3 POPULATION ECOLOGY AND ANIMAL BEHAVIOUR

The ecology and population dynamics of fauna species often determines the level of impact these species incur from the construction and operation of roads. The populations likely to be impacted by the road need to be identified and examined so that appropriate amelioration measures can be implemented to reduce impacts.

Determining the distribution, abundance and likely impacts on the population as a result of a road or other transport infrastructure is difficult. General theories relating to the isolation and fragmentation of populations and habitats (areas in which fauna live) have been developed largely over the last 20 to 30 years. These theories provide a ‘blanket view’ of likely impacts from habitat fragmentation and population isolation, and are not species specific. Research into these theories and locations that have suffered significant habitat fragmentation have found that individuals and populations react differently to isolation and fragmentation. Some species are impacted to a higher degree than other species. This is largely related to the behavioural characteristics of the species and its relationship with other species within the environment.

This chapter provides a general description of the theoretical background regarding habitat fragmentation and isolation and the impact this has on fauna species. It also includes a basic outline of the behavioural characteristics of species so the reader may gain a better understanding of the potential impacts resulting from the construction and operation of roads.

3.1 THEORETICAL ISSUES

3.1.1 Habitat fragmentation

Background

Habitat fragmentation is generally considered to be a reduction in the continuity of a habitat through disturbance or loss. This disturbance or loss may be the result of either natural or unnatural disturbances. Natural disturbance or loss of habitat may be due to factors such as changes in climatic conditions including flood or drought, fire, and competition or predation by other species. Unnatural disturbance or loss (created by people) is seen today as likely to have a more significant long-term impact upon species and populations. Unnatural habitat fragmentation may be caused by activities such as the clearing of land for housing, agriculture, or construction of transport corridors through vegetated areas (see Figure 3.1 for an example of habitat fragmentation by linear infrastructure corridors). Another example of unnatural fragmentation is the wheat belt in Western Australia. Research in Kellerberrin has found that habitat loss and fragmentation is the prime cause of fauna species losses in this area (Saunders et al. 1993).

Figure 3.1 An aerial depiction of linear infrastructure corridors severing native habitat areas (Coomera area, south-east Queensland)

Source of Image: Department of Natural Resources

Although reduction in habitat size is a major factor determining the impact of habitat fragmentation (ie. the disturbance footprint), the disturbance of adjacent vegetation often increases the impact felt by local fauna species (ie. by means of edge effects). For example, where a network of vehicle access tracks pass through an area of open eucalypt forest, the tracks themselves may cause only a limited amount of habitat loss. However, weeds such as Lantana (*Lantana camara*) often recolonise and dominate the areas adjacent to each track, and feral predators penetrate further into bushland by using the newly constructed tracks. The results are considerable edge effects, discussed further in Section 5.3.1.

The primary impacts upon fauna populations from habitat fragmentation are a reduction in suitable habitat size and the increased chance of isolation from other populations of the same species. With particular reference to forest bird populations, several studies have demonstrated that wildlife diversity and species richness (ie. a high number of different species occupying one area) are related to fragment size. That is, a reduction in habitat size results in a decrease in species diversity and richness (De Santo and Smith 1993).

A reduction in the size of suitable habitat for a species often means that individuals are forced to hunt or forage in areas that increase the chance of death. This includes crossing cleared lands, roads or entering other individuals territories including that of predators. The increased chance of mortality, and thus the reduction of individuals in the population, may not significantly impact large populations. Smaller populations however, with less individuals, are likely to be placed at risk of local extinction (Petterson 1985).

Small populations are more vulnerable to decline and extinction than large populations for two main reasons. First, both small and large populations are subject to ongoing disturbance processes of both unnatural and natural origin. A large population with a wide distribution and large gene pool is more likely to survive such processes and possess an ability to adapt to new conditions (see Section 3.1.3). Secondly, Soule (1987) and Simberloff (1995) demonstrated that small populations are more sensitive than large populations to chance variations in population parameters, genetic processes, environmental processes and natural catastrophes. Small populations are more likely to suffer significant mortality rates during any chance variation of existing conditions, leading to reduced opportunities for successful reproduction.

