Department of Transport and Main Roads

Source: Transport and Main Roads image library © The State of Queensland

Manual

Fauna Sensitive Transport Infrastructure Delivery
Chapter 2: Ecology concepts

June 2024

Translating and interpreting assistance

The Queensland Government is committed to providing accessible services to Queenslanders from all cultural and linguistic backgrounds. If you have difficulty understanding this publication and need a translator, please call the Translating and Interpreting Service (TIS National) on 13 14 50 and ask them to telephone the Queensland Department of Transport and Main Roads on 13 74 68.

Feedback

Please send your feedback regarding this document to: tmr.techdocs@tmr.qld.gov.au

Key Points

- Biodiversity encompasses all living things at the genetic, species, and ecosystem level. All three components of biodiversity are necessary for the continued survival of life and contribute towards the complexity of life on earth.
- Species interactions and relationships shape and influence the structure and composition of an ecosystem.
- Home ranges, area and habitat requirements vary greatly among species. However, the ability to move across the landscape, known as ecological connectivity, is crucial for an individual's survival and the long-term persistence of populations.
- Landscape elements, such as stepping-stones (small-sized patches of native vegetation or habitat) and terrestrial and riparian corridors (linear links of vegetation and waterways), help aid ecological connectivity.
- Transport infrastructure which does not effectively account for species needs and species ecology can cause or exacerbate habitat loss, fragmentation and degradation, contributing to species extinctions.

Contents

Tables

Figures

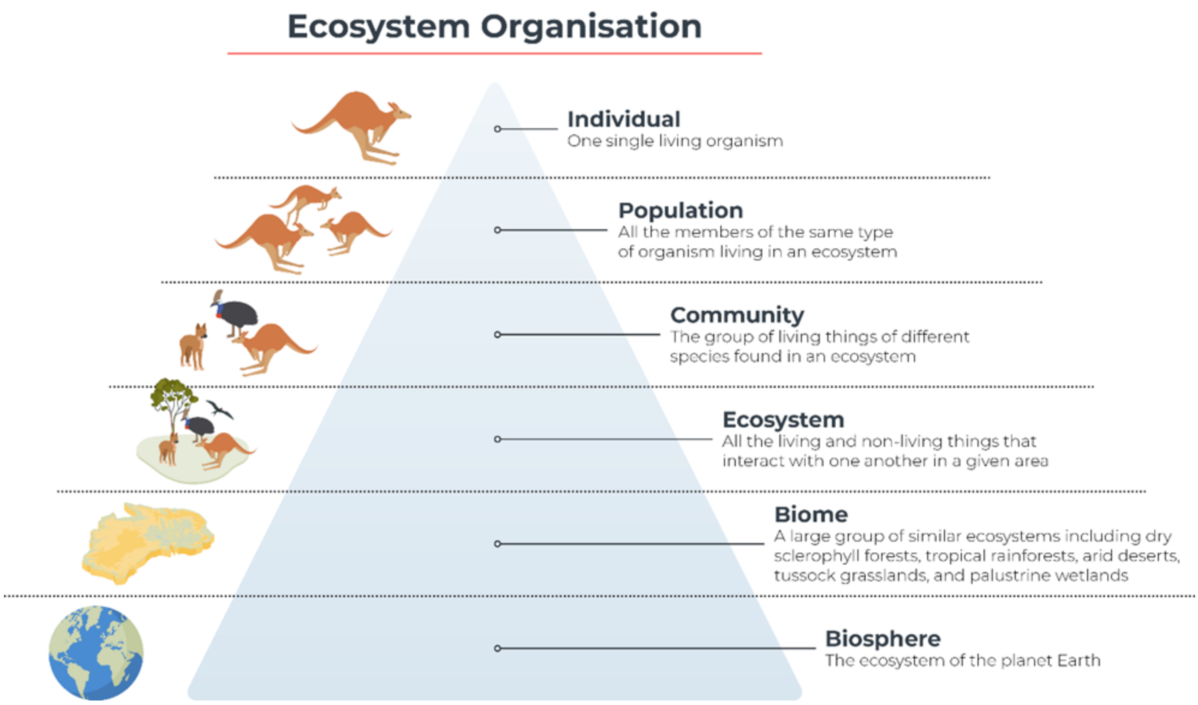
1 Introduction

1.1 What is ecology and biodiversity?

Ecology is the study of the interactions that determine the distribution and abundance of organisms[1]. These interactions involve both living factors such as animals, plants, and bacteria as well as non-living factors including water, soil and the atmosphere. The interactions and relationships among living and non-living factors make ecological systems complex as each component plays a unique role in maintaining a functioning ecosystem. Transportation ecology is focused on understanding how these interactions can be impacted or enhanced by transport infrastructure projects to maximise benefits to fauna.

Ecosystems are organised from individual organisms, populations and communities through to biomes and biospheres (Figure 1.1(a)).

