allow light and water to penetrate the culvert, providing a more suitable substrate and microclimate. Slotted culverts with fencing was installed in 2022 and 2023 on a narrow low-volume access road in the Royal Botanic Gardens Cranbourne, Victoria (Figure 6.1.2(a)). A wide range of species have been observed using the small culverts, including occasional use by the blotched blue-tongue lizard and rare use by tree dragons, lowland copperhead, eastern tiger snake and long-necked turtle[45]. Slotted culverts are likely most effective on low-speed and low-volume roads because the incidence of noise, ALAN, and environmental pollutants will be higher on major roads.

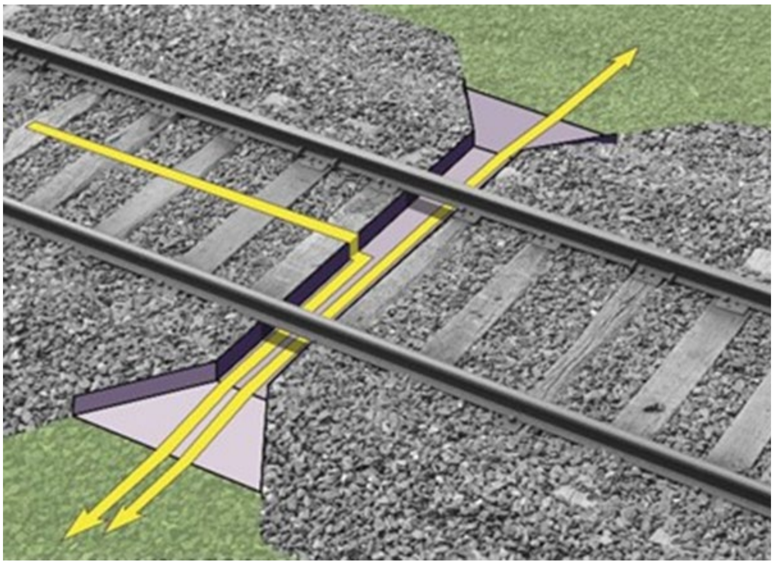
Micro-tunnels (Figure 6.1.2(b)) enable turtles and other species that can get trapped between railway tracks to drop down and move off the railway and facilitate movement across the railway.

Figure 6.1.2(a) – Slotted culvert installed in Royal Botanic Gardens Cranbourne, Victoria for small mammals, reptiles, and amphibians.

Source: © Rodney van der Ree, WSP.

[43] (Goldingay et al. 2022)
[44] (Rodriguez et al. 1996)
[45] (Dr Terry Coates, Royal Botanic Gardens Victoria, pers. comm.)

Figure 6.1.2(b) – Micro-tunnel between sleepers to allow trapped turtles to escape and facilitate movement across the railway.



Source: © Scott Watson.

6.2 Fencing

Fencing is essential to prevent reptiles from accessing the road or railway and funnelling them to crossing structures. The effectiveness of fencing is dependent on its location, design, and how well it is maintained. The design should be species-specific and consider fence height, mesh size, that the base is buried, and whether an overhanging lip is required to prevent reptiles from climbing over. More details of exclusion fencing is given in Chapter 6.

Most fences that have been installed for reptiles have been for turtles in North America and Europe. For example, 24 kilometres of barrier fencing was installed along a state highway in California to funnel the threatened desert tortoise (*Gopherus agassizii*) to wildlife culverts. Surveys along unfenced and fenced sections of highway found that the fencing reduced turtle mortality by 93% (12.6 dead turtles per kilometre per year compared to 1.3, respectively)[46]. Furthermore, population surveys adjacent to the road revealed that tortoise activity was approximately 30% greater along fenced sections of the highway.

6.3 Light management

There is no research in Australia on the effectiveness of techniques or maximum lux levels to minimise the impacts of ALAN on reptiles, with the exception of numerous projects for sea turtles[47]. The most effective strategy to reduce light pollution on sea turtles is to eliminate lights within coastal regions and at beaches where they are known to nest, especially during the egg-laying and egg-hatching period. The principles and actions in the *National Light Pollution Guidelines for Wildlife*[48] should be considered in areas where reptiles may be impacted by ALAN.

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[46] (Boarman et al. 1997)
[47] (DOEE 2020)
[48] (DOEE 2020)

Lighting that can be considered for elimination include:

- Light sources illuminating areas that require no security or lighting for other reasons.
- Light sources that illuminate areas that are vacant or have little foot traffic.
- Decorative lighting.
- Light sources that provide more than adequate illumination for the purpose.

However, not all lights are able to be eliminated. Other light pollution strategies involve:

- Shielding to reduce light spillage onto nesting areas.
- Use of low-pressure sodium-vapor lighting rather than Light-emitting diode (LEDs).
- Implementation of 'Turtle Safe Lighting'. Red lights emit a very small portion of the visible light spectrum which is less intrusive to sea turtles and hatchlings.
- Use of lighting on sensors to ensure they only operate when people are passing and illumination is needed.