Management practices to reduce impacts

The fragmentation of habitats is often unavoidable as the demand for land and infrastructure increases. Many areas have already become fragmented and have seen a decline in native species.

Management practices to reduce impacts include the avoidance of large habitats, retaining as much native plant diversity in adjacent habitats if avoidance is not possible, and providing vegetated corridors between smaller habitat fragments (ie. wildlife corridors). Wildlife corridors and their role in conservation of fauna species are discussed further in Chapter 4.

Concluding remarks

Habitat fragmentation has impacts on many animal populations, but especially populations with small or low numbers of individuals. Exceptions tend to be opportunistic species that are able to adapt to disturbed environments and introduced predators that thrive in fragmented habitats. Consequently, it is the species presently at risk of extinction (i.e. scheduled or threatened species) that are the most affected by habitat fragmentation. However, with continued fragmentation other more common species may also become locally threatened.

3.1.2 Island biogeography

Background

The island biogeography theory was first established by MacArthur and Wilson (1967) in their study of marine islands. They investigated the relationship of island size and isolation, and the population dynamics of the species present. The theory describes a dynamic equilibrium between extinction and recolonisation rates, which determines the number of species on an island (Saunders and Ingram 1987). The major factors that influence the rate of recolonisation and extinction are the distance between the island and the mainland source (i.e. a measure of isolation), and the total area of the island (Bennet 1990).

Island biogeography has subsequently been applied to the study of habitat fragmentation as both concepts describe a small habitat that is fragmented or isolated either by natural or unnatural processes. The habitat then becomes a small island of remnant habitat in the sea of disturbed landscapes. The level of isolation encountered by organisms in a fragmented environment will vary according to the size of the fragment and the mobility of the organism. In the majority of fragmented environments produced through unnatural causes, the so called ‘sea’ is a hostile environment which can be perilous for the movement of organisms, particularly vertebrate fauna.

Natural ‘islands’ may be the result of a fire or flood that misses a particular habitat patch. Alternatively, natural islands may simply be the result of variations in natural landforms. For example, a small patch of rainforest vegetation that surrounds a natural spring in otherwise dry open forest, or a stand of palm trees in a rainforest or open forest (see Figure 3.2). Unnatural habitat islands are often the result of vegetation clearing such as in the wheat belt of Western Australia or in any urban environment around the world. The construction of linear infrastructure corridors including pipelines, roads or power-lines often bisect habitats and creates vegetated 'islands'.

Figure 3.2 An 'island' of palm trees within eucalypt forest (Bruce Highway, near Nambour turnoff, south-east Queensland)

Management practices to reduce impacts

The effects of island biogeography are difficult to measure or predict, but they can have profound effects on populations. Therefore, any measures that would reduce isolation and increase the rate of movement would have a significant conservation benefit. Accordingly, vegetated patches of remnant forests referred to as stepping stones, or preferably continuous corridors of habitat that link isolated patches, are recommended in design strategies for nature conservation. Further, the presence of corridors to facilitate movement of animals could supplement declining populations before they reach extinction. This was termed the 'rescue effect' by Brown and Kodric-Brown (1977).

Concluding remarks

The island biogeography theory predicts that wildlife corridors will increase the conservation status of isolated habitat by facilitating a higher level of species movement and hence richness. This is achieved by increasing the rate of movement of species and supplementing declining populations and reducing the rate of species extinction. The ability and opportunity of individual animals to move between isolated populations is crucial. For example, when movement between populations is reduced, local extinctions will be high and recolonisation rates will be low. If this occurs regularly, regional extinctions will result (Fahrig and Merriam 1985).

3.1.3 Genetic isolation

Background

The fragmentation of habitats may result in the genetic isolation of a fauna species. This occurs where the habitat areas become isolated and species are not able to move between populations. The lack of movement of individuals between populations results in a decrease of genetic material entering the isolated population. Individuals within this isolated population must mate with relatives of the same species (inbreeding), or with other species or subspecies within the same environment (outbreeding). Inbreeding between relatives can result in fewer offspring, or offspring that are weak or sterile and may also result in the accumulation of harmful recessive genes. Offspring produced through outbreeding are often weak or sterile and may have incompatible chromosomes and enzymes making their long-term survival less likely (Primack 1993).