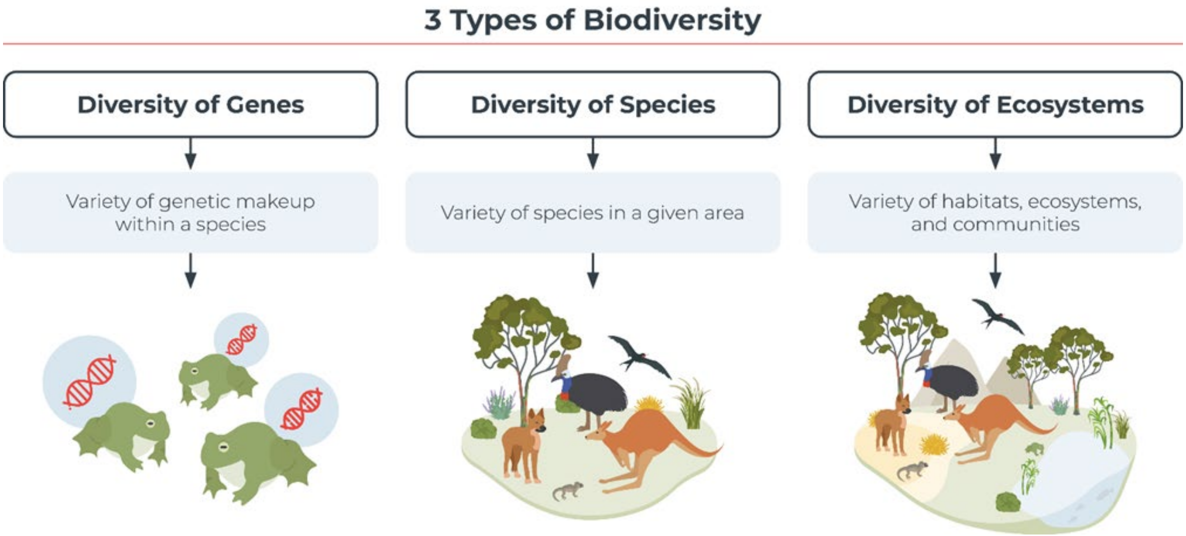
Figure 1.1(a) – Ecosystem organisation



Biodiversity, or 'biological diversity' is a term frequently used in ecology and is a measure of variation at the genetic, species, and ecosystem level (Figure 1.1(b)). All three components of biodiversity are necessary for the continued survival of life and contribute towards the complexity of life on earth as we know it.

[1] (Krebs 2009)

Figure 1.1(b) – Types of biodiversity



1.2 Species interactions and relationships

There are several types of interactions among species and these interactions shape and influence the structure and composition of an ecosystem in a myriad of ways (Table 1.2). Food chains and food webs showcase the complexity and importance of species interactions. They describe the transfer of energy from bacteria and fungal micro-organisms that decompose organic debris and plants which convert sunlight into food, through to herbivorous primary consumers and carnivorous secondary and tertiary consumers (Figure 1.2). Each organism is intrinsically linked and the removal of one of these 'links' could be detrimental to the overall health of an ecosystem. All species, even common species not currently threatened by extinction, may play important ecological roles or provide critical ecosystem services and such species should be protected. Careful consideration of all species in an area is necessary to fully understand the potential impacts of a transport project and ensure the impacts to all species is carefully managed.

Table 1.2 – Types of species interactions and relationships

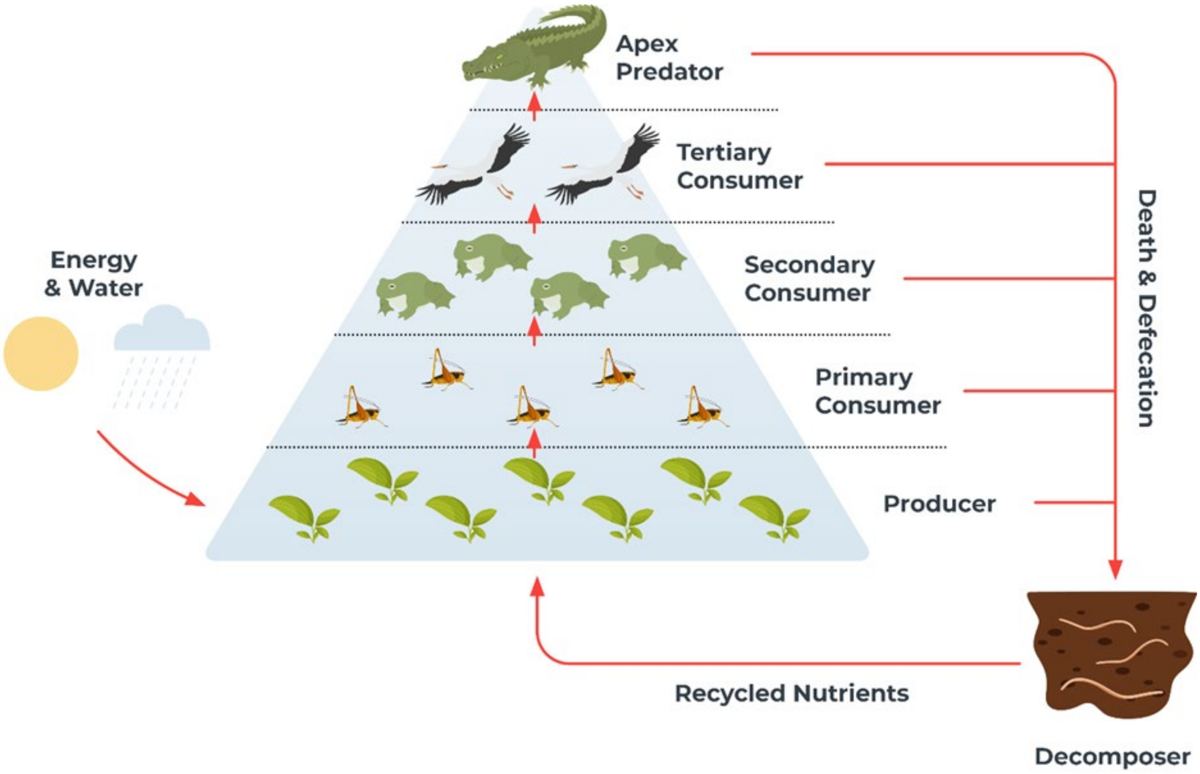
SPECIES INTERACTION	DEFINITION
Predator-prey relationship	In most cases, predators keep the size of prey populations below the number that an ecosystem can successfully support. However, when natural predators are removed from the ecosystem, prey species often increase in abundance, sometimes to the point where habitat is destroyed due to an over-abundance of herbivore prey. This relaxation in predation pressure can also result in increased competition and reduced diversity among prey species[2] as well as altering of ecosystem processes. For instance, in areas where the population of Tasmanian devil (*Sarcophilus harrisii*) has declined due to disease, feral cat abundance is higher, which in turn negatively impacts on small native mammal populations[3].

