7. TARGET SPECIES DESIGN CONSIDERATIONS

7 TARGET SPECIES DESIGN CONSIDERATIONS

General principles:

- Any species native to the project's region can be considered a target species for fauna connectivity structures.
- Non-native species should not be considered target species of fauna connectivity structures.
- Due to the cost of building fauna connectivity structures priority should be given to locally or regionally important species threatened by road infrastructure.
- Identifying target species is an important step in the:
  - o Planning process where the location and design of fauna connectivity structures is, to a large extent, determined by the location and movement of target species.
  - o Process of determining appropriate monitoring procedures to evaluate a structure's success.
- The design of fauna connectivity structures should consider a variety of species, not just a single target species.
  - o For example, a land bridge should form a habitat connection for populations of invertebrates (for example, beetles), birds or smaller vertebrates (for example, lizards) rather than considering the movement requirements of only one species or group of species (for example, macropods).
  - o Table 6.0.2 (Section 6: Measures to Achieve Fauna Sensitive Roads) provides additional information on fauna structures suitable for a variety of target species.

7.1 Fish

7.1.1 Background

- Movement throughout waterways is critical to the survival of native fish.
- Fish movement allows access to food and shelter, to avoid predators, to migrate for spawning and to search for mates to reproduce.
- Fish passage structures should be considered whenever infrastructure crosses fish habitats such as rivers, streams, wetlands and lakes.

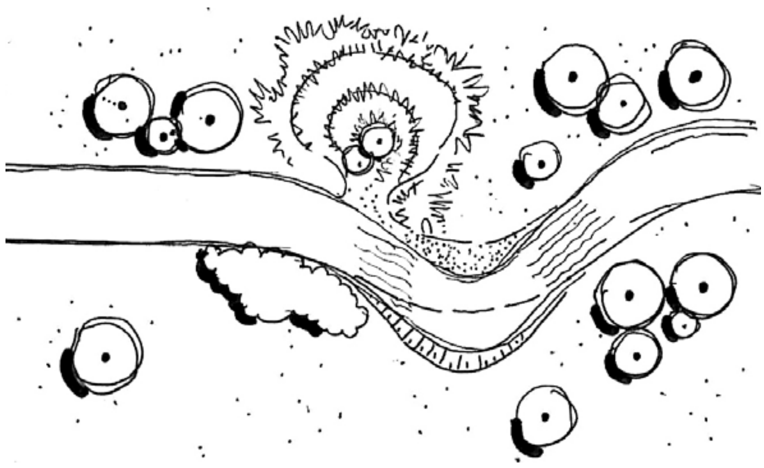
7.1.2 Designs and structures

- Consider local research and documentation when pursuing detailed designs.
- Design to be undertaken in conjunction with an appropriate expert or the relevant government agency.
- Fish passage needs to be provided in ephemeral streams, as well as for the full range of water levels in non-ephemeral waterbodies.
- Fish passage must be considered when infrastructure crosses fish habitats and movement corridors and has the potential to negatively impact on fish movement.
- Fish passage structures must be considered when roads reduce connectivity between fish habitat areas.
- Important aspects to consider for aquatic fauna:
  - o water velocity;
  - o water turbulence;
  - o light penetration;
  - o length, width, depth and slope of crossing;
- maintenance of crossing (that is, to avoid waterways becoming overgrown or full of debris);
  - o existence of any drop-offs either side of the crossing; and
  - o noise, light and pollution during construction.
- Infrastructure must not change a fish's existing ability to move both upstream and downstream.

