Knox Wildlife Conservation and Connectivity Report

November 2017

Prepared for
Knox City Council

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Executive Summary

The movement of wildlife among habitats is critical for the conservation of biodiversity and the healthy functioning of ecosystems. These movements occur over a range of spatial and temporal scales, from short daily movements to access food, shelter and mates, to annual global-scale migrations and everything in between. There is a cascading raft of effects when wildlife movements are restricted, resulting in population declines and ultimately, local species extinctions

The City of Knox in the outer eastern suburbs of Melbourne is situated at the foothills of the Dandenong Ranges and is the transition between the forests of the ranges and the suburbs to the west. Knox is characterised by its 'bushy' feel, with its well-treed suburban landscape, important areas of public open space and numerous bushland reserves and waterways providing important habitats for the conservation of biodiversity and supporting numerous valuable ecosystem services.

There are five Rural Land Precincts (RLP) around the perimeter of the Knox municipality that range in size from 127 ha to 975 ha and support a diversity of land-uses, including private residential, a range of agricultural activities, quarrying, national park and other conservation, and recreational open space. There is pressure to develop these RLPs, and the City of Knox commissioned this report to investigate the current role of these precincts in supporting the conservation and movement of wildlife and to identify the areas of the precincts and elsewhere in Knox that contribute strongly to these functions.

We collated a range of spatial data layers and records of wildlife occurrence from various disparate data sources and analysed them in a GIS framework, characterising the biodiversity and landscapes of Knox. The wildlife records were also combined into a single master database to form a comprehensive 'Knox Wildlife Atlas'. This Atlas is a valuable resource for Knox CC as it allows them to easily compile biodiversity information for specific locations to inform management and planning decisions in an efficient and comprehensive way. The utility and value of the Knox Wildlife Atlas can be extended in the future by developing software platforms and processes that allow the data to be easily maintained, updated and accessed in house by Council Officers and as a public engagement and communication tool to share information with residents and the general public about the diverse communities of plants and animals who also reside within the municipality.

In undertaking our assessment of the wildlife connectivity and conservation opportunities, we identified a suite of ten focal species that represented a range of movement abilities and habitat requirements. These focal species were then used to determine the locations and features within Knox that are important for conservation and movement of wildlife. Importantly, we identified the features of the landscape that were correlated with the occurrence of focal species and used this to make recommendations and conclusions to protect and enhance the habitat features that our focal species rely on.

Our investigation confirmed the important role of the Knox municipality as a transition between the Dandenong Ranges and the suburbs to the west in terms of both natural vegetation and wildlife habitat. The waterway corridors and RLPs provide a significant extent of native bushland in Knox and also support the vast majority of recent sightings of the ten focal species we investigated. Without the RLPs, these focal species, and many other species that have similar traits, would not exist within the Knox municipality. Importantly, the analysis also showed that the non-rural lands of Knox are less valuable for wildlife compared to the waterways and RLPs, demonstrating the likely outcome if the RLPs are developed in a similar manner to the remainder Knox.

We compiled records of all fauna sighted in Knox since 1995 from various databases and have presented these as the Knox Wildlife Atlas. This comprehensive collation of wildlife sightings is of critical importance as a data input during future planning and decision-making for Knox because it enables important habitat to be readily identified. The Knox Wildlife Atlas should be kept up to date with new sightings at least annually, ensuring it remains current and can inform decision making in a timely manner.

We recommend that Knox adopt the findings of our analysis and integrate them into planning to ensure the important areas of the RLPs and major waterways for habitat and movement of wildlife are protected and managed appropriately going forward. Specifically, we recommend retaining existing controls on minimum lot sizes within RLPs are retained wherever possible, identify specific barriers along the waterway corridors that limit wildlife movement and identify modifications to improve connectivity, and highlight which areas of the landscape are important for biodiversity conservation. We also recommend specific areas for further research and investigation to inform some of the next steps in conserving biodiversity within the City of Knox.

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1. Introduction

Ecology and Infrastructure International Pty Ltd, in collaboration with EcoAerial and Urban Ecology In Action Pty Ltd, were commissioned by Knox City Council (KCC, and hereafter 'Council') to undertake a habitat corridor and fauna movement study for the municipality of Knox. While the focus was initially on areas within the peri-urban, green wedge and rural lands (i.e. Rural Land Precincts), the scope was expanded to consider all habitat and potential movement pathways for wildlife across the Knox local government area.

1.1 Project Background, Aims and Report Structure

Ecology and Infrastructure International Pty Ltd received confirmation to proceed with this project on 20th December 2016. The scope of works included:

- A review of wildlife connectivity in urban and peri-urban landscapes;
- Collation and interrogation of data on occurrence of wildlife within Knox;
- GIS collation, mapping and analysis; and
- Fieldwork to confirm species occurrence and/or to investigate fauna movement.

During the course of the project, Council decided to exclude fieldwork because of (i) the availability of reasonably comprehensive data sets of wildlife records from various sources; (ii) the potentially large spatial scale of the study area; (iii) the wrong time of year for survey of certain species (e.g. frogs) and (iv) the 'hit and miss' challenge of identifying and prioritising which locations to survey, given the limited budget for fieldwork.

It is helpful to provide some insight to the structure of this report and the framework behind the methodology (Figure 1). We reviewed relevant legislation, agreements and strategies at a range of spatial scales (from international to local) to identify trends and best practise in conservation of movement and connectivity for wildlife, including for urban and peri-urban landscapes. We then collated and incorporated numerous wildlife observation data sources and evidence from the Knox municipality, the region and internationally, including a comprehensive analysis of barriers and connectivity for the Port Phillip and Westernport Catchment (O'Malley et al. 2011) to produce this report. The sections of the report in which further details of each of the frameworks, regional plan, our analysis and the supporting documents and evidence base are detailed in the vertical panel of Figure 1. In addition to this report, we have compiled and produced the "Knox Wildlife Atlas", which includes all the wildlife records we collated from all the various sources during the course of this project. This atlas is intended to provide Knox with a comprehensive snapshot of current wildlife occurrence within the municipality and can be added to in the future as new observations are made.

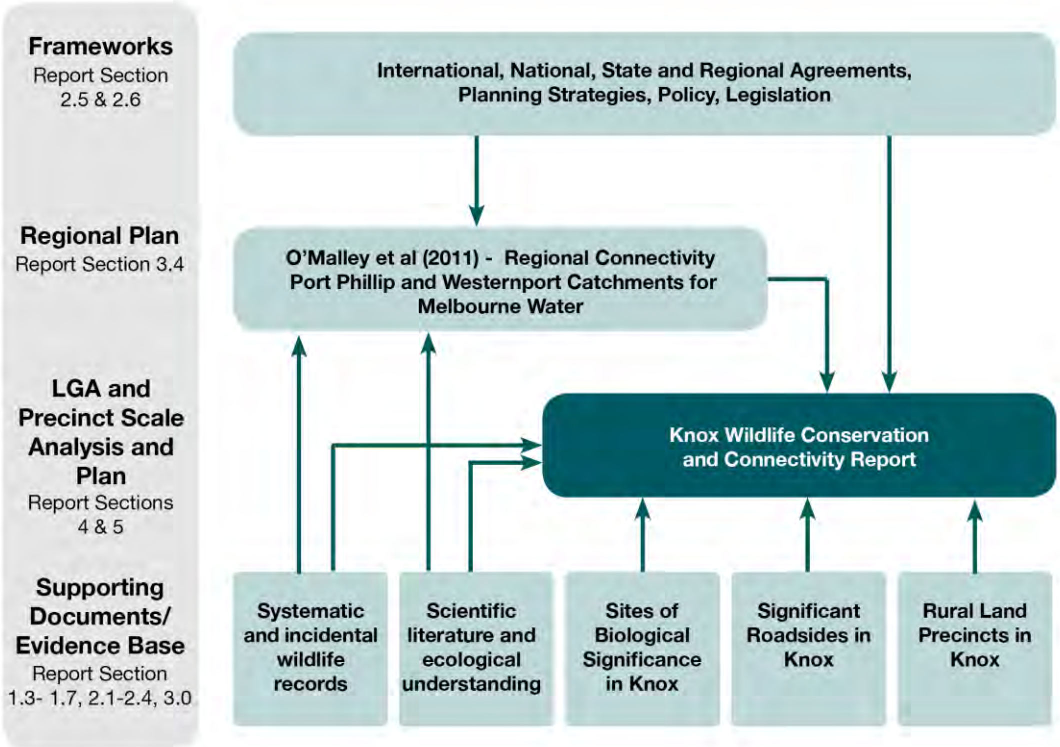


Figure 1. Report context and methodology.

We reviewed relevant legislation and strategies at a range of spatial scales (upper light green panel and vertical grey panel), identified existing reports on connectivity for the region (middle light green panel) and combined a range of data and information (bottom light green boxes) to produce the "Knox Wildlife Conservation and Connectivity Report".

1.2 The municipality of Knox

The municipality of Knox is in the outer eastern suburbs of Melbourne, approximately 25 km from the central business district of Melbourne and covers an area of approximately 114 km^2. Knox has grown rapidly over the past 30 years, and is currently home to approximately 160,000 residents in the following suburbs: Bayswater, Boronia, Ferntree Gully, Knoxfield, Lysterfield, Rowville, Sassafras, Scoresby, Studfield, The Basin, Upper Ferntree Gully, Wantirna and Wantirna South. Many of these suburbs have been extensively developed in the past 30 years into areas of low- to medium-density residential land-uses, with more recent in-fill development of higher-density townhouses occurring in certain areas of the municipality, especially in areas close to major transport hubs, such as Boronia and Bayswater. Knox City Council shares its border with six adjacent Local Government Areas (LGAs), namely the Cities of Casey, Greater Dandenong, Maroondah, Monash, Whitehorse and the Shire of Yarra Ranges (Figure 2).

Figure 2. Map showing the municipality of Knox within the eastern suburbs of Melbourne and selected suburbs. The light green shading shows areas of public open space. Inset shows the City of Knox (red outline) in relation to the Greater Melbourne area (CBD shown by ★ in inset image). Data sources: Watercourse Network 1:25,000 - Vicmap Hydro (HY_WATERCOURSE/) © State of Victoria; Road Network - Vicmap Transport (TR_ROAD/) © State of Victoria.

Knox occupies a transition between the continuous built form of the 'suburbs' towards the west of municipality and the vegetated hillsides of the Dandenong Ranges to the east of the municipality. The topography of Knox has influenced this pattern of development, with primarily flat areas to the west, grading to undulating hills and steeper slopes of the Dandenong Ranges to the east. The undulating areas roughly correspond with the Gippsland Plain Bioregion, with the hills and steeper slopes corresponding to the Highlands Southern Fall Bioregion. Further description of the geology, rainfall and vegetation communities within these bioregions is given in extensive detail in Lorimer (2010a). This transition includes numerous larger tracts of natural and semi-natural landscapes as well as smaller bushland reserves and other forms of public open space scattered throughout the residential and industrial matrix (Figure 2, Figure 3). Significant natural landscapes include the Lysterfield Valley and Lysterfield National Park, Dandenong Ranges National Park, Churchill National Park and the Dandenong Creek (also known as Dandenong Valley) Parklands. These natural areas are significant at metropolitan, regional and local levels.

Importantly, the Dandenong Foothills, located in the eastern portion of Knox are valued highly by the local community for their aesthetic appeal and for giving Knox its unique bushland feel. In addition, the Lysterfield Valley has been classified by the National Trust as 'an attractive pastoral landscape which forms part of a green wedge between the suburban areas of Rowville and Dandenong North and the urbanised Ferntree Gully-Belgrave ridge of the Dandenongs'.