[2] (Primack 2010)
[3] (Cunningham et al. 2020)

SPECIES INTERACTION	DEFINITION
Symbiotic relationship	These relationships may be: • mutually beneficial for both species • commensal whereby one species benefits and the other derives neither benefit nor harm, or • parasitic which occurs when one species benefits to the detriment of the other. For instance, ectomycorrhizal fungi form symbiotic relationships with native trees such as eucalypts and sheoaks (*Allocasuarina spp*). The fungi aids the tree roots to gain access to nutrients and water, thereby contributing to the tree's resistance to drought. The northern bettong (*Bettongia tropica*), endemic to north-eastern Queensland, feeds on the fungi, playing an essential role in dispersing the spores and maintaining forest health[4], and is thus a keystone species[5].
Keystone species	A keystone species is one that is relatively rare in a community. They have the ability, through their behaviour or activities, to determine or influence community structure and have effects that are usually much larger than would be predicted for their relative abundance. The removal of a keystone species from any given environment, for example through loss of connectivity or wildlife-vehicle collision (WVC), can cause a large shift in the structure of a community and may even cause the extinction of other species (Krebs). The southern cassowary (*Casuarius casuarius*) is an example of a keystone species in Queensland because they have a role in maintaining rainforest plant diversity. The southern cassowary consumes fruit and seeds from over 200 species of plants which they disperse through their droppings. They are also the only long-distance dispersal agent for large-seeded fruits which are too big for other animals to eat and relocate. Southern cassowaries are also capable of eating fruits and seeds that are toxic to other species[6]. Without the cassowary, the rainforest in the Wet Tropics would gradually change and become less diverse. Therefore, protecting cassowary habitat is crucial not only for the threatened species itself but also to maintain the overall diversity and health of the rainforest ecosystem.

[4] (Nuske et al. 2018)
[5] (Krebs 2009)
[6] (Wet Tropics Management Authority undated)

Figure 1.2 – Simplified example of the food chain energy flow



2 Species habitat and fauna movement

This section defines habitat and fauna movement, both of which are important factors for species survival, noting that different species have different requirements.

2.1 What is habitat?

Plant and animal species exist in certain places and at certain times. The area in which a species is able to live, either temporarily or permanently, is called its habitat[7]. A species' habitat needs to be suitable, providing it with the adequate food, shelter, and resources it needs to survive and successfully reproduce. Therefore, the environmental elements that are suitable for one species may not be suitable for another, and so each species has their own unique habitat requirements.

For example, the greater glider (*Petauroides volans*) (Chapter 14) inhabits taller, moist eucalypt forests along the east coast of Australia in Queensland, New South Wales and Victoria. They prefer temperate forested areas with a diversity of eucalypt species, to cater for seasonal variation in their diet, and old trees with hollows to provide adequate shelter[8]. In contrast, the wallum froglet (*Crinia tinnula*) (Chapter 18) is found in the sandy coastal lowlands of South East Queensland and New South Wales where it prefers acidic wetland habitats within Melaleuca swamps, sedgeland, wet or dry heathland and wallum / woodland. However, the wallum froglet is also known to persist in disturbed habitats including roadsides, quarry sites and exotic pine plantations[9].

[7] (Krebs 2009)
[8] (Threatened Species Scientific Committee 2016)
[9] (Queensland Department of Environment and Science 2021)

Habitat quality can affect the distribution of a species by influencing the availability and quality of food. For example, the greater glider has a larger home range and travels further on a nightly basis when it inhabits less productive forests and more open woodlands compared to those living in higher quality habitat where resources are more abundant[10]. Poor habitat can also lead to decreased survival and will likely result in individuals raising fewer young compared to when habitat quality is high. However, many native species can successfully utilise highly degraded areas, such as the black-shouldered kite (*Elanus axillaris*) which hunts for rodents in farmland and along cleared road verges, and the threatened powerful owl (*Ninox strenua*) that can live in urban and suburban areas[11].

2.2 Distribution of wildlife

Terrestrial wildlife is patchily distributed across the landscape in response to temporal and spatial variation in the quality of habitat. The areas that support species may be in disjunct patches of habitat separated by cleared areas, or they can occur naturally in larger areas of varying quality habitat. These groupings of sub-populations of a species are often referred to as a metapopulation, with varying levels of movement and interaction among them[12]. There are other ways in which fauna are distributed and populations may function, however metapopulations are the most common. In addition, the metapopulation system is a very helpful way to conceptualise the impacts of transport infrastructure on terrestrial fauna and develop mitigation strategies.

There are two typical ways that terrestrial metapopulations are understood to function, namely:

- the island-mainland model, and
- the patchy population model.

As shown in Figure 2.2.