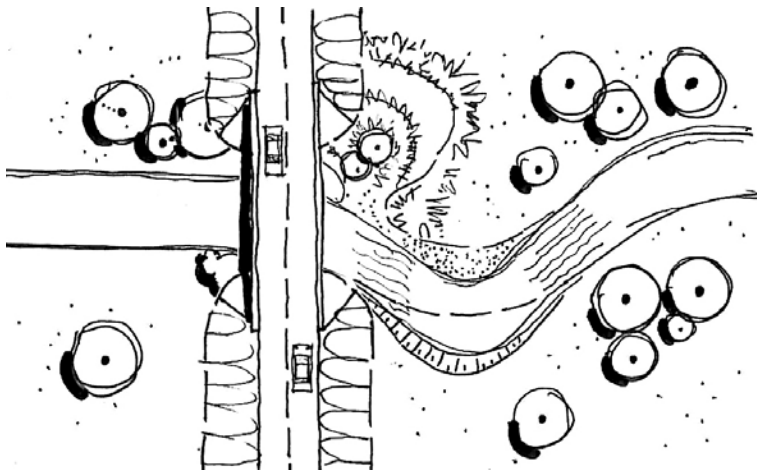
- The type of stream crossing will depend on the:
  - crossing's purpose and anticipated frequency of use;
  - site characteristics (for example, bank height, bed stability, flow regime, depth);
  - upstream and/or downstream environmental values;
  - outcome of public consultation; and
  - budget.
- As a general rule-of-thumb preferred structures are as follows (in descending order of preference):
  - Bridges;
  - Arch culverts and open-bottom box culverts;
  - Stream simulated design with buried base box culverts;
  - Pipe culverts.
- Design flow magnitudes for fish passage are much less than commonly used in drainage design flows for trafficability, inundation and/or erosion protection (Kapitzke 2009).

Site selection for structures

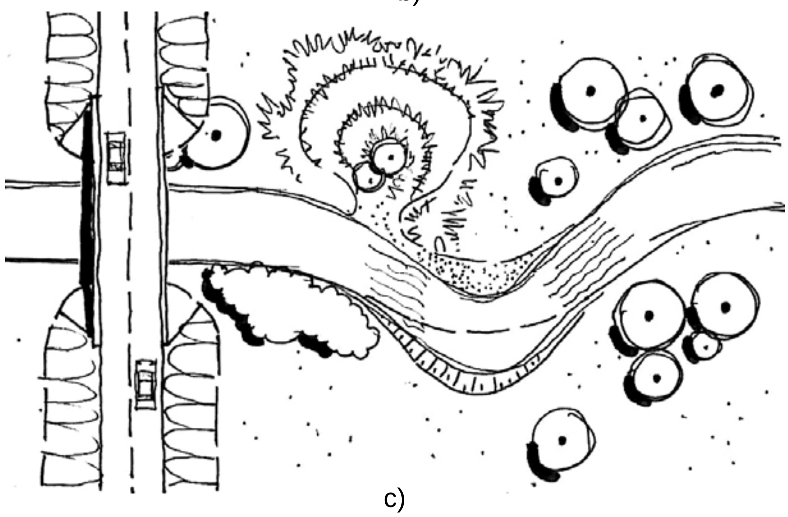
- Refer to Figure 7.1.1.
- Consider the implications of the project for aquatic species at the catchment scale.
- Minimise the number of times roads cross waterways.
- Existing road crossings should be used where possible (ie, do not construct new or additional waterway crossings unless absolutely necessary). Existing structures should be assessed for fish passage requirements to determine whether work is required to remove barriers to fish movement.
- If a new road needs to cross a waterway (or additional waterway crossings are required) and there is a choice of sites for the crossing, the following should be considered:
  - Avoid wetland and floodplains;
  - Avoid environmentally sensitive areas such as fish habitat areas, high conservation value wetlands, known spawning grounds, nursery areas and riffles and rapids;
  - Avoid areas where contaminated sediments could mobilise;
  - Avoid unique, endangered or highly valued areas;
  - Avoid sharp bends;
  - Avoid sections of unstable channel;
  - Avoid major riffle systems;
  - Avoid meandering waterways;
  - Additional care will be needed if the crossing is upstream of domestic and town water supplies, aquaculture and other industrial off-takes, sensitive ecosystems and/or recreational areas are present;
  - Avoid areas of aesthetic value.



a)



b)



c)

Figure 7.1.1 Site selection for road crossings over waterways (adapted from Fairfull and Witheridge 2002).
a) Existing habitat.
b) Less desirable site selection as bridge placement damages sensitive habitat areas.
c) Optimal site selection for road crossing over waterways as sensitive environments are avoided.