1.3 Flora of Knox

Knox supports < 5% native vegetation cover, with most associated with the national parks and creekline corridors (Figure 3). Two-thirds of this native vegetation consists of Dry Forests (1228.5 ha) Ecological Vegetation Class (EVC) group, and 28% consists of Riparian Scrubs or Swampy Scrubs and Woodlands (518.6 ha, 28%), with the remaining 5% consisting of three other groups of woodland or forest (Table 1). A breakdown of the amount of each broad EVC group is provided in Appendix 1.

Table 1. Total area of major Ecological Vegetation Class groups in the City of Knox based on the State of Victoria's NV2005_EVCBCS dataset.

Ecological Vegetation Class Group	Area (hectares)
Dry Forests	1228.5
Herb-rich Woodlands	33.3
Lowland Forests	4.9
Riparian Scrubs or Swampy Scrubs and Woodlands	518.6
Wet or Damp Forests	48.5
Grand Total	***1833.7***

In 2010, Graeme Lorimer collated over 43,000 flora records and concluded that 472 species of indigenous flowering plants and ferns would have occurred within Knox since European settlement (Lorimer 2010a). Of these, he concluded 27 can be confidently presumed locally extinct, with an additional similar number also likely extinct. At the time of writing his report in 2010, he also believed it likely that a dozen or so undetected species were likely to occur in Knox, bringing the total number of extant species of indigenous plants to approximately 450 (Lorimer 2010a). A comprehensive description of the status of these species and their significance at local, regional, state and national levels is given in Lorimer (2010a).

In 2010, Knox was home to at least 234 species of environmental weed, with many classified as being serious threats to the conservation of indigenous plant species (Lorimer 2010a).

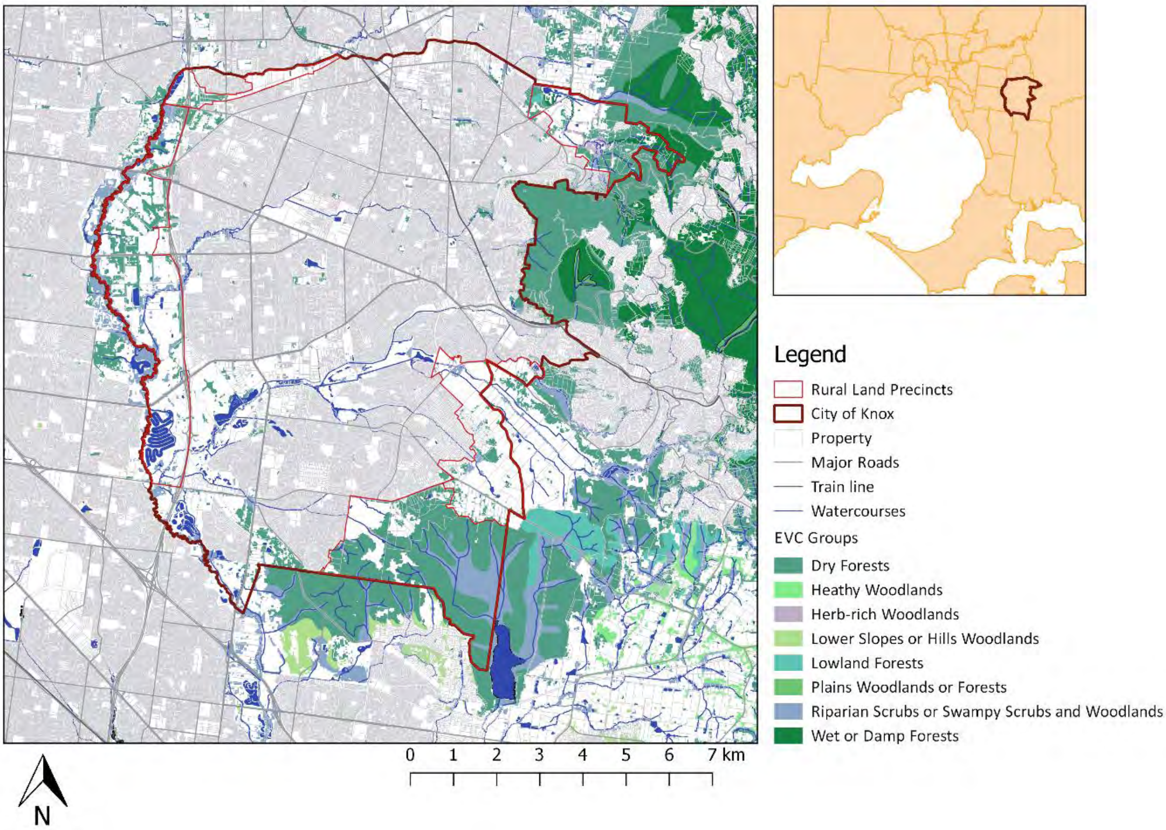


Figure 3. Map of Ecological Vegetation Classes (EVC) groups within Knox.

Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria.

1.4. Fauna of Knox

The level of knowledge of the occurrence, distribution and abundance of wildlife within the City of Knox is much lower compared with the indigenous flora and ecological vegetation classes. Whilst vast quantities of records are available within the Victorian Biodiversity Atlas and the Atlas of Living Australia, these have never been compiled and synthesised at a municipal level for KCC. One of the primary objectives of this project is to collate and summarise the wildlife occurring within Knox, and these results are provided in Section 4.1 of this report. Further detailed description of wildlife within each of the Rural Land Precincts is provided in Section 4.2. All the records we collated have been placed into a master database called the Knox Wildlife Atlas, and while this contains the most complete assessment of wildlife in Knox to date, it is not comprehensive nor without error or omission as it is a compilation of various datasets, each of which were collected for different reasons. However, it does form the foundation of a valuable resource that Knox can use internally to help inform decisions and actions across departments within Council, and externally to facilitate important conversations between Knox CC and the general public around which wildlife species live where across the municipality.

1.5. Sites of Biological Significance in Knox

Knox City Council have been proactive in identifying and managing important sites for the conservation of biodiversity for many years. In 2004, Graeme Lorimer published the first edition of the 'Sites of Biological Significance in Knox' report, with a revision and update published in Edition 2 in 2010 (Lorimer 2010a). The second edition of the Sites of Biological Significance report has two volumes and summarises the ecological value and condition of approximately 120 sites across Knox that support remnant or restored indigenous vegetation. Significantly, the second volume also notes the decline in condition of a handful of sites due to road construction projects and private development since the 1st edition was published in 2004.

The Sites of Biological Significance report is a comprehensive assessment of the plant species and vegetation communities that occur on both public and private land within Knox. Based on analysis of existing databases, anecdotal records and painstaking field surveys, the report summarises the plant species and vegetation communities at each site, and includes 48 specific recommendations for management, including numerous site-specific recommendations. The study found that 77 sites are significant at the State level, primarily because of the occurrence of two ecological vegetation classes that are listed as 'Endangered', namely Valley Heathy Forest (EVC 127) and Swampy Woodland (EVC 651).

The report highlighted the following pertinent points:

- One hundred and eighty-five plant species, or 41% of all of Knox's surviving indigenous plant species, are Critically Endangered in Knox, i.e. they fall into the highest risk category for local extinction. This is an indication that scores of species could die out in Knox over the next decade – a remarkably rapid collapse of biodiversity – unless corrective action is taken. Some of these species are threatened state-wide.
- In the other two categories of locally threatened species (i.e. endangered and vulnerable), there are another 190 species, bringing the total proportion of indigenous plant species that are locally threatened to 84%.
- Eighty-one of the 117 sites identified in this study contain at least one plant species that is Critically Endangered with extinction in Knox or more widely. The loss of any one of these eighty-one sites is likely to either render a species extinct from the municipality (or more widely), or significantly increase the risk of this happening.
- Every one of the 112 sites recommended to be protected by a planning scheme overlay contains at least one locally threatened species.
- Sixty-two plant species that are Critically Endangered with local extinction have never been recorded in a formal conservation reserve, making private land and properties like the Healesville Freeway Reservation critical for the survival of these species in Knox.
- Some of the threatened species that are not represented in reserves are highly reliant on sites owned by government, such as schools, roadsides, utility installations or freeway reservations. In many cases, private residential land is critical – particularly in the cases of the quarries in the Lysterfield Hills.

The Sites of Biological Significance reports provide a detailed plant species list for each habitat type at each site, allowing for changes over time to be assessed. Other significant features at each site, such as large old trees, wetlands, location of selected endangered species and areas of weed infestation were also recorded and mapped.

1.6. Connectivity and corridors in Knox

The municipality of Knox has a number of important 'corridors' and linear habitats that connect the foothills of the Dandenong Ranges to its northern, western and southern boundaries (Figure 4). These corridors are primarily along waterways or within roadside reserves.

There is approximately 89.5 km of watercourse meanderings in Knox along the major waterways, with Dandenong Creek the longest (~42.8 km), followed by Blind Creek (16.8 km), Corhanwarrabul Creek (12.7 km), Ferny Creek (6.2 km), Monbulk Creek (5.4 km), Dobson's Creek (3.7 km) and Ferntree Gully Creek (2.0 km). The extent of native vegetation along these waterways is quite variable, with some stretches supporting relatively intact vegetation communities and others supporting relatively degraded bushland or largely cleared areas. The three major waterway corridors in Knox were the focus of extensive vegetation surveys in 1997, which focussed on identifying plant species occurrence and abundance and mapping vegetation communities or habitat types (Reid et al. 1997). Fourteen major habitat types were identified at the time of the survey, ranging from perennial waterways to grassland, scrub, forest and woodland. The plant communities within the waterway corridors varied depending on their position within the landscape, degree of soil moisture due to inundation and topography and past land-uses. Importantly, some of the locations along the waterways supported rare and endangered species of plant and vegetation communities. Of concern though, was that many sites contained significant weed infestations and very few scored highly on the authors' habitat quality ranking system. Furthermore, there are many sections of these waterways that have been piped and managed for purposes other than biodiversity. Nevertheless, the three creek corridors provide reasonably continuous strips of vegetation from the foothills, through Knox and to the Dandenong Creek, with great potential for improvement.

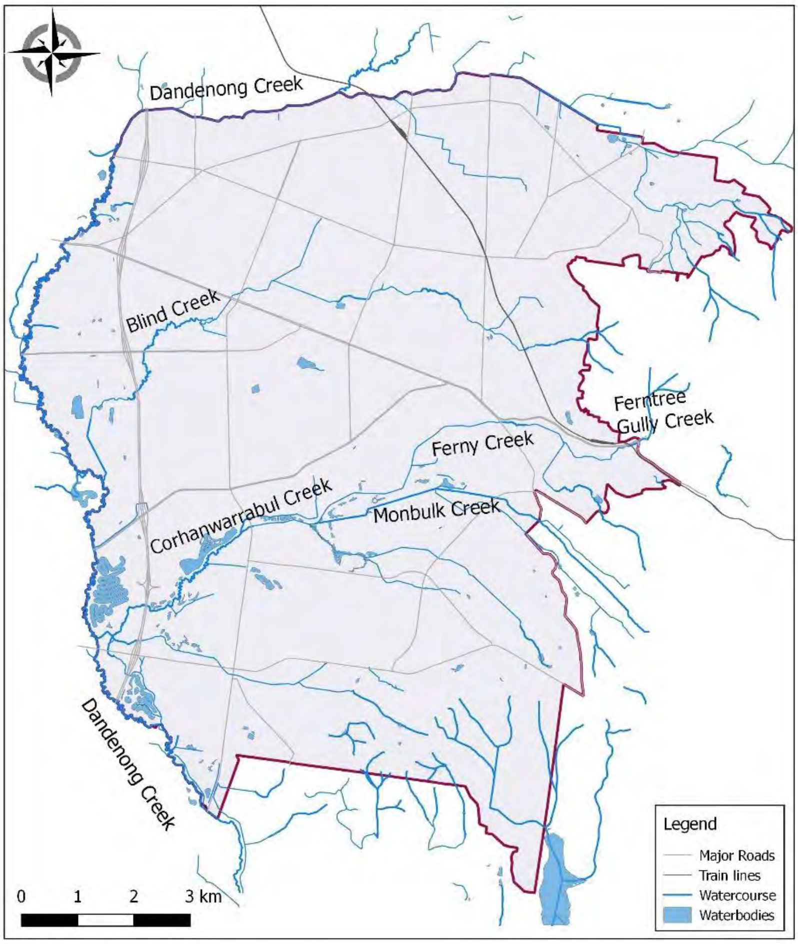


Figure 4. Map showing the major waterways and roads within Knox.