The most significant impact on fauna populations from genetic isolation is an inability to adapt to changing environmental conditions (changing conditions happen naturally, though human intervention may quicken the process). A population containing individuals with limited genetic variability are all adapted to one set of environmental conditions, and are generally unable to become acclimatised or adapted to new conditions. Environmental variability (the natural change in environmental conditions) and natural catastrophes can change environmental conditions very quickly. With a population composed of individuals with similar genetic characteristics (in effect almost 'clone' like), an environmental variation which will weaken and kill one individual is more than likely to lead to the death of all individuals in the population.

The genetic variation within any normal population is described by the bell-shaped curve (Figure 3.3). This figure illustrates the ability of a population to adapt to a new set of environmental conditions. Some individuals will be ideally suited to the present environmental conditions, whereas others will not be suited (or adapted) to these conditions and may not survive in the present environment. However, should environmental conditions change, through a drought or climate change for example, individuals that were not ideally suited to the previous environmental conditions may thrive under the new conditions and vice-versa.

Small populations are more susceptible to environmental change as more 'suitably adapted' individuals are likely to be present in populations with higher numbers than those with only limited numbers.

Management practices to reduce impacts

To reduce the impacts of genetic isolation on a population, genetic exchange within populations needs to occur. This occurs naturally through random breeding within the population, which is facilitated by the regular movement of fauna. However, in artificial environments, habitat fragmentation and island biogeographical effects restrict random breeding. Therefore, as the retention of large intact areas is not always possible, it is imperative that vegetated corridors are retained. By doing so, the isolation of habitats will be reduced, and therefore the chance of genetic isolation will be decreased.

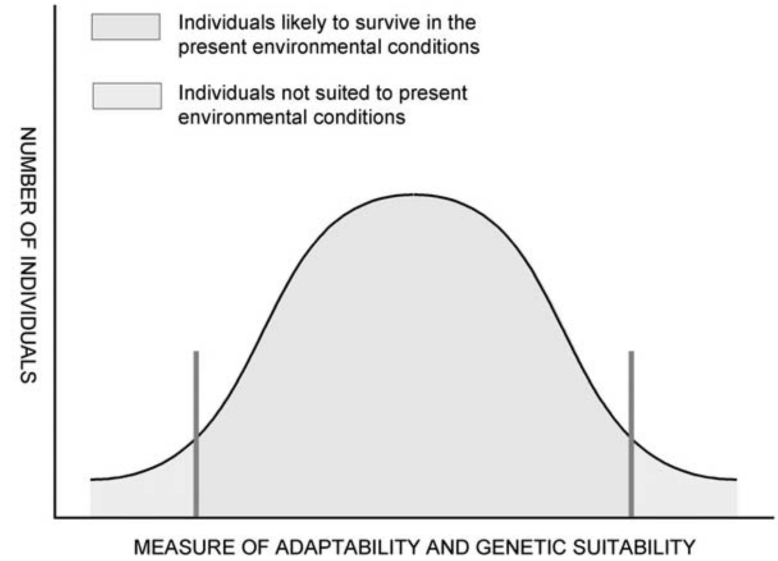

Figure 3.3 The bell shaped curve describing genetic variation within a population

Concluding remarks

The discussion above highlights the major concern of wildlife managers and the reason why conserving large habitats, and therefore large populations, is critical to species conservation. Namely, the retention of genetic variability provides species with a buffer to survive extreme changes in environmental conditions.

3.2 BEHAVIOUR OF ANIMAL SPECIES

The role of roads acting as barriers to movement, migration and dispersal of terrestrial vertebrate fauna has been documented both in Australia (see Bennett 1991, 1992 for review) and overseas (see Kozakiewicz 1993 for review). The most obvious barriers to faunal movement are roads with wide multiple carriageways. However, the role of small secondary roads as barriers to movement are also of importance, particularly as localised movement between habitats is vital to many animals for seasonal feeding and breeding, as well as for the dispersal of young.