Site Assessment

- Determine:
    - The presence/absence of local native fish species (local authorities, appropriate expert or locally relevant primary data sources may be of assistance).
    - Waterway and flow characteristics.
    - The types of fish activity that occur in the place of interest determine the most effective crossing design.
        - For example, migration for breeding requires upstream and downstream movement.
    - The movement capabilities of the local fish. This determines the maximum water flow rate.
        - Most Australian native fish are very poor swimmers. The best method of maintaining fish passage is to maintain the natural water velocity through the road crossing.
        - Structures may be incorporated to provide rest areas.

Structure design

See Section 6: Measures to Achieve Fauna Sensitive Roads for design details. Specifically:

- Section 6.6: Underpass: Culvert;
- Section 6.8: Underpass: Bridge.

7.1.3 Construction

- Should occur at times of low flow and outside of resident fish migrations (particularly those associated with breeding activities).
- Remove all aspects of old waterway crossings located within the waterway channel.
- Take all reasonable and practical measures to prevent or minimise environmental disturbance during construction, including the minimisation of fish passage restrictions.
    - Minimise disturbance to the outer bank of stream bends during works and while gaining access to the waterway.
- Remove all temporary in-stream sediment controls and sidetracks as soon as possible.
- Where practical, construct the crossing in stages to allow flow diversion.
- Construct side access tracks from clean fill (free of fines) using pipe or box culvert cells to carry flows or alternatively employ the use of a temporary bridge structure.
- Return all disturbed areas to their original condition.
- Remove all redundant structures.
- Maintain water quality during and after construction.

7.1.4 Maintenance

- Time in stream maintenance activities to minimise overall environmental disturbance, by taking into consideration fish migration periods and seasonal high flows.
- Maintain stream crossings regularly.
- Avoid disturbance to marine plants.
- Carry out regular inspections and maintenance on crossings, after periods of high flow, prior to when fish start to migrate.
    - Clear debris from the crossing's surface, entrance and exit.
    - Remove excess silt from the entrance and exit of the culvert/s if more than a third of the entrance is blocked.
    - Ensure erosion is not being exacerbated.

- Maintenance activities may both hinder and improve fish passage. In general, the removal of debris improves fish passage. However, in some cases, the removal of sediment can adversely affect the development of desirable fish habitat.

7.1.5 Key references

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7.2 Amphibians

7.2.1 Background

- Road mortality has been cited as a potentially important factor in the worldwide decline of amphibians.
  - This can be attributed to amphibian movement patterns related to foraging and breeding activities. Such movements increase the likelihood of amphibians crossing roads and result in mortality.
  - Amphibians are also attracted to the roads during rain, again leading to mortality.
- Adult amphibians often demonstrate strong fidelity for breeding sites resulting in relatively discrete populations (Jackson 1996).
- The viability of small ponds is likely to be dependent on gene exchange and the supplementation of populations via dispersal.
- Given their reliance on small, temporary ponds, many amphibian populations may be vulnerable to local extinction events during periods of unusually dry weather. Over time, these populations are probably maintained via a process of supplementation and recolonisation, thus connectivity is vital for maintaining regional or metapopulations.
- The presence of thriving amphibian populations is commonly used as an indication of a healthy environment.
- Research indicates frogs have a strong preference not to move across concrete.
- Amphibians are sensitive to environmental pollutants due to their:
  - permeable skin and eggs;
  - their position in the foodweb as mid-level consumers;
  - their potential for prolonged exposure to contaminants in both aquatic and terrestrial habitats; and
  - early development in aquatic environments, where they are exposed to chemical contaminants during critical developmental periods.
- Road run-off is likely to affect amphibian populations, therefore, mitigation of such impacts must be considered throughout the entire road project.

General measures to reduce impact on amphibian populations:

- Locate roads away from key habitats, such as wetlands, streams and pond sites.

- Maintain buffers of undisturbed native vegetation around and adjacent to key habitats to discourage human access to these areas.
- Provide suitable landscape linkages, such as riparian management areas, parks and greenways, to allow movement between important seasonal habitats.
- Prefer protective riparian vegetation extending over the waterway and adjacent land passage sections, which should be damp with shallow ponds and puddles.
- Maintain existing hydrological flow regimes and water quality during post-construction.
- Minimise roadkill of amphibians migrating between seasonal habitats by locating roads away from these areas. Consider road-crossing structures where this is unavoidable (see Section 6).
- Control the spread of non-native animals and plants; introduced amphibians can compete with and prey on native amphibians; weedy exotic plants can overtake native vegetation and choke wetlands.
- Encourage residents and site workers to take an interest in protecting these species by providing interpretive materials such as signs and brochures.
- Consider designs that accommodate all life cycle stages.
- Ensure effective management of road drainage and runoff to minimise water pooling.