Data sources: Watercourse Network 1:25,000 - Vicmap Hydro (HY_WATERCOURSE/) © State of Victoria; Road Network - Vicmap Transport (TR_ROAD/) © State of Victoria.

1.6.1. Dandenong Creek corridor

Within Knox, the Dandenong Creek extends in a westerly direction from Doongalla Estate Reserve to Wantirna and then turns southwards towards Dandenong (Figure 4), eventually emptying into Port Phillip Bay at Carrum. Along its length through the City of Knox, Dandenong Creek forms the municipal boundary between Knox and the Cities of Maroondah, Whitehorse, Monash and Greater Dandenong. As a connecting corridor, Dandenong Creek forms an important bioregional corridor, connecting the foothills of the Dandenong Ranges to the Port Phillip Bay. In addition to its connectivity role, Dandenong Creek also provides significant habitat for a range of species, including at least 163 species and sub-species of indigenous plants and numerous rare and regionally significant species (Reid et al. 1997). Information about wildlife within the Dandenong Creek Corridor is provided in Section 4.2.

1.6.2. Corhanwarrabul Creek and its tributaries – Ferny, Ferntree Gully and Monbulk Creeks

Ferntree Gully Creek flows from the foothills of the Dandenongs into Ferny Creek in Upper Ferntree Gully, which then merges with Monbulk Creek at Knoxfield and Rowville, where it becomes Corhanwarrabul Creek (Figure 4). Corhanwarrabul Creek then flows into Dandenong Creek near

Wellington Rd/Monash Highway. Combined, these waterways total approximately 26.3 km through the municipality of Knox, and support a range of vegetation types that are associated with the foothills of the Dandenong Ranges to the more swampy areas that more prone to inundation near Dandenong Creek. The area around Corhanwarrabul Creek was subject to intensive agricultural activity historically and most native vegetation had been cleared and the creek straightened (Lorimer 2010b). Despite this historic clearing, some sections of Corhanwarrabul Creek currently support reasonably intact areas of native vegetation, although much is the result of revegetation efforts. Numerous flood retention wetlands and filtration wetlands have been constructed along Corhanwarrabul Creek in Rowville and Ferntree Gully, greatly improving the quality and natural flows of water. Some sections of Corhanwarrabul Creek are piped through Ferntree Gully, such as at Hancock Drive and Glenfern Road. Detailed descriptions of the vegetation along Corhanwarrabul Creek and its upper tributaries is provided in a number of reports to KCC (Reid et al. 1997; Lorimer 2010b).

1.6.3. Blind Creek

Blind Creek is located approximately mid-way between Corhanwarrabul Creek and Dandenong Creek and similarly flows in a south-westerly to westerly direction from the foothills. Originating in the foothills near Ferntree Gully, it is mostly piped and/or straightened from the Tim Neville Arboretum to Lewis Park near Knox City Shopping Centre, piped under Stud Rd and open until joining Dandenong Creek near Jells Park (Figure 4). Blind Creek contains numerous sections of relatively high quality patches of native vegetation, which Lorimer (2010b) describes as ranging from 'fair' to 'good' condition. Despite the historical modifications to the Blind Creek Corridor, it remains an integral linkage across the municipality of Knox for wildlife and some sections are of state significance for their botanical richness.

1.6.4. Roadside habitats and corridors

In addition to the major waterways there are numerous roadsides that support stands of native vegetation that are significant in terms of both their quality, length and position in the landscape. Some of the more significant roadsides reserves include sections along Mountain Highway, Boronia Road, Wellington Road, High Street Rd, Kelletts Rd, Glenfern Rd and many smaller residential streets within the foothills of the Dandenong Ranges National Park in The Basin and Boronia. Comprehensive surveys of the vegetation along 45.3 km of roadsides within the Knox municipality was published by Graeme Lorimer in 1998 (Lorimer 1998), including the quality and extent of different vegetation communities or associations, as well as the location and abundance of species of rare plants.

In contrast to the waterway corridors, many of the roadside corridors occur as relatively short sections of road, and often with relatively large clearings and gaps between the more intact patches of native vegetation and mown grass under a remnant overstorey. The width of the strips of the native vegetation within the roadside corridors are also typically significantly narrower than the waterways, and often less than 20 m in width. Furthermore, roadside corridors are under pressure from both sides of the reservation (i.e. from the road itself and adjacent land-uses on the other side) that degrades habitat quality and reduces habitat extent. For example, Lorimer (1998, pg. 1) found that 'the vast majority of roadside vegetation in good ecological condition is adjacent to public land, and is extremely rare in front of residential land' primarily because of the suite of negative processes that occur in residential areas. In addition, Lorimer also detected 55 species of environmental weed along the roadsides that he deemed were serious or very serious threats to the viability of the native plants and plant communities.

Nevertheless, the roadsides provide important linkages at the local scale, often connecting small bushland reserves with each other. In many cases, the roadside reserves are also extensions to the many bushland reserves, providing critically important habitat for both flora and fauna. Significantly, the 45 km of roadside that Lorimer surveyed in 1997 supported 17 types of native vegetation, out of a possible 18 that have been recorded within the Knox municipality, and 255 indigenous species and subspecies of plant. Importantly, Lorimer also detected 31 species of indigenous plants that were locally uncommon or threatened, and these have been mapped in Lorimer (1998).

The current condition of these roadsides as corridors for the movement of wildlife is unknown because the surveys by Lorimer were undertaken 20 years ago and many sites have probably become degraded with the passage of time or destroyed due to road widening, maintenance works or other developments. A comprehensive review of the vegetation of these roadsides is warranted in order to direct where future revegetation works should be undertaken. It was beyond the scope of this project to visit each roadside identified by Lorimer (1998) or as a site of Biological Significance and assess its current condition or gaps in connectivity. However, it should be noted that pristine or high quality intact vegetation is not required for the roadside to act as a corridor for many species of wildlife as habitat structure is often a more important determinant of usage for many species of terrestrial wildlife than botanical intactness. Therefore, ensuring the vegetation, in this case roadsides, retain multiple vegetation layers, logs and large trees with hollows will facilitate their function as corridors for the movement of wildlife.

1.7. The Rural Lands Precincts of Knox

There are five Rural Lands Precincts (RLP) within the municipality of Knox, with all distributed around the perimeter of the municipality, and adjoining neighbouring LGAs (Figure 5). Combined, the RLPs cover an area of 2859 ha, accounting for a little over a quarter of the area of Knox. The dominant land-uses within these precincts includes farmland, bushland, and a range of types of public open space. Importantly, much of the remnant vegetation within Knox occurs within the RLPs. Therefore, it is no surprise that these precincts are a significant contributor to the rural feel and aesthetic that defines Knox overall, and these particular areas of the Knox municipality. In all cases, the dominant land-uses and vegetation types within each RLP is mirrored to some extent within the adjacent LGA. This means that activities within one LGA will affect the viability and integrity of the area within the neighbouring LGA.

The RLPs differ from each other in their extent of remnant vegetation, area, dominant landuses and threats. For example, The Basin RLP (RLP 1) includes a large area of farmland with a single landowner (the Salvation Army). In contrast, the Lysterfield Valley and Hills (RLP 2a) is also farmland, but owned by many different owners, while Lysterfield Quarries and Surrounds (RLP 2b) includes a number of quarries and Lysterfield National Park. The Dandenong Creek Valley (RLP 3) is the largest precinct and the Healesville Freeway Reservation (RLP 4) the smallest. The threats to each RLP also varies, with the RLP 2a and 2b potentially impacted by the proposed Dorset Rd extension, and the RLP 4 is on land reserved for a major freeway.

While a large proportion of the vegetation within each RLP has been described within the Sites of Biological Significance Reports by Lorimer (2010a, b), none of this information has been specifically collated and presented at the precinct scale. Comprehensive summaries of the remnant vegetation, property sizes, number of Gardens for Wildlife properties and public open space within each RLP is given in Section 4.2.

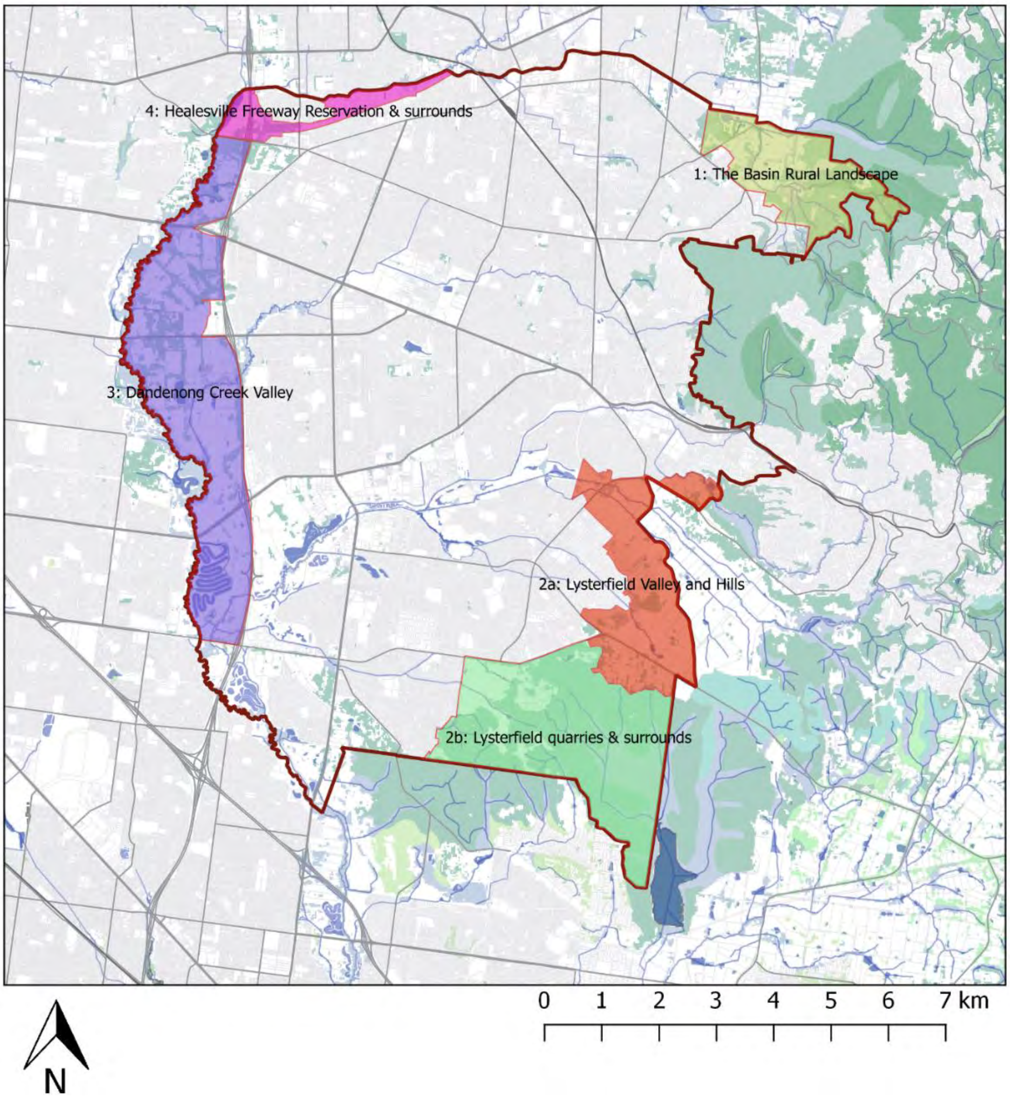


Figure 5. Location of each Rural Land Precinct within the municipality of Knox.

Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria; Data sources: Watercourse Network 1:25,000 - Vicmap Hydro (HY_WATERCOURSE/) © State of Victoria; Road Network - Vicmap Transport (TR_ROAD/) © State of Victoria; Cadastral Area Boundary - Vicmap Property (VMPROP_CAD_AREA_BDY/) © State of Victoria.

2. Habitat loss, fragmentation and connectivity

2.1 Habitat loss and fragmentation

The loss, fragmentation and degradation of habitat is considered one of the primary threats to the conservation of biodiversity globally (Wilcox & Murphy 1985; Saunders et al. 1991; Bennett 1999). Habitat fragmentation is the process of dividing a once-continuous habitat into smaller pieces, resulting in the loss of habitat, a reduction in the size and quality of the remaining habitat patches, and an increase in the isolation of the patches from each other as the matrix expands (Andren 1994; Forman 1995; Lindenmayer & Fischer 2006). The impacts of habitat loss and fragmentation are potentially widespread and pervasive and include the loss of species, changes to the composition of communities of wildlife and disruption of ecosystem processes. Once the clearing process has ceased, the changes continue as invasive species (e.g. predators, weeds) move in, often outcompeting the native species of plants and animals. Additional changes in the patterns of wind, rainfall, humidity and evapotranspiration further affects species trying to persist in smaller, more isolated patches of habitat. Many of these threats originate from outside the patch of habitat, a process known as an "edge effect", which can be measured for many hundreds of metres from the boundary (Murcia 1995).

Ecosystem services are important functions that the ecosystem provides to us, such as nutrient cycling, controlling or maintaining hydrological flows, erosion control, cleaning the air, litter decomposition as well as spiritual, emotional and health benefits (Shanahan et al. 2015) from time spent in nature. Ecosystem services include simple but critically important services such as pollination – without a healthy ecosystem, there are insufficient pollinators to pollinate food crops, resulting in a decrease in food supply. Another simple example is the filtration effect of soil and wetlands which capture pollutants from stormwater, thereby reducing pollution levels in our bays and oceans.

Even in continuous habitat, wildlife are not distributed uniformly evenly across the landscape, but rather occur in patches of habitat with some degree of movement among the patches. This arrangement is often referred to as a 'metapopulation' (Figure 6) (Hanski & Gilpin 1991). Within a metapopulation, the smaller sub-populations operate more or less independently of each other, which means that some sub-populations can be surviving well while others may be small and declining. Indeed, some of the sub-populations may actually go locally extinct from time to time. However, the persistence of the species in the area overall relies on the movement of animals from larger or more viable populations (i.e. a source population) to those in smaller or poorer-quality patches of habitat to supplement them before they go extinct, or to recolonize them if extinction has occurred. This is critical because extinction of the species in the region occurs when all the sub-populations have gone locally extinct.

Therefore, sufficient healthy sub-populations within an area are required to maintain viable populations of wildlife within an area, as well as allow animals the opportunity to move among them. In urban areas, such as Knox, these metapopulations are most clearly evident as small patches of bushland scattered amongst a sea of residential and industrial development. The parts of the landscape that facilitate animal movement varies according to the needs of individual species but includes corridors of habitat along waterways or road reserves, 'stepping stones' of habitat in small patches as well as potentially a well-treed suburban matrix (LaPoint et al. 2015).

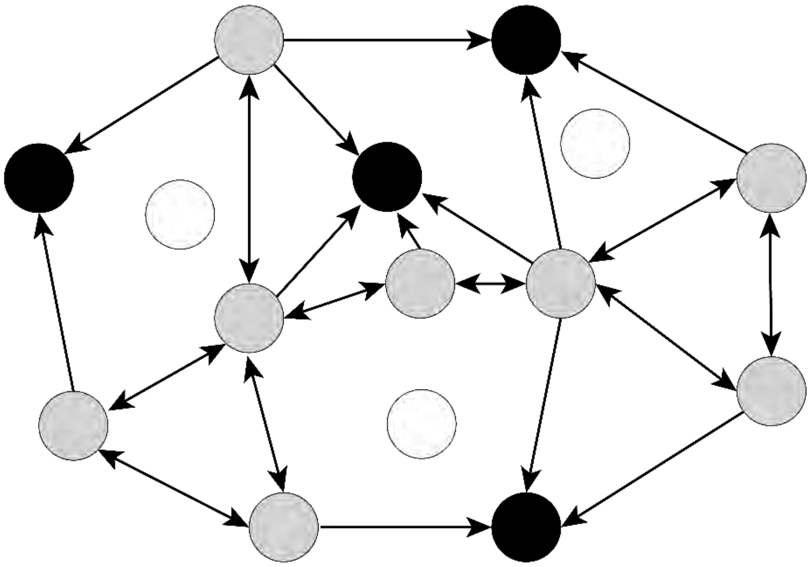


Figure 6. Schematic of a simple metapopulation.

Each patch of habitat is denoted by a circle, with vacant habitats (i.e. sub-population has gone extinct) shown in white; patches with poor quality habitat (also known as a sink habitat, where the population is declining) shown in black and good quality patches with healthy populations that are producing excess offspring (also known as a source habitat) that can disperse into declining or extinct populations shown in grey.

2.2. What is connectivity and why is it important?

Successful movement of individuals is fundamental to life and scores of projects globally have recognised this and are focussing on protecting, enhancing and restoring ecological connectivity (Crooks & Sanjayan 2006; LaPoint et al. 2015). Most species need to move at some stage in their lifetime and these movements can occur over a range of distances and times. For example, individual animals need to undertake ***daily movements*** from where they sleep to where they obtain their food and to find mates, which may occur over very short or very long distances depending on the movement ability of the species and the distribution of resources. ***Dispersal*** is typically a once-per-lifetime event and occurs when offspring leave the area in which they were born or raised and attempt to find and establish their own territory. ***Migrations*** are typically seasonal movements, and often occur to follow seasonally-abundant food sources or to track suitable climatic conditions. Migrations can occur over relatively short distances, such as some species of amphibians and turtles in colder climates that leave their wetland before it freezes in winter to reach more elevated parts of the landscape for over-wintering, to the global movements of birds between temperate and tropical regions or between hemispheres (see Section 2.5.1 for examples of international treaties that aim to protect long-distance migratory species). Knox is home to numerous seasonal migratory species, including the EPBC listed Grey-headed Flying-fox *Pteropus poliocephalus* which forages within the municipality with some individuals migrating annually between Queensland and southern Australia (van der Ree et al. 2006), and the Pied Currawongs *Strepera graculina* and Rose Robins *Petroica rosea* which descend from alpine areas to Knox each winter. Other migrants are more nomadic and tend to follow erratically available food sources, such as flowering eucalypts (e.g. Musk Lorikeets *Glossopsitta concinna* and Red Wattlebirds *Anthochaera carunculata*). A type of movement that has more recently been elevated in importance is the need for species to shift their geographic range in response to climate change. As the global temperature warms, some species may be forced to move to new areas in order to remain within a climatic envelope that fits within their tolerance limits and contains food sources that are similarly suited to the climatic conditions.

Climatic changes have been predicted for the Eastern Alliance for Greenhouse Action area, of which KCC forms part (see CSIRO 2013 for details). For this wider area, by 2050, temperatures are predicted to be both hotter, by between 1.7°C and 2.5°C, and drier, with 14% less rainfall, than existing conditions. By 2070, these temperatures will further increase to between 2°C and 3°C above current conditions, and rainfall will further reduce to 21% less than currently experienced. It was further predicted that these environmental conditions would lead to the loss or contraction of some EVCs within the EAGA area, particularly for wetland-associated EVCs (Meacher & Blair 2013). For 21 plant species whose distributions were projected under these changing climatic conditions for the two time periods, there was a general trend for distributions to shift towards the north-east. Some plants showed little, or no, change, while *Eucalyptus ovata* and *E. rubida* showed the most significant changes (Meacher 2013).

There are two definitions associated with landscape connectivity that require clarification. ***Structural connectivity*** is a physical attribute of the landscape such as the arrangement of habitat types or land-cover classes and is generally measured along a spectrum from 'high' to 'low'. Structural connectivity is often measured within a geographic information system (GIS) by quantifying various landscape metrics such as patch size, degree of isolation or by measuring features that enhance or impede movement. In contrast, ***functional connectivity*** is organism-orientated, where behavioural responses of the organism are interpreted to suggest which parts of the landscape are connected from the perspective of the organism. Functional connectivity can be measured directly by tracking the movement of individual animals, either by direct observations, radio- or satellite-tracking, or by measuring gene flow across the landscape. Functional connectivity can also be modelled, using least-cost path analysis (Adriaensen et al. 2003), circuit theory (McRae et al. 2008) or other approaches which attempt to estimate landscape resistance, which in this case is the energetic cost to move and/or the risk of dying while moving. For example, the 'resistance' of a landscape to the movement of a forest-dependent bird would range from close to zero for a forest (i.e. no impact on movement), with a semi-rural landscape a little more difficult, high-density residential more difficult still and an 8-lane freeway or central business district of a major city almost definitely close to 1 (i.e. impassable). See Section 3.4 for an example of how landscape resistance was used to identify corridors for movement in the Port Philip and Westernport Catchment (O'Malley et al. 2011). Both functional and structural connectivity can be modelled, measured and mapped according to the habitat and movement parameters of the species of interest.

As introduced earlier in this section, species are distributed across the landscape as a series of interacting sub-populations which is called a metapopulation (i.e. Figure 6). The functioning of a metapopulation relies on animals being able to move about the landscape. If the sub-populations are not functionally connected, they are essentially small islands in a sea of inhospitable land-use. If a sub-population in one patch declines due to disease, wildfire, predation, or other causes, it may decline to the extent that it goes locally extinct. And the decline and ultimately the risk of extinction of the species in the landscape is directly correlated with the number of sub-populations and the number of animals within each sub-population. Without adequate movement of animals to 'rescue' declining sub-populations, or to re-establish locally extinct sub-populations, the species is highly likely to become extinct in the overall area.

Various relevant terms are defined in Text Box 1 and an 'easier to understand' description of connectivity for wildlife and why it matters is provided in Appendix 2.

2.3. Elements of connectivity – corridors, stepping stones, and the matrix

Landscape connectivity is the degree to which a landscape facilitates or impedes the movement of individuals or gametes (Taylor et al. 1993; Tischendorf & Fahrig 2000). Many different landscape elements contribute to connectivity, including corridors, stepping stones, continuous habitat and for some species, the matrix itself (Figure 7). There are generally two categories of species based on the type and pattern of habitat they require to move across the landscape. The first are *generalists* who do not require any specific arrangement or type of habitat to move across a landscape, and the second are specialists who have quite specific requirements. Species that fall into the first group are typically 'matrix tolerant' and are often ubiquitous in developed or modified landscapes, such as Magpies *Cracticus tibicen* or the Noisy Miner *Manorina melanocephala* in south-east Australia. The second group are those with less tolerance for modified landscapes and who require specific features in the landscape for persistence, and it is these species that are relevant for planning in Knox (see also Section 3.3). It is also important to distinguish between habitat used for 'living' and habitat used primarily for 'moving'. For example, a recent study of Sugar Gliders *Petaurus breviceps* in the eastern suburbs of Melbourne found that they only ever slept in tree hollows in bushland reserves, but most travelled into adjacent residential areas to feed, sometimes up to 180 m from the bushland-backyard interface (Caryl et al. 2013). This suggests that Sugar Gliders would be willing to travel relatively short distances (i.e. a few hundred metres) through residential areas to reach new bushland areas, which provide essential habitat sustain populations. In contrast, the Common Brushtail Possum *Trichosurus vulpecula* is capable of living its entire life within backyards. In this example, the Common Brushtail Possum is a generalist species, and the Sugar Glider more specialist.