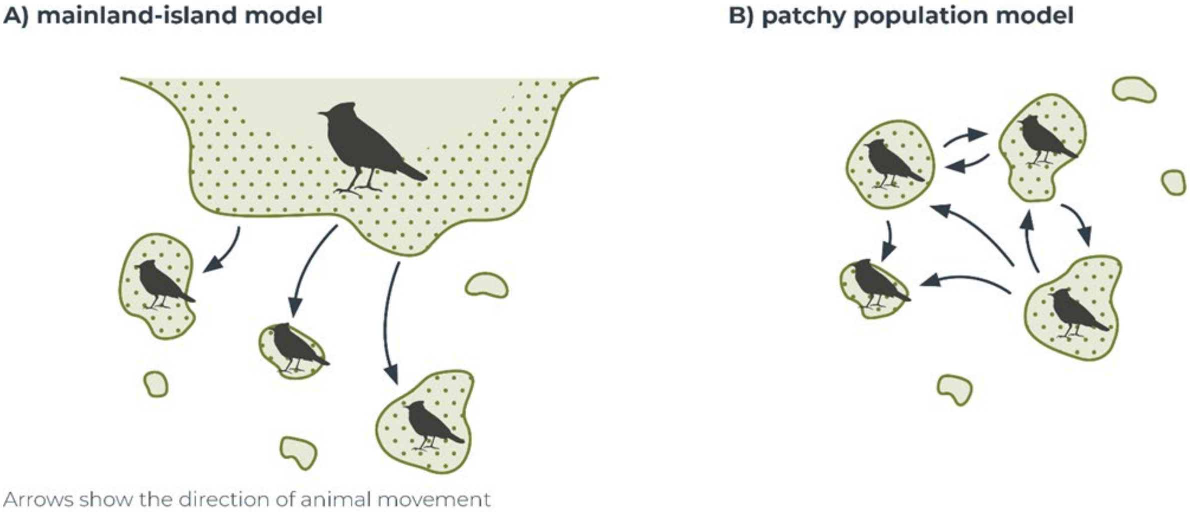
The island-mainland model is comprised of a large patch of habitat with a large population that provides individuals that disperse into and maintain populations in the adjacent smaller patches. Without the mainland providing ongoing recruits, the populations in the ‘islands’ would eventually go extinct. In the patchy population model, there are numerous patches and populations of varying size and animals move variously among many of the patches. In both situations, the survival of the overall metapopulation depends on the number and size of the sub-populations and the degree of movement among the patches.

The risk of extinction of a sub-population is higher for smaller and more isolated populations because they are more susceptible to variation in demographic factors (e.g. birth and death rates), genetic factors (e.g. inbreeding), environmental factors (e.g. rainfall, predation) and natural catastrophes (e.g. floods, wildfires). The risk of extinction is also higher for more specialised species compared to generalists.

The metapopulations with the highest likelihood of persistence are those that occupy larger patches of higher quality habitat and those with the highest levels of connectivity and movement amongst patches.

[10] (Eyre, and Smith et al 2007)
[11] (Pavey 1995)
[12] (Hanski and Simberloff 1997)

Figure 2.2 – The two ways that terrestrial metapopulations operate: (A) mainland-island model or (B) patchy population model. Arrows show the direction of animal movement



Source: Modified from Bennett (1999).

2.3 Fauna movement

Animals move for a diverse number of reasons, at different times of the year and at a range of spatial scales (Table 2.3). Transport infrastructure can disrupt the unique way that different species move around the landscape, impeding the movements that are essential for species survival.

Table 2.3 – Types of fauna movement that can be impacted by transport infrastructure

MOVEMENT TYPE / NEED	DEFINITION
Home Range	Individual animals move to find the resources they need to survive. This typically daily movement is often restricted to a specific area over which a species regularly travels in search of food, resources or mates and is called its home range. Most animals, excluding some nomadic species, have a home range that is relatively stable over time and often defended from other individuals. The size and location of a species home range may change over time depending on the species requirements. The degree of overlap in home ranges with adjacent individuals varies between sexes and among species. At times, animals may be restricted to one area within their home range, such as a nest site when breeding. A defended home range is termed a 'territory'. Species such as the Australian magpie (*Gymnorhina tibicen*) commonly defend a territory, especially during the breeding season. Home ranges and area requirements vary greatly among species, mainly because they are largely driven by the behaviour of the species, sex, available food resources, breeding, and competition. More information on the home ranges of different species is included in the species profiles (Chapters 9 to 21).
Sedentary	Species having stable home ranges or territories, where an individual occupies a relatively small area compared to the population distribution[13].

[13] (Mueller and Fangan 2008)

MOVEMENT TYPE / NEED	DEFINITION
Nomadism	Some species are nomadic meaning they have no fixed territories and no stable home range. An example of a nomadic species is the grey-headed flying-fox (*Pteropus poliocephalus*) which currently occurs along the east coast of Australia between Bundaberg in Queensland and Adelaide in South Australia. Recent studies have shown that they can forage for food approximately 50 kilometres from their camp[14] and travel a few hundred kilometres per night between camps and more than 2500 kilometres annually[15]. The movement of this species is also closely tied to food availability, with food shortages driving animals away from an area and food abundance acting as an attractant (Chapter 10).
Migration	Migration is the relatively long-distance movement of an entire population or species. To be counted as a true migration, the movement should be an annual or seasonal occurrence, or a major habitat change as part of the species lifecycle. Key drivers of migration include breeding, seasons of the year and the availability of food. The satin flycatcher (*Myiagra cyanoleuca*) is a small migratory bird that is widespread across eastern Australia. In autumn, this species migrates north to spend their winter in northern Australia and New Guinea before returning south in spring to breed and spend summer in south-eastern Australia[16]. Migration can also occur at much smaller scales, such as turtles moving out of ponds to upland areas to breed. Migration is also essential for the maintenance of fish populations. Movements by fish can be regular seasonal migrations or irregular movements in response to water flows and can be undertaken by some or most of the population (Chapter 19). The distance that fish move is not relevant to defining a migration event. For instance, movement of fish two metres from a nursery habitat to a juvenile habitat or hundreds of kilometres to a spawning ground are both examples of migration because they are essential for the completion of the life cycle. Movement to and from drought refugia is also considered migration because it is essential to sustain the natural flux and distribution of the population, and these movements can be intergenerational.
Dispersal	Dispersal is typically a once-in-a-lifetime event, such as offspring leaving their area of birth to establish a new territory. Unlike home ranges and migration, dispersal is often used as a generic term to describe species movements which can lead to gene flow, the transfer of genetic material from one population to another. The flow of genetic material is important to ensure populations maintain a healthy and diverse gene pool. This allows populations to avoid inbreeding and disease, and gives them the best possible chance of adapting to changing environmental conditions. Therefore, dispersal and the ability of species to move across the landscape is an important factor that influences population dynamics, facilitates genetic diversity, and regulates population size and density.