Breeding-site specific measures:

- Preserve all wetlands, ponds, pools and streams.
- Protect shallow water areas and their vegetation from trampling and other disturbance.
- Avoid altering natural patterns of flooding and drying of wetlands.
- Maintain sufficient terrestrial habitat or access to terrestrial habitat for amphibians to complete all life history phases.
- Avoid known breeding ponds for frogs when designing and constructing access tracks.

Environmental contamination prevention specific measures:

- Reduce the use of chemical compounds in the road corridor.
  - Restrict the use of herbicides and growth retardants to control vegetation, as well as fire retardants and insecticides over and adjacent to waterbodies.
  - Adopt integrated pest control methods that decrease the reliance on chemical herbicides and insecticides to reduce contamination of aquatic habitats.
    - For example, increase use of native plants, pest-resistant varieties of exotics and design features that minimise and confine intensively managed areas.
- Contain contaminants through appropriate road run-off management.
- Trap and filter contaminants through vegetative buffers and other means before they enter water bodies.
- Restrict the use of chemicals near any frog ponds, streams, ditches, underpasses. This is essential to safeguard breeding habitats.
- Undertake pH monitoring and correction (if required) during tunnel excavation, groundwater extraction and infiltration to maintain suitable habitat conditions.

7.2.2 Designs and structures

See Section 6: Measures to Achieve Fauna Sensitive Roads for design details. Specifically:

- Section 6.6: Underpass: Culvert;
- Section 6.11: Barriers: Fencing;
- Section 6.14: Habitat enhancement: Frog Ponds;
- Section 6.18.2: Other methods that influence the effectiveness of fauna structures: Lighting.

Section 9.1: Case Studies: Tugun Bypass also provides an example of frog habitat and movement mitigation measures.

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7.3 Platypus

7.3.1 Background

- Require permanent fresh water, an intact benthic invertebrate food chain and consolidated banks in which to build burrows.
- Changes in their habitat as a result of land use, impoundment, channelisation, riparian zone clearing, erosion, silting pollution and eutrophication can compromise platypus populations.
- In the absence of site specific trapping or observational data, a guide to likely stream utilisation by platypus can be assessed by site survey. Should take into account:
    - Land use;
    - Riparian zone vegetation;
    - Stream and bank parameters;
    - Presence of burrows; and
    - Local knowledge.

7.3.2 Designs and structures

- See Section 6: Measures to Achieve Fauna Sensitive Roads for design details. Specifically:
- Section 6.6: Underpass: Culvert.

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7.4 Arboreal species

- An arboreal species is an organism that lives in trees for more than half of its time during at least one stage of its lifecycle.
- A semi-arboreal species is an organism which is routinely found in trees but spends less than half of its time there.

7.4.1 Background

- Without canopy connectivity, many arboreal species face extinction due to elevated competition for limited resources, reduced home ranges, and/or genetic inbreeding (due to barrier effects).
- This impact is most severe for arboreal species which are strictly arboreal, such as lemuroid ringtail possum, and those species which rarely descend, such as Herbert River ringtail possum.
    - Maintaining connectivity across road infrastructure for arboreal species is, therefore, vital to mitigate the fatal impact of roads.
- Those arboreal species that do descend, for example common brushtail possums, are the second most common roadkill in South-east Queensland (Queensland Department of Main Roads 2002).

7.4.2 Designs and structures

See Section 6: Measures to Achieve Fauna Sensitive Roads for design details. Specifically:

- Section 6.1: Overpass: Land Bridge;
- Section 6.4: Overpass: Canopy Bridge;
- Section 6.5: Overpass: Poles;
- Section 6.9: Non-structural mitigation: Canopy Connectivity;
- Section 6.11: Barriers: Fencing;
- Section 6.15: Habitat enhancement: Nest Boxes;
- Section 6.18.2: Other methods that influence the effectiveness of fauna structures: Lighting;
- Section 6.18.3: Other methods that influence the effectiveness of fauna structures: Noise.