Wildlife vary enormously in their tolerance and use of different types of habitat for living and movement. Some species are very specialised and require certain features within their habitat for it to capable of supporting movement. For some species, connectivity is only achieved by maintaining large continuous tracts of habitat (scenario a in Figure 7), while others require continuously connected habitat, albeit with thinner strips, known as corridors (scenario c in Figure 7). An important determinant of corridor use relates to the width of the corridor, with some species requiring wide corridors (e.g. up to 200 m in width) while others are capable of using much narrower corridors, sometimes down to 10 – 20 m. Stepping stones are another means of achieving connectivity where continuous corridors are not possible, and they cater for species that are capable of traversing variable distances of not-suitable habitat (scenario b in Figure 7). Species capable of flight are most likely capable of using stepping stones, with the size of the stepping stone and the distance between them determining suitability. The remaining group of species are still dependent on patches of natural habitat but are capable of moving through the urban or residential matrix, provided it has a minimum cover of 'natural' elements, such as trees, that are spread out across the landscape (scenario d in Figure 7). This type of landscape is often referred to as a 'variegated' landscape because patches of habitat are not easily distinguished from the matrix.

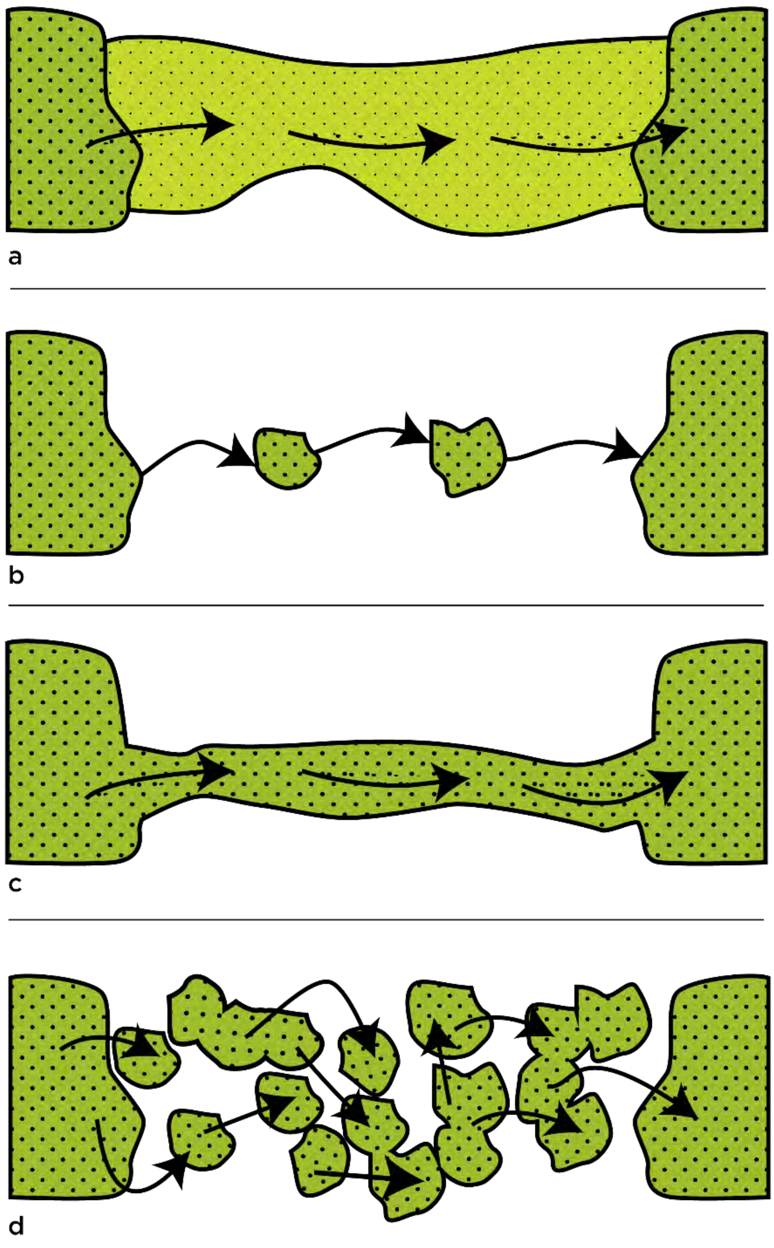


Figure 7. Different ways in which landscape connectivity can be achieved.

(a) continuous habitat is maintained within a landscape; (b) stepping stones of different size or spacing along a mostly linear route where animals must cross unsuitable areas; (c) continuous corridors of varying width which provide an uninterrupted link between two larger patches of habitat, and (d) is where the intervening matrix has sufficient 'habitat' to allow wildlife to persist within the matrix as well as move between larger patches of habitat.

Text Box 1: Defining connectivity and habitat

There is a lot of jargon and confusion amongst researchers and practitioners around terminology in conservation biology. Here, we provide useful, simple definitions to explain various concepts and features of landscapes relevant to the discussion.

Landscape connectivity: the degree to which a landscape facilitates or impedes the movement of individuals or gametes. Landscape connectivity can be 'structural' or 'functional'. S*tructural connectivity* is a physical attribute of the landscape such as the arrangement of habitat types or land-cover classes and is generally measured along a spectrum from 'high' to 'low'. *Functional connectivity* is organism-orientated, where behavioural responses of the organism are interpreted to suggest which parts of the landscape are connected from the perspective of the organism.

Habitat: the area or natural environment in which an organism or population normally lives, and includes physical factors such as soil, shelter, moisture, light and moisture as well as biotic factors such as the availability of food, and the presence of predators or disease. The definition of habitat is species-specific – for example – a wetland is habitat for a frog or waterbird, but is not habitat for a Sugar Glider.

Habitat patch: these are the discrete blocks of habitat that are distinguishable from the surrounding matrix.

Core habitat or core area: are patches of habitat that are critical for the conservation of a species or community. Core habitat patches are often quite large (e.g. Lysterfield National Park) but may also be small patches of high quality habitat or provide critically important resources, such as for feeding or nesting.

Corridor, habitat corridor, wildlife corridor, dispersal corridor, movement corridor: provides a continuous, or near continuous, linear strip of habitat through an inhospitable environment, where the habitat within the corridor differs from the surrounding land in terms of vegetation and land-use and connects at least two patches of habitat (Bennett 1999).

Bioregional corridor: are often very wide and very long corridors that connect or pass through regions. Bioregional corridors may connect mountains to the ocean, run along mountain ranges or along large rivers. Bioregional corridors are often the focus of large-scale habitat restoration efforts, such as the Great Eastern Ranges Initiative (http://www.greateasternranges.org.au/), Habitat 141 (https://www.greeningaustralia.org.au/project/habitat-141) and Kosciuszko to Coast (http://www.landcare.nsw.gov.au/groups/kosciuszko-to-coast), however they may also be smaller in scale than these national initiatives, such as Dandenong Creek that extends from the Dandenong Ranges to Port Phillip Bay.

Stepping stones: are small patches of habitat that are separated by the matrix that provide connectivity for wildlife by providing opportunities for small movements or 'hops' from stepping stone to stepping stone. If there are sufficient stepping stones between large patches, they can provide connectivity across the landscape. Depending on the requirements of the target species, stepping stones can range in size and complexity from small patches of bushland to individual trees or clumps of grass. For example, gliders may use scattered trees in cleared farmland and residential areas as stepping stones provided they are within gliding range.

Habitat mosaic: is a matrix that contains a 'scattering' of natural vegetation more or less evenly spread across the landscape, such that it can't be classified as simply 'habitat' or 'matrix'. Some parts of Knox with extensive tree cover along streets and in residential properties could be considered a habitat mosaic.

Matrix: is the area of unsuitable habitat that surrounds suitable habitat. Traditionally, the matrix was seen as completely inhospitable, however numerous studies have since shown that the matrix varies along a gradient from completely inhospitable to quite satisfactory, depending on the species-specific tolerance to modified landscapes.

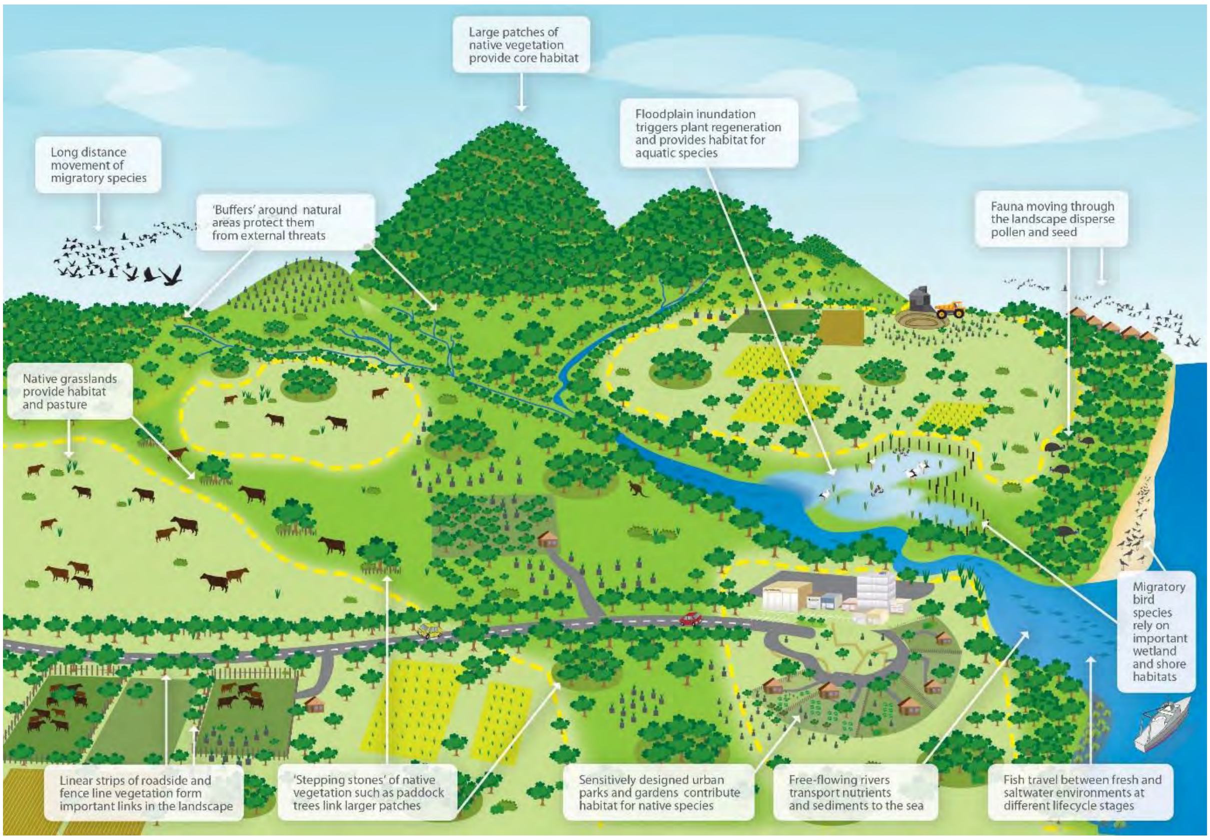


Figure 8. Schematic showing the myriad of different components of landscapes that contribute to connectivity.