3 Connectivity in the landscape

The ability for fauna to move unimpeded within and among habitats is crucial for an individual's survival and the long-term persistence of the metapopulation. Connected habitats allow organisms to move and disperse freely, increasing access to resources and facilitating gene flow among populations. Ecological connectivity underpins the survival and evolutionary potential of ecosystems, communities and species, and has been described as the glue that holds populations together.

[14] (Richards and Hall 2012)
[15] (Welbergen et al 2020)
[16] (DAWE 2021)

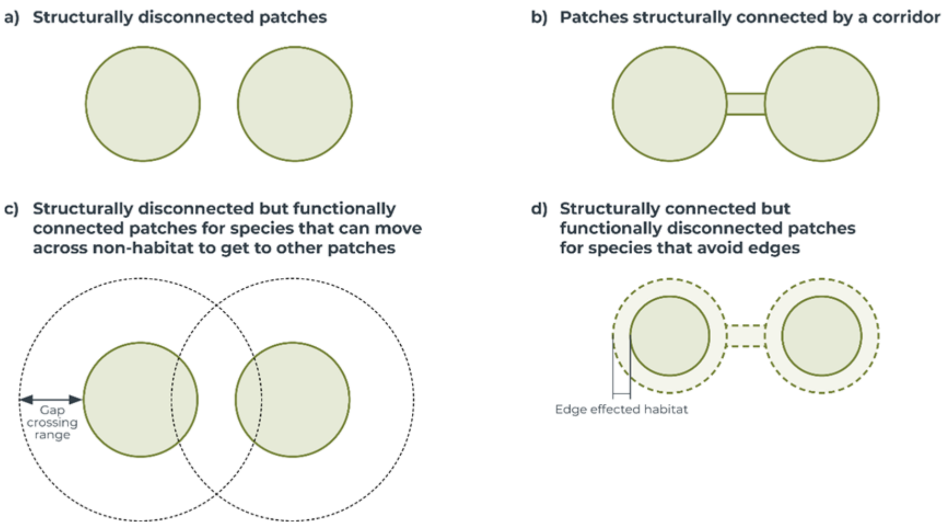
Transport infrastructure can act as barriers or filters to movement, disrupting connectivity and increasing the risk of extinction.

Ecological connectivity can be conceptualised as either structural or functional[17]. Structural connectivity describes the physical attributes of the landscape, such as the type and arrangement of habitat in an area without any regard to the species that may use those structural elements[18]. Structural connectivity is typically measured using a GIS and quantifies the number, type, size and arrangement (e.g. distance apart) of patches of habitat that may facilitate the movement of species.

Functional connectivity is a more nuanced or realistic view of ecological connectivity because it describes or quantifies the actual amount of movement that occurs in a landscape. It is usually assessed by tracking the movement of wildlife or measuring gene flow. Functional connectivity can also be predicted by quantifying the biological and behavioural attributes of a species relating to movement, such as the typical or maximum distances moved and the size of gaps of non-habitat that species are willing to cross. This information is then overlayed with maps of the structural connectivity in a landscape, and areas that are connected for a specific species, or group of species, are identified.

The concept of structural and functional connectivity are further described in Figure 3, a diagram which shows two disconnected habitat patches (a) and two patches that are structurally connected by a corridor (b). A species that can move beyond the boundaries of patches and into the non-suitable environment might perceive the disconnected neighbouring patches as functionally connected (as marked by the dashed pale green area) (c). Yet a core-habitat species, which avoids habitat edges, may not move into the corridor (d). Hence patches that are structurally connected may remain functionally disconnected for such species.

Figure 3 – Functional and structural connectivity



[17] (LaPoint et al. 2015)
[18] (Watson et al. 2017, and Hitly et al. 2020)

3.1 Types of connectivity

The following are examples of landscape elements that provide ecological connectivity:

- **Stepping-stones:** Typically smaller-sized patches of native vegetation or habitat, such as single trees, small wetlands, host shrubs, scattered rocks, etc. Stepping-stones allow for some connectivity for certain species by providing resources and refuge that assist them with moving through the landscape between larger patches of habitat[19] (Figure 3.1).
- **Terrestrial corridors:** Typically a linear strip of vegetation that provides a continuous (or near continuous) pathway between two larger areas of habitat (Figure 3.1). They can occur at varying scales, from several kilometres to just a few meters wide.
- **Wetland and riparian corridors:** Linear links of existing wetlands, waterways and drainage lines with or without native vegetation.