More details about mitigating impacts of ALAN are given in Chapter 6.

6.4 Artificial shelters, breeding sites and habitat modification

Many species of reptiles will use artificial structures[49] for shelter, including building material (e.g. roof tiles, scrap metal, rubble) and specifically designed structures, such as artificial bark on trees or cast concrete-polymer rocks[50].

The provision of artificial habitat may assist in mitigating the impacts of transport infrastructure on reptiles by increasing population size to buffer against increased mortality or to encourage reptiles to move away from the road. For example, freshwater turtles in North America have used artificially constructed breeding sites, such as 'floating nests'[51]. A similar approach is being trialled in Australia on the Murray River to provide the Murray River Turtle, eastern snake-necked turtle, and broad-shelled snake-necked turtle with egg laying locations that are protected from foxes[52]. Fencing, including the use of electric fences, can be used in specific areas to protect freshwater turtle nests from predation by red foxes[53].

Reducing the attractiveness of transport infrastructure and verges, such as basking opportunities and food or water sources, may also reduce the rate of WVC.

7 Construction

7.1 Translocation

The greatest impact of construction is the injury and mortality of reptiles during vegetation removal, habitat clearing, and the stripping of top soil – especially for species that hide under rocks, in soil cracks, and in leaf litter (Chapter 7).

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[49] (Cowan et al. 2021, Watchorn et al. 2022)
[50] (Croak et al. 2013)
[51] (Santori et al. 2018)
[52] (Moon 2021)
[53] (Streeting et al. 2023)

While translocation of individuals prior to clearing is typically undertaken, it may lead to high rates of mortality after relocation[54] and many translocations are unsuccessful[55]. Recent research has shown that successful translocations are more complex than simply moving animals out of harm's way and require comprehensive understanding of the species ecology and biology, extensive planning, and long-term follow-up management to be successful[56].

The recent Toowoomba Range Second Crossing in Queensland passed through critical habitat for the threatened collared delma. To reduce mortality during clearing, an intense translocation program was developed[57] and included the following activities:

1. A pilot study to evaluate the likely success of the translocation program, involving a separate translocation outside the construction footprint of the project.
2. Intensive investigations to quantify collared delma microhabitat to identify suitable locations for release.
3. The use of a 'soft-release enclosure' to reduce predation during the settling in period.
4. The collection and translocation of collared delma prior to and during the tree clearing.
5. Intensive monitoring of the survival of animals over two years, and
6. The removal of the soft release enclosure fence to allow for the gradual release into the wild.

The translocation program, which was completed in 2019, resulted in[58]:

- The translocation of 114 collared delma.
- The recapture of 43 individuals with 37 recaptured once, seven recaptured twice and three recaptured three times.
- The identification of ten hatchling / juveniles, suggesting that the translocated collared delma successfully reproduced.
- All collared delma recaptured in the monitoring program increased in size or weight, indicating that translocated individuals were healthy.

The distance that animals are translocated is also important, with decreasing rates of survival as distance increases. A study in Western Australia that tracked the fate of 10 translocated snakes found:

- 100% mortality in snakes relocated more than three kilometres from the initial capture point.
- 50% mortality in snakes relocated within 200 metres from the initial capture point[59].

Further construction considerations are provided in Chapter 7.

[54] (Cornelis et al. 2021)
[55] (Germano and Bishop 2009, Berger-Tal et al. 2020)
[56] (Cornelis et al. 2021)
[57] (Nexus 2019b)
[58] (Nexus 2019b)
[59] (Ashleigh et al. 2018)

8 Maintenance and operation

Transport infrastructure corridors can provide important habitat for reptiles, especially species with small home ranges and in highly cleared areas. Maintenance activities along transport infrastructure should consider the potential presence of reptiles and whether the proposed maintenance will have a negative impact on those species. For example, grass slashing, weed spraying, and grading during times of year when the reptiles are present or breeding and unable to quickly move away, may present a risk to survival (Chapter 8). Improving habitat complexity and providing refuges for reptiles may help to mitigate impacts of maintenance activities.

Managing transport infrastructure for firebreaks, either through formal fire events or illegal vegetation clearing by landholders, can also have major impacts for fauna species, in particular reptiles that use understorey and midstorey vegetation. For example, most of the Australian skink species utilise leaf litter for feeding and refuge. When these elements of an ecosystem are changed, the quality of habitat can be impacted.

The routine maintenance of underpasses, especially the removal of sediment from drainage culverts and multi-use culverts, may temporarily reduce the functionality of the underpass after the natural substrate that has built up over time is removed. Therefore, culverts that provide passage for reptiles should be identified and the need to clear out the substrate should be assessed prior to undertaking culvert cleaning.

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