It is clear that maintaining connectivity in a landscape relies on numerous and diverse landscape elements functioning together, such that if one movement path is temporarily damaged or destroyed other alternatives are available. Source: (DoSEWPC 2012)

2.4. Corridor width – how wide does a corridor need to be?

Corridors can perform multiple functions (Figure 9), namely (i) the provision of habitat; (ii) a pathway for movement, such as dispersal, migration and foraging; (iii) an influence on the surrounding vegetation; and (iv) acting as a barrier or filter to the movement of some species. For some species, corridors can provide most resources an individual may require throughout its life, such as Squirrel Gliders *Petaurus norfolcensis*, Brush-tailed Phascogales *Phascogale tapoatafa* and Yellow-footed Antechinus *Antechinus flavipes* occupying 20 – 40 m wide roadside corridors in central Victoria (van der Ree & Bennett 1999; van der Ree 2002, 2003; van der Ree & Bennett 2003). In many regions, corridors provide the only examples of plant species that remain in otherwise developed areas, including agricultural and urban areas (Lorimer 2010b) For other species, the corridor provides temporary habitat while it is moving through the landscape between patches of habitat. Corridors have been used to influence adjacent landscapes for many years, such as through the use of shelterbelts in agricultural areas to ameliorate harsh climatic conditions for stock. Other corridors can be a barrier or filter to the movement of wildlife, such as cleared transmission lines through forest that prevent some gap-sensitive species from crossing over.

Figure 9. Some examples of the many types and functions of corridors.

(Left) provision of habitat in otherwise inhospitable landscape to support resident species, in this case road reserves in central Victoria for Squirrel Gliders, Brush-tailed Phascogales and Yellow-footed Antechinus; (Middle) corridors that influence adjacent land-uses, such as shelterbelts to protect stock; and (Right) corridors that may act as a barrier to the movement of wildlife, such as roads cleared utility easements through forest. It is important to note that most corridors also support the movement of wildlife simultaneously. For example, a cleared powerline easement may provide habitat for small mammals that prefer open habitat (e.g. Clarke et al. 2006) as well as limit the movement of birds that only occupy interior forest habitat.

The ability of a species to use a corridor is dependent on a number of factors, primarily including (i) the quality of the habitat within the corridor; (ii) corridor width; (iii) corridor length; and (iv) the 'severity' or 'harshness' of the landuses and threatening processes in the adjacent matrix. For example, a corridor of remnant forest that is 50 m wide may be adequate for a species that is sensitive to disturbance if the matrix is a native forest plantation, but may be inadequate for the same species if the adjacent land-use is high-density residential, intensive agricultural or heavy industrial.

There have been many attempts to calculate 'rules of thumb' for the minimum width of corridors to facilitate their certain functions. While the working mantra of "the wider the better" or "as wide as possible" should be adopted where possible, corridors generally fall into these broad groupings:

a) Approximately 20 m wide for short corridors (e.g. a few hundred metres) and generalist species.
b) Approximately 50 m wide if the corridor to provide habitat for generalist species, provide a minimum buffer from adjacent land-uses and cater for a larger diversity of species over short-medium lengths (up to 1 – 2 km).
c) Approximately 200 m wide to provide relatively high quality interior habitat for long corridors (e.g. ~ 5 km).
d) Approximately 1 km wide for bioregional corridors connecting large areas over long distances (e.g. 10s of km).

If the corridor is to fulfil other functions as well as wildlife movement, such as public open space, wildlife habitat, buffer from adjacent land-uses, utility easements, it needs to be wider again to accommodate the often-competing demands.

2.5. International, national, state and local connectivity strategies and plans

There are numerous plans and strategies at a range of spatial scales which focus on preserving and enhancing connectivity for biodiversity. Because landscape connectivity is important across a range of spatial scales, these strategies have been written, adopted and enacted by various agencies and organisations, ranging from international treaties for migratory birds down to specific recommendations at the local municipality-level to facilitate the movement of a specific species of wildlife across a specific road. The next sections summarise some of these strategies, demonstrating that planning for connectivity for wildlife movement by KCC fits into a larger program of works, designed to maintain functioning ecosystems and healthy biodiversity.

2.5.1. International treaties and conventions

The Australian Federal Government (DoEE 2017c) has signed onto a number of environmental treaties and agreements protecting species that migrate across international territories. These agreements include migratory bird agreements with Japan (JAMBA, 6 Feb 1974), China (CAMBA, 20 Oct 1986) and the Republic of Korea (ROKAMBA, 6 Dec 2006). Australia is also a signatory to the Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention), the Ramsar Convention on Wetlands, the Agreement on the Conservation of Albatrosses and Petrels (ACAP, 1 Feb 2004), and the East Asian - Australasian Flyway Partnership (6 November 2006). An outline of each of the agreements is provided below.

Migratory bird agreements (JAMBA, CAMBA and ROKAMBA)

These international agreements are in place to ensure the conservation of migratory birds using the East Asian - Australasian Flyway. Their primary function is to protect important migratory bird habitat (DoEE 2017a).

East Asian - Australasian Flyway Partnership

The East Asian - Australasian Flyway Partnership is an informal voluntary initiative adopted in the list of the World Summit on Sustainable Development as a Type II initiative. Launched in 2006, the key objectives are to protect migratory waterbirds and their habitat, and the livelihoods of people dependent upon them.

The East Asian-Australasian Flyway includes 22 countries from the Arctic Circle, through Asia to Australia and New Zealand (EAAFP 2017).

Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals)

The Bonn Convention, or the Convention on the Conservation of Migratory Species (CMS), is an environmental treaty under the auspices of the United Nations Environment Programme. The agreements may range from legally binding treaties (called Agreements) to less formal instruments, such as Memoranda of Understanding. It is the only global convention specializing in the conservation of migratory species, their habitats and migration routes. The key objective is to conserve and / or restore habitat and militate against obstacles to migration (CMS 2017).

Ramsar Convention on Wetlands (Ramsar Wetlands)

The Ramsar Convention includes both natural and human-created wetlands, which under the convention includes swamps, marshes, billabongs, lakes, salt marshes, mudflats, mangroves, coral reefs and rivers regardless of whether they are natural or artificial, permanent or temporary. The Ramsar Convention encourages the designation of sites containing representative, rare or unique wetlands, or wetlands that are important for conserving biological diversity.

A wetland must meet measurable ecological characteristics to be included as a Ramsar site. Ecological characteristics can be based on the ecological, botanical, zoological, limnological or hydrological importance. Once included as a Wetland of International Importance, the signatory must manage it in such a way that it maintains its ecological character. The Western Treatment Plant west of Melbourne is a prime example of a human made Ramsar Wetland, whilst the Edithvale-Seaford Wetlands are a naturally occurring Ramsar Wetland.

Directory of Important Wetlands in Australia

The Directory of Important Wetlands in Australia (DoEE 2017b) provides information of what defines important wetlands outside of those listed under the Ramsar Convention, and the many flora and fauna species that depend on them. The criteria for determining nationally important wetlands in Australia were agreed by the ANZECC Wetlands Network in 1994. A wetland may be considered nationally important if it meets at least one of these six criteria:

1. It is a good example of a wetland type occurring within a biogeographic region in Australia.
2. It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.
3. It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail.
4. The wetland supports 1% or more of the national populations of any native plant or animal taxa.
5. The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level.
6. The wetland is of outstanding historical or cultural significance.

Of particular relevance is Criteria 3 in that these sites facilitate not only connectivity for both intercontinental migratory birds but also intracontinental species (DoEE 2017b).

Each of the international treaties / agreements acknowledges the importance and promotes connectivity across international and national boundaries for breeding, foraging and the population health of migratory species. The primary objective is to ensure clear frameworks and strategies are in place to support landscape connectivity through protecting habitat in the form of stepping stones between the migratory exit point and the final destination.

Australia's obligations for species listed under each of the above agreements and their habitat are encapsulated within the Commonwealth's *Environment Protection and Biodiversity and Conservation Act 1999.*

2.5.2. National plans for connectivity

There is one key plan for establishing corridors at a national scale and a number of plans that cross state borders, examples of which are included in this next section.

National Wildlife Corridors Plan

The National Wildlife Corridors Plan (2012) acknowledges that landscape restoration works undertaken by community groups, non-government agencies (NGO) and private land owners has the potential to contribute to the creation of wildlife corridors. The plan provides a framework for adding value to conservation traditionally represented through formal reservation and management.

The Corridors Plan recognises the crucial function of connectivity for wildlife and aims to make the landscape habitable for communities of plants and animals, allowing their movement, adaptation and evolution (DoSEWPC 2012).

Habitat 141 - Outback to Ocean Landscape Conservation Plan

Habitat 141 is a 50 year project among an alliance of more than 10 organisations to restore and reconnect the landscapes along the 141st longitude. The 141st longitude is recognised as a biodiversity hotspot starting at the southern coast of South Australia and along the Victorian border north to the rugged rangelands of New South Wales.

The conservation plan provides a framework for delivering the plan based on the best available information and knowledge, identifying priorities for action based on recommendations from leading scientists. Priority projects identified during an initial workshop have achievable objectives, strategies and actions developed that are clearly measurable (Koch 2015).

The Trans-Australia Eco-Link – South Australia and Northern Territory

The Trans-Australia Eco-link wildlife corridor was announced by the Northern Territory and South Australian Governments in 2010 (IUCN 2010). The corridor is expected to cover approximately 1.4 million square kilometres providing a landscape approach to connectivity through a continuous refuge of native habitat from Port Augusta to Arnhem Land.

The Eco-link builds on existing corridor strategies, such as NatureLinks, implemented in South Australia, which links central Eyre Peninsula of South Australia to the Western Australian border. The key elements of the corridor strategy consist of:

- protected core areas of habitat in conservation parks, reserves and heritage agreement sites;
- linking areas of remnant and restored habitat; and
- creating buffer zones to preserve these areas.

The Great Eastern Ranges Initiative

The Great Eastern Ranges Initiative is aiming to bring stakeholders together from Western Victoria through NSW and the ACT to Far North Queensland to protect, link and restore healthy habitats over the 3,600 km length of the Great Dividing Range. The initiative is based on supporting voluntary partnerships through a strategic and scientific approach.

The key objectives are to mitigate the potential impacts of climate change, invasive species, land clearing and other environmental changes on our richest biodiversity and iconic landscapes. Priority areas for action are identified through spatial analysis, regional planning, project development and monitoring success (GER 2017).

2.5.3. State plans and strategies for connectivity

Adelaide International Bird Sanctuary – South Australia

The Adelaide International Bird Sanctuary is 25 km north of Adelaide and encompasses sections of the decommissioned Dry Creek Saltworks. The sanctuary is recognised as a globally significant site for migratory birds and the site plans are guided by the aims and objectives of the international East Asian-Australasian Flyway network (NRAMLR 2017).

Gondwana Link – South-western Australia

Gondwana Link is in its thirteenth year of operation and encompasses local, regional and national stakeholders across six regions of south-western Australia (http://www.gondwanalink.org/). The Gondwana Link project provides an excellent example of a well-tested structured framework to achieve its stated aims of:

- restoring ecological connectivity across south-western Australia, from the dry woodlands of the interior to the tall wet forests of the far south-west corner
- protecting and restoring biodiverse bushland on an unprecedented scale
- building a living link that reaches eastward across the continent.