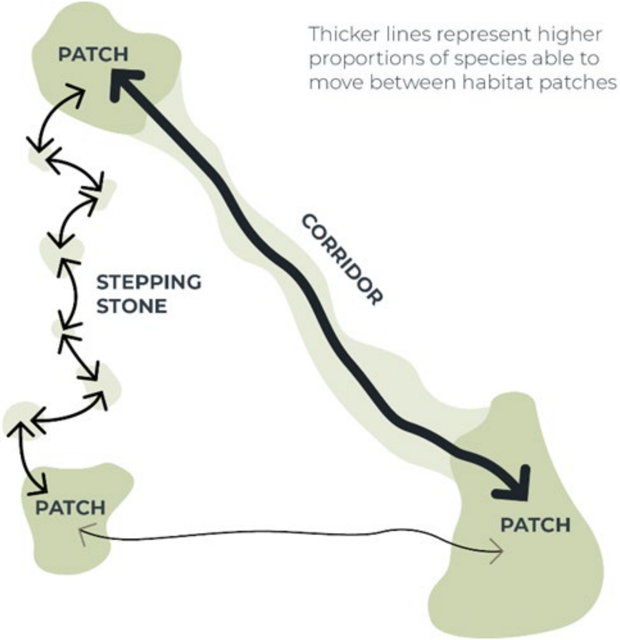
Different species have different movement needs and require different landscape elements to move around. While small reptiles may use narrow corridors, larger animals (e.g. kangaroos) require larger areas for daily movement, such as cleared farmland for foraging and patches of trees for shelter. In contrast, stepping-stones may be utilised by highly mobile species such as lorikeets and flying-foxes, but not by small reptiles that won't cross the cleared areas between the patches of habitat. Different species have different gap crossing abilities that vary depending on movement abilities and habitat requirements. In addition, there may be minimum patch-size thresholds that must be met in order for patches to support functional connectivity.

It is also important to understand that landscape elements which provide functional connectivity can also provide habitat. For example, remnant vegetation along roadsides and waterways can provide effective linkages, but there are also many species of plants and animals that live permanently in those areas. In fact, road corridors and waterway corridors are critically important habitat for a large diversity of birds, bats, arboreal mammals and invertebrates in otherwise highly cleared landscapes[20]. However, the habitat retained within a corridor or small patch may not be suitable for all wildlife species. For example, a riparian corridor supporting rainforest and dense understorey vegetation is unlikely to support the movement of koalas (*Phascolarctos cinereus*), which prefer a corridor of readily accessible trees. Conversely, sparsely vegetated woodland corridors would not support swamp wallaby (*Wallabia bicolor*), which prefers thick undergrowth.

---

[19] (Bennett 2003)
[20] (Bennett 1988, 1990, Hobbs 1993, Major et al. 1999, van der Ree and Bennett 2001, 2003)

Figure 3.1 – Landscape elements that can provide ecological connectivity



4 Extinction and vulnerability to extinction

Many species are threatened due to habitat loss, habitat fragmentation, and habitat degradation. In Australia, the rate of extinction is currently about four species per decade, and is predicted to increase in coming decades due to ongoing loss, fragmentation and degradation of habitat and global climate change[21].

A species or community is considered threatened when it is likely to become endangered and at risk of extinction within all or much of its range. Extinction refers to the dying out or extermination of a species. The species most vulnerable to extinction include those that (i) occupy a narrow geographical range, (ii) have only one or a few populations, (iii) have a small population, (iv) are experiencing a declining population, and (v) those that are hunted or harvested by people[22].

When a population of a given species is small, it is more susceptible to extinction because it lacks the genetic diversity required to respond to changing conditions, such as climate change or new diseases. The number of individuals necessary to ensure the long-term survival of a species is called the minimum viable population. Unfortunately, many species, especially those that are threatened, have population sizes smaller than the recommended minimum[23].

In Australia, threatened species are assigned a conservation status under relevant state and federal legislation (i.e. vulnerable, endangered, critically endangered) which reflects its extinction risk (Chapter 5). Nationally, more than 1700 species and ecological communities are known to be threatened and at risk of extinction, and are listed under the federal *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act). In Queensland, over 1020 species of animals and plants are listed as threatened under the Queensland *Nature Conservation Act* 1992, almost half of

[21] (Legge et al. 2023)
[22] (Primack 2010)
[23] (Primack 2010)

which are also listed under the EPBC Act. Such lists are constantly being updated, usually to include more species and to alter the status of those already listed.

The loss of a population from a local area is called ‘extirpation’, and the complete loss of a species from all of its habitat in the wild is ‘extinction’. It is important to recognise that a species does not go extinct ‘overnight’, but rather it occurs when many local populations are extirpated and recolonisation is unable to occur.

4.1 Habitat loss

Habitat loss is the process by which a natural habitat is altered to the point where it is no longer capable of supporting the native species that naturally occur in the area. Habitat loss is commonly caused by a range of human activities including agriculture, forestry, mining and urbanisation. The result of habitat loss is a reduction in the amount of habitat available for a species to live in.

Habitat loss may cause the direct mortality of wildlife inhabiting the areas being cleared. Alternatively, habitat loss may force wildlife to disperse into surrounding areas which may already be fully occupied by other individuals or species, may contain less suitable habitat with fewer resources or may contain a higher number of predators.

In addition, the effects of climate change are resulting in the gradual and continual loss of ecosystems across the globe. A clear example of this is the world heritage listed Wet Tropics of Queensland, where climate change is listed as the most significant threat to the area[24]. The cooler mountain-top habitats of the Wet Tropics are particularly vulnerable to the impacts of rising temperatures, as are the species that inhabit those areas. For example, some endemic possums are already showing signs of rapidly declining numbers[25]. The amount of habitat available to these species will only decrease as temperatures continue to rise.