Section 9.2: Case Studies: Compton Road – Brisbane City Council also provides an example of a project implementing arboreal species mitigation measures.

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7.5 Koala

7.5.1 Background

- Queensland subspecies: *Phascolarctos cinereus adustus*
- Birthing season:
  - August to May with peak between November and January.
- Home range:
  - Approximately 10-12 hectares for males and five to six hectares for females in South-east Queensland.
  - Coastal populations generally have smaller home ranges than inland populations. Home ranges vary between one koala every three hectares in coastal habitats to one koala every 200 hectares in semi-arid habitat.
  - Males and females can share parts of home ranges, but males are less tolerant.
  - Although home ranges may overlap, koalas remain solitary.
  - Daily movement: usual movements are within a few hundred metres.
  - Move to a different tree at least once every 24 hours.
  - Averse to changing paths and will try to use same path even when blocked.
- Dispersal:
  - Koalas have been known to disperse over 10 kilometres.
- Preferred Vegetation:
  - The most appropriate vegetation may be difficult as tree preference changes with season, sex and age.
  - Trees of varying ages, species and sizes (Smith 2004).
  - Avoid sites with large numbers of stumps and low vegetation.
  - Trees with diameter at breast height (DBH) of 310 mm (greater than 200 mm and no more than 500 mm).
  - Significant koala food trees are Angophora; Corymbia; Eucalyptus; Lophostemon and Melaleuca (Environmental Protection Agency 2006).

- Favoured food tree species include tallowwood (*Eucalyptus microcorys*), grey gum (*E. propinqua*), Queensland blue gum (*E. tereticornis*), red mahogany (*E. resinifera*) and Queensland white stringybark (*E. tindaliae*).
- *E. robusta* is particularly favoured by female koalas (Matthews *et al.* 2007).
- For understorey species, koalas prefer casuarina, banksia, melaleuca and acacia.
- Koalas utilise non-eucalypt species for shelter and as secondary food sources (McAlpine *et al*. 2006b).
- In a study over 35 months, it was found that no one tree was utilised by more than three koalas (Matthews *et al.* 2007).
- Suitable vegetation may not be inhabited if adjacent to human land use.
- Mortality
- Roads have been identified as a leading cause of koala mortality.
- Collisions with vehicles mainly occur during breeding and dispersal seasons.
- Highest number of male deaths occurs from July to October, peaking in October (greater than 100 reported casualties in October).
- Highest number of female deaths occurs during July and October (greater than 60 reported casualties).

- Population density:
    - Dependent on habitat-type and quality of habitat.
    - 0.005 to 2.5 koalas/hectare.
    - 0.2 – 0.5 to more than two koalas/hectare in forested habitat.
    - Approximately one koala/200 hectare.
    - Density in urban areas is as high as 0.25 koala/hectare whilst density in bushland areas and remnants is 1.26 koala/hectare.
- Koala populations require at least 5000 individuals to maintain sustainable genetic diversity. The existing koala population in the Koala Coast consists of a total of 4611 individuals, which comprises multiple isolated subpopulations. The small size of the subpopulations increases the probability of inbreeding and decreases the populations' viability. Although inbreeding is an issue, most koala subpopulations become extinct from direct mortality, due to lack of suitable habitat and collisions with vehicles, prior to loss of genetic diversity becoming an issue.
- Although still uncertain, it is widely considered that one koala per generation must disperse across a road barrier to maintain genetic diversity.

7.5.2 Designs and structures

- Fauna structures to take into account koala's repetitive pathway behaviour. Conduct surveys examining koala routes, paths and home-ranges prior to installation.

See Section 6: Measures to Achieve Fauna Sensitive Roads for design details. Specifically:

- Section 6.1: Overpass: Land Bridge;
- Section 6.3: Overpass: Cut and Cover Tunnel;
- Section 6.5: Overpass: Poles;
- Section 6.6: Underpass: Culvert;
- Section 6.11: Barriers: Fencing;
- Section 6.18.5: Other methods that influence the effectiveness of fauna structures: Road Safety Barriers.