2.5.4. Regional and local plans for connectivity

Northwest Ecological Connectivity Investigation

The Northwest Ecological Connectivity Investigation has been commissioned by Hume and Brimbank councils in Melbourne's north. The primary objective is to identify ecological connectivity priorities for the development of an Ecological Connectivity Plan across the two municipalities.

This investigation uses the same connectivity modelling framework previously undertaken for Melbourne Water. The framework uses a GIS to assess landscape connectivity for surrogate lifeform groups and / or indicator species and landscape scale habitat suitability and resistance to fauna movement (connectivity) at a landscape (O'Malley et al 2011).

Waterways Corridors: Guidelines for greenfield development areas within the Port Phillip and Westernport Region

Melbourne Water's (MW) Waterway Corridors Guidelines (Melbourne Water 2013) provides advice on MW's minimum standards for corridor width and vegetation quality when infrastructure / development is proposed near waterways in greenfield areas. The guidelines cover existing waterways and constructed waterways.

The guidelines are prescriptive and provide detailed information on the overall setback widths, core riparian and buffer zone widths. The guidelines are intended for use for by government authorities, local government and developers.

Murrumbidgee River Corridor Management Plan 1998

The Murrumbidgee River Corridor consists of land and water up to 4 km wide along the 66 km length of the Murrumbidgee River through the ACT. The management plan sought to address the management issues, objectives, management policies and procedures within the corridor whilst ensuring that it is consistent with the National Capital Plan and the Territory Plan.

The plan identifies the function of the corridor, and provides management objectives, strategies, guidelines and identifies where further investigations are required in order to fill knowledge gaps. A particular focus is management guidelines of leasehold grazing areas for rural lessees (Department of Urban Services 1998).

Banyule City Council

The Banyule Wildlife Corridor Program (Brown 2000) was developed to link areas of natural habitat to sites of environmental significance within the municipality in order to facilitate the movement and dispersal of native animals and plants. It was acknowledged that there were residential areas with remnant vegetation that could facilitate connectivity between larger areas of natural habitat and the sites of botanical significance.

The core focus of the program was to increase the awareness and involve the major the stakeholders, i.e. the community, in protecting and re-establishing wildlife corridors and where appropriate provide financial incentives. Key on-ground strategies include:

- Protection of indigenous vegetation and natural habitat remnants throughout the City of Banyule;
- Undertaking revegetation and habitat restoration activities within the wildlife corridors and habitat links; and
- Encouraging the re-establishment of habitat on private land within and adjacent to wildlife corridors.

2.6. Relevant Environmental Policy and Legislation

The following Commonwealth and State Acts provide guidance and direction for the management of waterways, vegetation and wildlife habitat, including within wildlife corridors.

Environment Protection and Biodiversity Conservation (EPBC) Act 1999

One of the main aims of the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) is to provide for the conservation of biodiversity and the protection of the environment, in particular those aspects that are considered to be Matters of National Environmental Significance (MNES). The current nine MNES are:

- world heritage properties
- national heritage places
- wetlands of international importance (often called 'Ramsar' wetlands after the international treaty under which the wetlands are listed)
- nationally threatened species and ecological communities
- migratory species
- commonwealth marine areas
- the Great Barrier Reef Marine Park
- nuclear actions (including uranium mining)
- a water resource, in relation to coal seam gas development and large coal mining development.

Under the Act, actions that are likely to have a significant impact upon MNES require approval from the Environment Minister to undertake those actions. An action includes any project, development, undertaking, activity or series of activities.

Ramsar - The Convention on Wetlands of International Importance 1971

The Convention on Wetlands is an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and appropriate use of wetlands and their resources. The Convention uses a broad definition of the types of wetlands covered in its mission, including swamps and marshes, lakes and rivers, wet grasslands and peatlands, oases, estuaries, deltas and tidal flats, near-shore marine areas, mangroves and coral reefs, and human-made sites such as fish ponds, rice paddies, reservoirs, and salt pans.

Victorian Planning Provisions

Under Clause 52.17-2 of Victoria's Planning Provision a permit is required to remove, destroy or lop native vegetation, including dead native vegetation. This does not apply if exemptions under Clause 52.17-6 are relevant or the area for removal is included in a schedule or Native Vegetation Precinct Plan. Before deciding on an application a responsible authority must consider a number of issues outlined in Clause 52.17-5.

Planning and Environment Act 1987

The Planning and Environment Act 1987 established the framework for the use, development and protection of land in Victoria. The Act provides for the preparation of standard provisions for planning schemes which are administered by local government.

Permitted clearing of native vegetation - Biodiversity assessment guidelines

Permitted clearing of native vegetation – biodiversity assessment guidelines (the Guidelines) replaced Victoria's Native Vegetation Management: A Framework for Action as an incorporated document in Victoria's Planning Provisions in December 2013. The Guidelines provide instructions on how an application for a permit to remove native vegetation is to be assessed under the Planning and Environment Act 1987, including requirements to undertake a site assessment, site-assessment methodology, and any specific conditions that may form part of the permit such as offsetting.

The key objective of the Guidelines is to ensure there is no net loss in the contribution made by native vegetation to Victoria's biodiversity. To achieve this objective, the referral authority will consider in their decision to approve a permit whether the proponent has or will adequately address the following three step-process:

- avoid the removal of native vegetation that makes a significant contribution to Victoria's biodiversity
- minimise impacts on Victoria's biodiversity from the removal of native vegetation
- where native vegetation is permitted to be removed, ensure it is offset in a manner that makes a contribution to Victoria's biodiversity that is equivalent to the contribution made by the native vegetation to be removed.

Applications are assessed under three risk pathways (low, medium or high) depending on the size and significance of remnant vegetation proposed for removal. Proponents can refer to the online-tool Native Vegetation Information Management (NVIM) to understand which risk-pathway their application will be assessed under. The biodiversity report produced by the NVIM tool can be used as part of an application under a low-risk pathway, whereas a site assessment is required as part of an application under the medium or high-risk pathways.

Flora and Fauna Guarantee Act 1988

The *Victorian Flora and Fauna Guarantee Act 1988* (FFG Act) was established to provide a legal framework for enabling and promoting the conservation of all Victoria's native flora and fauna, and to enable management of potentially threatening processes. One of the main features of the Act is the listing process, whereby native species and communities of flora and fauna, and the processes that threaten native flora and fauna, are listed in the schedules of the Act. This assists in identifying those species and communities that require management to survive, and identifies the processes that require management to minimise the threat to native flora and fauna species and communities within Victoria.

A permit from DELWP is required to 'take' listed flora species that are members of listed communities or protected flora from public land. A permit is not required under the FFG Act for private land, unless listed species are present and the land is declared 'critical habitat' for the species.

Environment Effects Act 1978

Under Victoria's *Environmental Effects Act 1978* (EEA), projects that could have a 'significant effect' on Victoria's environment can potentially require an Environmental Effect Statement (EES). This Act applies to any public works 'reasonably considered to have or be capable of having a significant effect on the environment'. The Minister for Planning and Environment is the responsible person for assessing whether this Act applies.

Before commencing any public works to which this Act applies, the proponent must initiate an EES to be prepared and submit it to the Minister for the Minister's assessment of the environmental effects of the works.

The criteria for the types of potential effects on the environment that might be of significance and therefore warrant referral of a project include:

- potential clearing of 10 ha or more of native vegetation
- matters listed under the Flora and Fauna Guarantee Act 1988:
    - potential loss of a significant area of a listed ecological community; or
    - potential loss of a genetically important population of an endangered or threatened species (listed or nominated for listing), including as a result of loss or fragmentation of habitats; or
    - potential loss of critical habitat; or
    - potential significant effects on habitat values of a wetland supporting migratory bird species
- potential extensive or major effects on land stability, acid sulphate soils or highly erodible soils over the short or long term
- potential extensive or major effects on beneficial uses of waterbodies over the long term due to changes in water quality, stream flows or regional groundwater levels.

Catchment and Land Protection Act 1994

The *Catchment and Land Protection Act 1994* (CaLP Act) is the principle legislation relating to the management of pest plants and animals in Victoria. Under this Act, landowners have a responsibility to avoid causing or contributing to land degradation, including taking all reasonable steps to conserve soil, protect water resources, eradicate regionally prohibited weeds, prevent the growth and spread of regionally controlled weeds and where possible, eradicate established pest animals, as declared under the Act.

Wildlife Act 1975

The *Wildlife Act 1975* forms the procedural, administrative and operational basis for the protection and conservation of native wildlife within Victoria. This Act often sits as the default reference for other associated legislation, and is the basis for the majority of Wildlife permit / licensing requirements within the state. In accordance with this Act, any wildlife located within vegetation proposed for clearing may require salvage and translocation.

Plan Melbourne 2017-2050

Plan Melbourne 2017-2050 sets out the Victorian Government's vision and plan for how Melbourne will grow over the next 35 years. The Implementation plan for the next 5 years identifies several actions pertinent to this report; including Action 63- Waterway corridor master plans, Action 73- Green Wedge Management Plans, Action 91- Whole-of-government approach to cooling and greening Melbourne, Action 93- Metropolitan open space strategy, and Action 94- Protecting the health of waterways from stormwater runoff.

3.0 Methods

3.1. Study Area

To assess landscape connectivity and wildlife movement opportunities within Knox, it is critical to include the larger landscape context in which Knox is situated. For this report we have defined our Study Area as the City of Knox and a 1km buffer into adjacent local government areas.

Within the Study Area we have divided the landscape into seven precincts consisting of the Council's five designated Rural Land Precincts (RLPs), the remaining areas of Knox (Non-RLP), and the 1 km buffer into adjacent LGAs. The use of the Rural Land Precincts enables Council to link this work with their current review of the land-use in these areas to help inform decision-making related to future development within different areas of the municipality.

3.2. Collation of existing wildlife records and requests for data

Biodiversity records, specifically terrestrial and semi-aquatic vertebrates occurring within the study area were compiled from a number of different sources. The primary source was the State of Victoria's Victorian Biodiversity Atlas (https://vba.dse.vic.gov.au/vba/). The VBA (DELWP 2017) is the main repository of biodiversity data for Victoria, and is managed by the Department of Environment, Land, Water and Planning (DELWP). It contains more than six million records of species distribution and abundance from systematic surveys and general observations covering all fauna and flora species present in the state.

We also obtained records from the Atlas of Living Australia (ALA), Melbourne Water Frog Census, Birdlife Australia Atlas, Field Naturalists of Victoria and individual researchers. The ALA is a national biological database containing over 67 million occurrence records, based on specimens, field observations and surveys. We extracted all records for the KCC area from the ALA. We also requested records of our ten focal species (Section 3.3) from participants of the Knox Gardens for Wildlife program. See Appendix 3 for an overview of the different sources of biodiversity records that were compiled for this study.

As the format for these data was highly variable, we added a unique identifier to each record in each database, and then compiled all of the records into a single master database that we have called the "Knox Wildlife Atlas". We recommend that the Knox Wildlife Atlas form the beginning of a central repository of biodiversity records that are relevant to the City of Knox. The Knox Wildlife Atlas has been provided to KCC in a QGIS compatible format so it can be queried and added to over time. Future records can be added from new sources and searches using a similar process whereby all data sources can be searched simultaneously in the Knox Wildlife Atlas, but details about individual records can be found in the original datasets using the unique record identifier and the source file fields.

It is important to note that many organisations contribute biodiversity records to multiple databases, for example BirdLife Australia and the Field Naturalists Club of Victoria (FNCV) both hold their own datasets but also contribute these as records in the VBA. Therefore, there will be duplication in the records contained within the Knox Wildlife Atlas, and this will need to be accounted for when the database is used for any quantitative analysis. An example of how this duplication can be accounted for is provided in the methods for the Focal Species Analysis (Section 3.4.3). It was beyond the scope of this study to identify and resolve all duplicate records within the Knox Wildlife Atlas.