3.2.1 Movement, migration and dispersal

To most people the terms 'movement', 'migration' and 'dispersal' appear to represent the same or similar processes. However, to an ecologist they have quite different definitions. The definitions are as follows:

- 'Movement' is associated with individuals of a species and relates to regular travel within the species home range. Home ranges may be defined as areas that an individual regularly covers for feeding, nesting and breeding requirements (Burt 1943).
- 'Migration' is associated with an entire population or species and is generally of a seasonal nature. For example, the Red-bellied Pitta (*Pitta erythrogaster*) is only a summer migrant to northern Queensland from Papua New Guinea.
- 'Dispersal' on the other hand, is often used as a genetical term that relates to the geographical radiation of a species, where each member of the species has common mechanisms to aid geographical radiation. For example, tumble weeds found throughout America are all rounded in shape to aid travel and the plants themselves have their seed capsules located on branches toward the centre of the plant so as to prevent the seeds from all dislodging too early or all in the same area.

The following section discusses the area requirements of fauna and summarises how roads impact upon different fauna species as a result of their behaviour.

3.2.2 Area requirements

The area requirement of animals varies greatly among species. For example, the False Water Rat (*Xeromys myoides*) (see Figure 3.4) has a foraging range within mangroves of around 0.6 ha (Van Dyck 1995). Large predators such the Powerful Owl (*Ninox strenua*) (see Figure 3.5) commonly patrol home ranges of up to or in excess of 1,000 ha (Seebeck 1976). Area requirements are generally dependent on factors such as the behaviour of the species, available food resources, breeding, and competition between the same species and other species.

Most animals have a home range. Excursions beyond this range are rare or of a dispersal or migratory nature (Bennett 1990). In a given habitat, the size of a home range varies little between individuals of the same 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', and species such as the Australian Magpie (*Gymnorhina tibicen*) commonly defend a territory.

The variability in area requirements among species means that the retention of suitable corridor widths and/or suitable habitats will also vary considerably. In general, where roads bisect areas of significant habitat, the road should be as narrow as possible, and edges should be replanted with native species indicative of the surrounding habitats. In contrast, vegetated corridors that link core habitats should be as wide as possible.

Figure 3.4 False Water Rat

Source: Queensland Museum

Figure 3.5 Powerful Owl

Source: Queensland Museum

3.2.3 Population dynamics

The study of population dynamics is concerned with the changes that occur in the quality and quantity of individuals within a biological population through time (Kitching 1983). The number of organisms within a population can change in any time period through additions from births or immigration. Similarly, reduction in numbers can occur by the two complementary processes, death and emigration.

These processes have been the subject of many computer simulated population dynamics models. However, the common limitations to each of these models is that they assume that the organisms operate in a closed system (i.e. there are no influences acting on the population other than those of the population itself). This does not however, reflect natural situations accurately. Researchers are now attempting to simulate 'more realistic' models to account for the many variables that were originally modelled as constant. These variables include the rate of births and deaths, the age structure of the population and environmental variables to which the organism is exposed in the natural environment (e.g. fluctuations in temperature and rainfall, competition and predation).

In attempts to synthesise the way in which species with low population numbers may avoid extinction, research has targeted the concept of a 'minimum viable population' (Gilpin and Soule 1986). This type of model is still in its infancy with regard to bird and mammal populations and field investigations are required to confirm the findings of the simulated model. The majority of these models target species with exceptionally high reproductive rates and generation times, such as insect species (e.g. drosophilid flies), so that the models can be tested in laboratories relatively quickly. Therefore, principles that may be applied to all wildlife as a result of simulated models have not yet become available.

3.2.4 Summary of animal behaviour and how it relates to roads

The impact of road construction and operation on fauna will be influenced by the behavioural habits of the animal. The construction of roads through habitat areas can isolate populations or individuals, and has the potential to cause genetic isolation. The severing of migratory paths or home ranges may lead to numerous road deaths, as animals follow instinctive routes.

Management practices implemented during the planning, design, construction and operational phases may alleviate some of the impacts caused by roads. The key principles likely to have a positive influence on fauna populations are as follows:

- Avoid ‘core’ habitat areas wherever possible (ie. undisturbed habitats).
- Avoid bisecting large habitat areas wherever possible.
- Minimise clearing.
- Retain or establish vegetated corridors.
- Include appropriate structures that assist the safe movement of fauna across the road (see Chapter 6 for details).