7.5.3 Vegetation clearing

Currently there are strict legislative requirements in regard to the clearing of vegetation within koala habitat areas. The following outlines some of the principles associated with these.

- Sequential clearing principles should be employed.
- Sequential clearing conditions refer to all of the following:
  - Vegetation clearing carried out in a way that ensures koalas in the area being cleared (the clearing site) have sufficient time to move out of the clearing site without human intervention.
  - Vegetation clearing carried out in a way that ensures appropriate habitat links are maintained within the clearing site and between the site and its adjacent areas to allow koalas to move away;
  - Trees with koalas present are not to be cleared, as well as trees that overlap with such trees.
- Fauna spotter/catcher principles employed in koala habitat areas:
  - Must be present during clearing of koala habitat areas (including koala habitat trees – *Angophora, Corymbia, Eucalyptus, Lophostemon* and *Melaleuca*) that have a trunk with a diameter of more than 100 mm at 1.3 metres above the ground.
  - If there is more than one machine operating, there may be the requirement for more than one fauna spotter/catcher.
  - Must be in close proximity to the vegetation being cleared.
  - Their role is to spot fauna in vegetation, mark any trees appropriately and ensure that fauna are not injured during any clearing. They are also required to relay information to the machine operator/s.
  - Koalas are not to be physically removed from a tree to another location.
  - Any tree (or patch of vegetation) that has been identified as a risk to the animal if cleared, must not be felled, damaged or interfered with until the animal has moved from the site of its own accord.
  - Should an animal (not limited to koalas) be found sick or injured, contact must be made with a suitable treatment facility or QPWS hotline regarding the most appropriate course of action.
  - Must be suitably qualified for the task and also have the appropriate permits/licences in place from the State Government.

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7.6 Birds

7.6.1 Background

- Highways cause impacts to birds in four ways: direct mortality, indirect mortality, habitat fragmentation and disturbance (noise and lights).
- Research indicates that some bird species experience higher stress levels in environments with roads than those without (Wasser *et al.* 1997).
- To determine whether to create or eliminate bird habitat is dependent upon a number of factors, including the surrounding environment, the road environment and the degree of vulnerability (habitat loss and/or road kill) of the target bird species.
  - These issues must be determined prior to designing mitigation measures.
- Clearing of roadkill will reduce the likelihood of scavenger birds being hit by vehicles.
- Road mortality is a significant threat to cassowaries. In particular, increasing traffic volumes as a result of growing local and tourist populations have caused an increase in cassowary road mortality.
- Mitigation solutions for bird species based on specific impact issues are shown in Table 7.6.1.

Table 7.6.1 Mitigation solutions for bird species based on the specific impact issues.

Impact	Problem	Suggested solutions
Flightless birds	Flightless birds incur greater mortality risk due to conflicts with vehicles on roads. Winds over bridges can drag flying birds into vehicles.	• Open and vegetated passage provided under bridge structures. • Crossing structure with large openness ratios (underpasses) or wildlife overpasses. • Reduced speed limits may be appropriate for some specialised species.
Water birds	Waterbirds are attracted to pooled water adjacent to the roadside.	• Ensure there is no water pooling in areas where this may cause fauna impact issues.
Nocturnal Raptors	Owls generally hunt at heights similar to headlight height.	• Short fences along highway medians and right-of-ways, where this group of birds is the target species.
Ground nesters	Nesting individuals are impacted by mowing roadsides.	• Mow/maintain verges outside breeding seasons.
Scavengers	Scavenger birds are killed while	• Remove roadkill from road.

Impact	Problem	Suggested solutions
	foraging on roadkill.	• Increased frequency of roadkill clearing may be best targeted during the breeding season when roadkill numbers are at their peak.
Frugivores, honey and blossom eaters	Birds are attracted to food trees in the median strip and can be impacted by vehicles when around this vegetation.	• Avoid planting food tree varieties. • Remove food trees.