4.2 Habitat degradation

Habitat degradation is the suite of processes that lower the quality of habitat in an area. A key element of habitat degradation is that the change or damage is not usually immediately obvious. Instead, changes to the habitat occur slowly and incrementally, meaning the damage is less obvious compared to the physical loss or fragmentation of habitat. Habitat degradation can be caused by human activities such as forestry, agriculture, and urbanisation and/or through natural processes such as drought, wildfire, and floods.

A subtle form of habitat degradation is environmental pollution (Chapter 4). Examples of pollution include pesticides, herbicides, fertilisers, industrial chemicals and waste, emissions and sediment deposits. Air, water and soil pollution are prevalent across the globe, but are not always visually apparent. Therefore, the effects of pollution can often go unnoticed for a period, whilst continually contributing to the ongoing decline of habitat quality.

Noise pollution also contributes to habitat degradation for certain species, especially those that communicate vocally like birds and frogs (Chapter 4). Transport infrastructure generates noise during construction and operation which makes some habitats less appealing (Case Study 4.1). Light pollution also contributes to habitat degradation and is described in Chapter 4.

---

[24] (Wet Tropics Management Authority 2021)
[25] (Wet Tropics Management Authority 2021)

4.3 Habitat fragmentation

Habitat fragmentation refers to breaking up patches of habitat into multiple smaller patches that become divided and are separated by barriers to movement. Habitat fragmentation reduces ecological connectivity along a continuum, ranging from a complete barrier for some species through to a filter that reduces movement of other species or individuals. For example, a four-lane highway without trees in the centre median was almost a complete barrier to the movement of squirrel gliders (*Petaurus norfolcensis*), while narrower two-lane roads permitted their movement[26]. Barriers reduce the movement of individuals across the landscape which can lead to genetic isolation and a reduction in genetic diversity, subsequently increasing the risk of extinction.

In addition, habitat fragmentation creates edges between different landscape elements and results in edge effects. This describes a phenomenon where edges of fragmented habitat patches experience altered environmental and biological conditions (i.e. light, temperature, wind) compared to areas further inside the patch. As a result of these micro-climatic changes, habitat edges are often hostile to many native species, especially those which typically occupy interior habitats. Therefore, edges, including roadsides and railways, may be dominated by generalist species with excellent dispersal abilities and those capable of exploiting disturbed habitats, such as introduced predators and opportunistic native species (Case study 9.2). In this way, edge effects can exacerbate the impact of habitat fragmentation by reducing the functional size of habitat patches available for some species (Figure 4.3(a)).

A major cause of habitat fragmentation is the construction and operation of linear infrastructure, such as transport infrastructure, powerlines, and pipelines. Networks of linear infrastructure are conspicuous across most landscapes around the world (Figure 4.3(b)), and the ecological consequences are increasing as existing infrastructure is being widened and lengthened and new infrastructure is being built. While linear networks are typically narrow in nature and may only remove a minimal area of habitat, their construction can result in a substantial reduction of available habitat or significant barriers to fauna movement for some species. The cumulative effect of degraded habitat along the edges of linear infrastructure can result in significant impacts to some species of wildlife.

[26] (van der Ree et al. 2010)

Figure 4.3(a) – The process of habitat fragmentation and the compounding effect of edges (100 m wide) on 'interior' or edge-sensitive species.

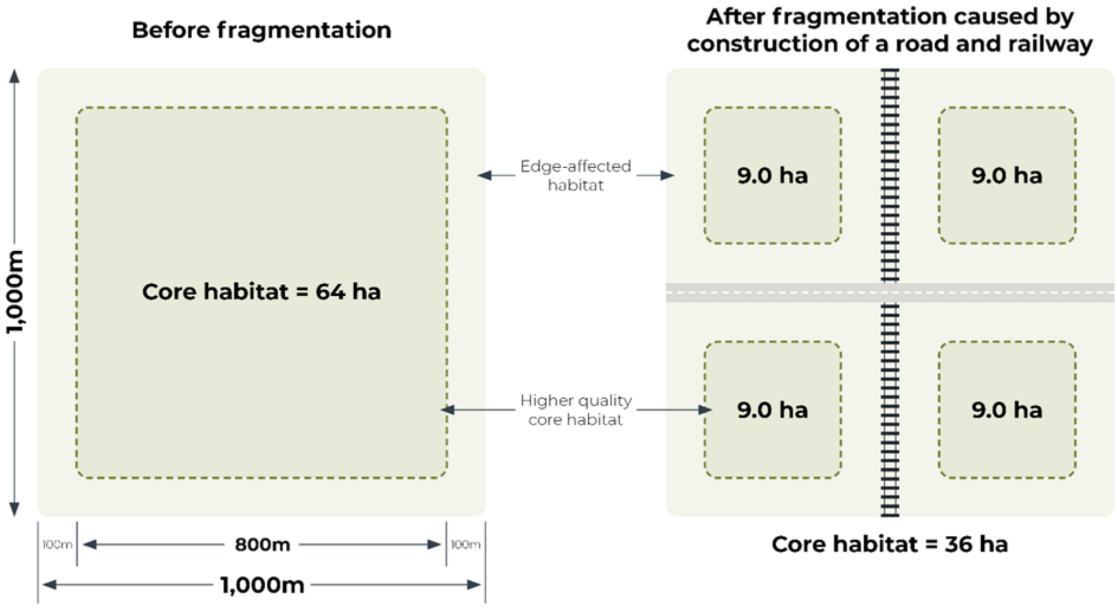


Figure 4.3(b) – Habitat loss and fragmentation due to transport infrastructure (Aerial view looking west along Smith Street Connection Road)

Source: Transport and Main Roads image library © The State of Queensland

References

Bennett, A. F. 1988. *Roadside vegetation: a habitat for mammals at Naringal, south-western Victoria*. The Victorian Naturalist 105:106-113.