7.6.2 Designs and structures

See Section 6: Measures to Achieve Fauna Sensitive Roads for design details. Specifically:

- Section 6.1: Overpass: Land Bridge;
- Section 6.6: Underpass: Culvert;
- Section 6.8: Underpass: Bridge;
- Section 6.10: Non-structural mitigation: Local Traffic Management;
- Section 6.11: Barriers: Fencing;
- Section 6.13: Barriers: Perching Deterrents;
- Section 6.18.2: Other methods that influence the effectiveness of fauna structures: Lighting;
- Section 6.18.3: Other methods that influence the effectiveness of fauna structures: Noise.

Section 9.2: Case Studies: Compton Road – Brisbane City Council also provides an example of a project implementing mitigation measures for bird species.

7.6.3 Key references

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7.7 Bats

7.7.1 Background

- Bats contribute significantly to the overall biodiversity of areas.
- In many areas of Australia the number of bat species present may equal the number of all other native mammal species present.
- Bats fulfil a unique purpose in the environment and are of notable service to humans. It is thought that bats feeding upon insects is an environmental service for agriculture as otherwise these insects would damage crops. The bats' service thus reduces the need for chemical insecticides and, consequently, they may be economically beneficial to humans.
- Large flying foxes (often called fruit bats) are fruit and flower eaters and dwell typically in riparian trees or those located near watercourses.
- Many Queensland bats are adaptable and will make use of various structures for roosting provided they are predator free and buffer extreme climatic conditions. Many bats use these different roosting sites on a seasonal basis. The use of roosting sites tends to vary across the state, by species, season, and features of the structures.
    - The highly specific selection criteria for bat roosts is linked to their metabolic rate requirements.
        - Bats have a large surface area ratio to body mass and thus require special techniques to retain body heat. For instance, bats generally seek roosting locations with trapped warm air, where light intensity and air movement is reduced. These conditions assist them in maintaining appropriate body temperatures.
- Roads can impact on bat populations/species by:
    - Increased mortality through roadkill.
    - Damaging roosting/maternity sites.
    - Decreasing the habitat availability either by general clearing or fragmentation.
- Road structures can act as habitat enhancements for microbats:
    - Bridge decks can provide alternative bat roosts when their natural habitat in caves and sheltered cliff overhangs has been disturbed.
    - Bridge decks may also provide some bats with a more preferable night roosting location as they can act as daytime heat sinks.
- Bats are attracted to light sources to feed on insects and can therefore fall prey as roadkill (refer to Section 6.18.2 Lighting for detailed information).
- No provisions in road structures have been made to accommodate any flying foxes.

7.7.2 Designs and structures

See Section 6: Measures to Achieve Fauna Sensitive Roads for design details. Specifically:

- Section 6.6: Underpass: Culvert;
- Section 6.15: Habitat enhancement: Nest Boxes;
- Section 6.18.2: Other methods that influence the effectiveness of fauna structures: Lighting.

7.7.3 Key references

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7.8 Macropods

7.8.1 Background

- Macropod-vehicle collisions are very common and can result in the death or injury to the animal and/or humans.
- Rock wallabies are required to be connected as colonies, as they cannot maintain the required genetic diversity as stand-alone populations.
- Timing of collisions:
  - High traffic volumes at dusk and dawn coincide with high movement times for macropods, which may result in increased rates of roadkill.
    - Macropods are stunned by headlights and do not move in time to avoid collisions.
    - Macropods shelter during the day and graze in the evening.
  - In winter collisions are reduced, most likely due to reduced movement/dispersion of macropods and smaller populations due to natural attrition.
- Hotspots for collisions:
  - Highways or streets are the most common collision areas whilst country roads are second most common (Abu-Zidan *et al*. 2002).
  - Watering points:
    - Vegetated drainage lines, adjacent to roads, tend to have a significantly higher kangaroo density. This is most likely due to the provision of water and shade during day and grazing opportunities in the evening.
  - Areas with more vegetation cover and greener plants (Klocker *et al.* 2006).
  - Roadside vegetation with regrowth (for example, after fire burn-offs in the road reserve new grass shoots may attract macropods to graze).
- Mitigation measures to reduce collisions include:
  - Excluding macropods from the road with fencing.
  - Providing safe crossing structures.
  - Changing driver behaviour.
  - Raising driver awareness through education in conjunction with signage and road markings.
  - Alerting and slowing down drivers (with signage and/or special temporary lighting on the road at night) during the period of grassy regrowth and after a fire burn-off.