Bennett, A. F. 1990. *Habitat corridors and the conservation of small mammals in a fragmented forest environment*. Landscape Ecology 4:109-122.

Bennett, A. F. 1999. *Linkages in the Landscape. The Role of Corridors and Connectivity in Wildlife Conservation*. IUCN, Gland, Switzerland and Cambridge.

Bennett, A. F. 2003. *Linkages in the Landscape: The role of corridors and Connectivity in Wildlife Conservation*. IUCN, Cambridge.

Cunningham, C. X., C. N. Johnson, and M. E. Jones. 2020. *A native apex predator limits an invasive mesopredator and protects native prey: Tasmanian devils protecting bandicoots from cats*. Ecology Letters 23:711-721.

DAWE. 2021. Myiagra cyanoleuca in Species Profile and Threats Database. Accessed 2021, http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=612.

Eyre, T. J. 2004. *Distribution and conservation status of the possums and gliders of southern Queensland. In The Biology of Australian Possums and Gliders*. Surrey Beatty & Sons, Chipping Norton.

Hanski, I., and D. Simberloff. 1997. The metapopulation approach. Pages 5-26. in I. Hanski and M. Gilpin, editors. *Metapopulation Biology: Ecology, Genetics and Evolution*. Academic Press, San Diego, CA.

Hilty, J. A., G. L. Worboys, A. Keeley, S. Woodley, B. Lausche, H. Locke, M. Carr, I. Pulsford, J. Pittock, J. W. White, D. M. Theobald, J. Levine, M. Reuling, J. E. M. Watson, R. J. Ament, and G. M. Tabor. 2020. *Guidelines for conserving connectivity through ecological networks and corridors*. IUCN, Gland, Switzerland.

Hobbs, R. J. 1993. *Effects of landscape fragmentation on ecosystem processes in the Western Australian wheatbelt*. Biological Conservation 64:193-201.

Krebs, C. 2009. *Ecology: The Experimental Analysis of Distribution and Abundance*. Sixth edition. Pearson.

LaPoint, S., N. Balkenhol, J. Hale, J. Sadler, and R. van der Ree. 2015. *Ecological connectivity research in urban areas*. Functional Ecology 29:868-878.

Legge, S., L. Rumpff, S. T. Garnett, and W. J.C.Z. 2023. *Loss of terrestrial biodiversity in Australia: Magnitude, causation, and response*. Science 381:622-631.

Major, R. E., D. Smith, G. Cassis, M. Gray, and D. J. Colgan. 1999. *Are roadside strips important reservoirs of invertebrate diversity? A comparison of the ant and beetle faunas of roadside strips and large remnant woodlands*. Australian Journal Of Zoology 47:611 - 624.

Mueller, T., and W. Fagan. 2008. *Search and navigation in dynamic environments - From individual behaviors to population distributions*. Oikos 117:654-664.

Nuske, S. J., S. Anslan, L. Tedersoo, M. T. L. Bonner, B. C. Congdon, and S. E. Abell. 2018. *The endangered northern bettong, Bettongia tropica, performs a unique and potentially irreplaceable dispersal function for ectomycorrhizal truffle fungi*. Molecular Ecology 27:4960-4971.

Pavey, C. R. 1995. *Food of the powerful owl Ninox strenua in suburban Brisbane, Queensland*. Emu 95:231-232.

Primack, R. B. 2010. *Essentials of Conservation Biology*.

Queensland Department of Environment and Science. 2021. Species profile — *Crinia tinnula* (wallum froglet). Accessed 2021, https://apps.des.qld.gov.au/species-search/details/?id=686.

Richards, G., and L. Hall. 2012. *Bats. Working the night shift*. CSIRO Publishing, Collingwood, Australia.

Smith, G. C., M. Mathieson, and L. Hogan. 2007. *Home range and habitat use of a low-density population of Greater Glider, Petauroides volans (Pseudocheiridae: Marsupialia), in a hollow-limiting environment*. Wildlife Research 34:472-483.

Threatened Species Scientific Committee. 2016. *Conservation Advice Petauroides volans greater glider*.in D. o. Environment, editor., Canberra.

van der Ree, R., and A. F. Bennett. 2001. *Woodland remnants along roadsides - a reflection of pre-European structure in temperate woodlands?* Ecological Management and Restoration 2:226-228.

van der Ree, R., and A. F. Bennett. 2003. *Home range of the Squirrel Glider Petaurus norfolcensis in a network of linear habitats*. Journal of Zoology (London) 259:327-336.

van der Ree, R., S. Cesarini, P. Sunnucks, J. L. Moore, and A. C. Taylor. 2010. *Large gaps in canopy reduce road crossing by a gliding mammal.* Ecology and Society 15:35.

Watson, D. M., V. A. J. Doerr, S. C. Banks, D. A. Driscoll, R. van der Ree, E. D. Doerr, and P. Sunnucks. 2017. *Monitoring ecological consequences of efforts to restore landscape-scale connectivity*. Biological Conservation 206:201-209.

Welbergen, J. A., J. Meade, H. E. Field, D. Edson, L. McMichael, L. P. Shoo, J. Praszczalek, C. Smith, and J. M. Martin. 2020. *Extreme mobility of the world's largest flying mammals creates key challenges for management and conservation*. BMC Biology 18:101.

Wet Tropics Management Authority. 2021. *Wet Tropics Management Authority Annual Report 2020–2021*.

Wet Tropics Management Authority. undated. *Cassowaries*. Accessed 2021, https://www.wettropics.gov.au/cassowaries.