7.8.2 Designs and structures

See Section 6: Measures to Achieve Fauna Sensitive Roads for design details. Specifically:

- Section 6.1: Overpass: Land Bridge;
- Section 6.5: Overpass: Poles;
- Section 6.6: Underpass: Culvert;
- Section 6.10: Non-structural mitigation: Local Traffic Management;
- Section 6.18.2: Other methods that influence the effectiveness of fauna structures: Lighting.

- Section 9.2: Case Studies: Compton Road – Brisbane City Council also provides an example of a project implementing macropod species mitigation measures.

7.8.3 Key references

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7.9 Small Mammals

7.9.1 Background

- Roads affect the abundance and distribution of small mammals.
  - There are differences in the density of small mammals that occur along the road corridor when compared with habitat outside of the road environment.
- Direct mortality of small mammals on the road has variable effects on their demographics, including a disproportionate loss of sex or age classes.
- Small mammals will use the majority of fauna crossing structures once they are well established.
- Numerous specific small fauna crossings may be required where small mammals regularly cross the road surface and suffer high mortality.

7.9.2 Designs and structures

See Section 6: Measures to Achieve Fauna Sensitive Roads for design details. Specifically:

- Section 6.6: Underpass: Culvert;
- Section 6.18.5: Other methods that influence the effectiveness of fauna structures: Road Safety Barriers.

7.9.3 Key references

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7.10 Reptiles

7.10.1 Background

- Generally, there are two types of impact that roads can have on reptiles:
  - Reduction in population due to vehicular collision as a result of being:
    - attracted to the road surface; or
    - desire to cross the road; or
    - species which are attracted to the road surface and also have a desire to cross the road. This group is vulnerable to collisions with vehicles.
  - Population isolation or habitat loss caused as the road becomes a physical barrier.
- Reptiles are often utilised to gauge the effectiveness of fauna crossing structures.
- During construction, the following impacts should be minimised as they have the potential to negatively impact upon reptiles:
  - Changes to microclimates through the disturbance to rocks, debris, shrubs, logs, leaf litter and grasses.
  - Weed invasions.
  - Alterations to fire regimes.

7.10.2 Designs and structures

See Section 6: Measures to Achieve Fauna Sensitive Roads for design details. Specifically:

- Section 6.1: Overpass: Land Bridge;
- Section 6.6: Underpass: Culvert;
- Section 6.11: Barriers: Fencing;
- Section 6.16: Habitat enhancement: Artificial Shelter Sites;
- Section 6.18.2: Other methods that influence the effectiveness of fauna structures: Lighting.

Section 9.2: Case Studies: Compton Road – Brisbane City Council also provides an example of a project implementing reptile species mitigation measures.

7.10.3 Key references

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7.11 Invertebrates

7.11.1 Background

- Invertebrate communities:
  - o Play a critical role in sustaining ecosystem health specifically, the abundance, diversity and activities of invertebrates contribute to nutrient cycling, energy storage and transfer.
  - o May be put at risk through habitat fragmentation.
  - o Can be used as an indicator of the ecological health of a fragmented area.
- Invertebrate monitoring can be used to evaluate the quality of habitat on land bridges, and hence their suitability as corridors for target vertebrate species. However, monitoring an entire invertebrate community is not realistic or cost-effective, therefore, a subset of taxa is usually chosen, for example:
  - o Spiders:
    - Shown to be informative indicators of environmental health.
    - Are top predators, so they are less numerous than other invertebrate groups, yet still diverse.
    - Both generalist and specialist species which respond dramatically to the availability of specific prey types, therefore, provide a good indication of overall invertebrate population health.
    - Cost-effective species to focus monitoring on to determine the ecological patterns of invertebrate communities.

7.11.2 Designs and structures

See Section 6: Measures to Achieve Fauna Sensitive Roads for design details. Specifically:

- Section 6.1: Overpass: Land Bridge;
- Section 6.16: Habitat enhancement: Artificial Shelter Sites;
- Section 6.18.2: Other methods that influence the effectiveness of fauna structures: Lighting.

7.11.3 Key References

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