3.3. Selection of focal species

Our comprehensive searches of the various databases returned hundreds of thousands of records of hundreds of species of wildlife that varied in terms of currency (some records originating from the 1800s), locational accuracy and species identification accuracy. Appendix 4 details the year of last sighting for all wildlife species within the study area and by each RLP. It should be noted that we only used records made after 1995 in our analyses and summaries of species occurrence for this project.

Attempting to identify important habitat features that support biodiversity and facilitate landscape connectivity for hundreds of species is an untenable proposition within the scope of this project. In these situations, a sub-set of species, collectively termed 'indicator' species, is often used when it is not possible to directly measure the species of interest. An indicator species is "an organism whose characteristics (e.g. presence or absence, population density, dispersion, reproductive success) are used as an index of attributes too difficult, inconvenient, or expensive to measure for other species or environmental conditions of interest" (Landres et al. 1988 p.317). There are many kinds of indicator species (e.g. umbrella, bio-indicator, keystone, surrogate, pollution indicator), each with a different meaning and intent (Lindenmayer & Burgman 2005). In practise, indicator species are usually a suite or group of species, rather than a single species, which ideally are sufficiently sensitive/demanding to respond to changes in environmental conditions as well as, if possible, be locally important (e.g. threatened or iconic) to raise its profile and garner public support. Importantly, indicator species should not be so sensitive or specialised that they only survive in large patches of intact wilderness or pristine habitats. For this project, we needed species that were moderately sensitive in order to derive useful results that will assist in planning development of the Rural Land Precincts.

In this study, we selected a suite of ten focal species (Figure 20, Table 7) for further consideration, based on the following criteria to ensure that all species considered were likely to have suitable habitat still present in the study area with sufficient records to draw meaningful conclusions.

- Being recorded as present within the Knox study area since 1995, and having a location accuracy of up to 300 m. Many records within the various databases included an assessment of the accuracy of the given locality where the species was observed. Where this 'locational accuracy' exceeded 300m, we excluded these records from the focal species analysis.
- A minimum of ten records within the Knox Wildlife Atlas. Over 100 species in the Knox Wildlife Atlas had less than five records, many with a single record, and thus the study area is unlikely to form important, or core, habitat for these species.
- Being representative of a larger group of organisms, either through their behaviour or habitat requirements. We selected species from different taxonomic groups and strata, including birds, arboreal and terrestrial mammals, amphibians, and terrestrial and semi-aquatic reptiles. This ensures that the findings and management recommendations are broadly appropriate for many species.
- Having been sufficiently studied to thoroughly understand their habitat and connectivity requirements to allow clearly supported management recommendations to be drawn.

Once the suite of focal species was selected, we sourced relevant ecological and biological information about these focal species from a variety of sources, which is presented in Appendix 5. We primarily relied on papers published in the scientific literature (i.e. peer reviewed), supported by reports and other 'grey' literature where necessary. For each species we focussed on identifying:

- Suitable breeding or resident habitat, and where the resolution existed, preferences within a range of suitable habitats;

- Suitable dispersal habitat (if different to resident or breeding habitat). Some species are able to move through a larger range of habitats than they are resident;
- Maximum and average movement or dispersal distances through both suitable breeding and dispersal habitat; and,
- Barriers or filters to dispersal, and the level of each barrier to movement. Some barriers will prevent all movement of a species, while others may only reduce dispersal or movement.

Where sufficient species-specific information existed, we used data that was collected geographically closer to Knox. Where sufficient data on a focal species did not exist, we substituted information from closely related species (always within the same genus) and this is noted in the results.

3.4. Mapping and modelling methods

3.4.1 GIS analysis

The existing characteristics of the Rural Land Precincts (RLP) and the remaining areas within City of Knox were summarised using available geospatial layers provided by KCC, and supplemented by additional data themes from the State of Victoria's Spatial Data Mart. A number of different terms are used to describe different data types and these are summarised in Text Box 2.

3.4.2 Summary of wildlife records within the study area

To examine general trends in wildlife records across the study area we assigned each record in the Knox Wildlife Atlas to the Precinct it was associated with, and these were summarised to provide information about important areas for the species within the Study Area (Table 4). As the focus of this report is on current populations of wildlife, we excluded any records that were collected prior to 01/01/1995. We also wanted to be confident in the locational accuracy of the records, so as a quality control measure we excluded all records which had a locational accuracy of > 1000m.

3.4.3 Focal species analysis

Records of the ten focal species within the Study Area were extracted from the Knox Wildlife Atlas. Each record was then assigned to the RLP in which it occurred, and these were summarised to provide information about important precincts for the species within the Study Area (Table 8, Table 9). As the focus of this report is on current populations of these focal species, we excluded any records that were collected prior to 01/01/1995. We also wanted to be confident in the locational accuracy of the records, so as a quality control measure we excluded all records which had a locational accuracy > 300 m. This locational accuracy is even finer than that used for the general summary of wildlife records as we were quantifying the characteristics of the landscape within 500 m of each record and therefore needed to be confident that the record was a close representation of the actual location where the species was observed in the real world. This is described in more detail later in this section.

Since there are likely many duplicates of records within the Knox Wildlife Atlas which are hard to identify and extract easily (e.g. FNCV and BirdLife Australia both submit records to the VBA) which would have implications for the focal species site analyses, we condensed the full collection of records for each focal species down to a set of **locations** where each species had been recorded. This was done by summarising the records by their combinations of geographic coordinates (latitude and longitude), where records with the matching coordinates are considered to belong to the same location. For each location we retained the list of focal species recorded at that location, the year of the latest record for each species at that location, as well as the total number of records for each species at that location. These were then considered to be independent **locations** for each species, and this allowed us to perform subsequent analyses without introducing biases due to duplicated records at a single location. This summarised dataset is provided in Appendix 4.

Text Box 2: Definitions of data types and areas used in our analysis

Data Source- Individual collection of records held by an individual or organisation.

Knox Wildlife Atlas- Master database containing compiled records from individual Data Sources, with a simplified set of information for each record, and a Unique ID which allows the original record to be located within the individual Data Source file if further information is required beyond that provided in the Knox Wildlife Atlas.

Location- A unique point in space (latitude/longitude). Locations were extracted from the full set of Focal Species Records, and each location will have a variable number of species or records associated with it. Multiple records of the same species at a location is essentially represented as a presence or occurrence value only.

Locational Accuracy- as species records are typically represented by a single point in a GIS theme, the locational accuracy is a way of articulating how closely the point in the database matches the place where the observation was made in the real world. Many of the databases we accessed assign a locational accuracy to each observation, usually represented in metres (e.g. ±100m).

Observation- A sighting, call, recording, scat, track, or other piece of evidence that indicates a specific species has been in the area. The observation has been reported to a database (e.g. the VBA, BirdLife etc), which we used to compile the Knox Wildlife Atlas.

Record- A single observation of a single species at one discrete point in time (date) and space (latitude and longitude).

Site- The area within a 500 m buffer around a Location for one of the ten focal species.

Study Area- The municipality of Knox, plus a 1km buffer that extended into adjacent municipalities.

To develop a better understanding of the characteristics of the local landscape where each focal species has been recorded we created a 500 m buffer around each location point. This area is what we refer to as a **site**. For each site we summarised the following landscape characteristics as outlined in

Table 2. The outcomes of these analyses provide insights into the landscape conditions in which the focal species are found (see 4.3. Focal species). This information can be used to inform decision-making for future actions within the Rural Land Precincts, or to identify important features of the landscape for protection or enhancement. Individual landscape characteristics may present an incomplete picture on their own, but when considered in combination help to explain the distribution of focal species across the Study Area.

Table 2. Data layers and GIS operations used to characterise the features of the landscape at each site.

Measure	Data Source	GIS method
Amount and type of each EVC from the NV2005 data layer from DELWP	Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria.	Intersect with Sites theme, recalculate area for features, summarize area by site
Length of rivers and streams	Watercourse Network 1:25,000 - Vicmap Hydro (HY_WATERCOURSE/) © State of Victoria.	Intersect with Sites theme, recalculate length for features, summarize length by site
Area of farm dams and billabongs	Draft layer provided by Melbourne Water	Intersect with Sites theme, recalculate area for features, summarize area by site
Area of open space, using the VEAC 2011 classifications and mapping	VEAC Metropolitan Melbourne Open Space Inventory (VEAC_METRO_OPEN_SPACE/) © State of Victoria.	Intersect with Sites theme, recalculate area for features, summarize area by site
Area of open space, using the ARCUE 2002 data layer	ARCUE Public Open Space Dataset © ARCUE, Royal Botanic Gardens Melbourne	Intersect with Sites theme, recalculate area for features, summarize area by site
Road density, as a proxy for degree of urbanisation, which is commonly used in many scientific studies to quantify the extent of urbanisation (McDonnell & Hahs 2008; Heard et al. 2010; Melbourne Water 2013)	Road Network - Vicmap Transport (TR_ROAD/) © State of Victoria.	Intersect with Sites theme, recalculate length for features, summarize length by site
Length of train line	PTV Train Track Centreline (PTV_TRAIN_TRACK_CENTRELINE /TRAIN_TR) © Public Transport Victoria	
Average size of property parcels, as an indication of development density	Cadastral Area Boundary - Vicmap Property (VMPROP_CAD_AREA_BDY/) © State of Victoria.	Intersect with Sites theme, summarize area by site (use original feature area values)

Extent of different Planning zones, as an indication of different land-uses	Planning scheme zones - Vicmap Planning (VMPLAN_PLAN_ZONE/) © State of Victoria.	Intersect with Sites theme, recalculate area for features, summarize area by site

For this analysis, we assumed that sampling effort across the municipality was relatively even, and that there were no massive biases in areas were records were collected. Because our focal species are also relative iconic, we would have expected sightings in unusual places (i.e. within the residential matrix) to be reported. Therefore, we expect that the records of the focal species are representative of their occurrence and relative abundance across the municipality.

3.4.4. Identifying important areas for conservation and movement of wildlife

To provide some guidance around ecologically important areas for wildlife habitat and movement within Knox, we used the information compiled in Appendix 5, and from other sources, to place buffers around some of the critical habitat elements for wildlife in the landscape. These buffers are outlined in Table 3. Buffer distances around streams and dams differ based on specifications of focal species.

Table 3. Details of size of buffers used to identify important areas for the conservation and movement of wildlife within Knox.

Ecologically Sensitive Habitat Element	Data Source	Buffer Distance	Reference
Riparian and freshwater areas			
1 in 100 year flood zones (natural and constructed waterways)	1 in 100 years flood extent © The State of Victoria, Department of Environment, Land, Water & Planning 2017	0 m	(Melbourne Water 2013)
Recommended Riparian buffer for Growling Grass Frog *Litoria raniformis*	Watercourse Network 1:25,000 - Vicmap Hydro (HY_WATERCOURSE/) © State of Victoria.	200 m	(Heard et al. 2010)
Stream Protection Zone including Core Riparian Zone (variable with stream order) and 10 m vegetated buffer	Watercourse Network 1:25,000 - Vicmap Hydro (HY_WATERCOURSE/) © State of Victoria.	50 m – Dandenong Creek 40 m – Blind Creek, Corhanwarrabul Creek, Monbulk Creek 20 m- all other waterways	(Melbourne Water 2013)
Farm Dams and Billabongs	Draft layer provided by Melbourne Water	375 m- 95% of turtle records in (Roe & Georges 2007)	See Appendix 5
Terrestrial elements			

Transition zones around remnant vegetation which protect integrity of existing vegetation and act as habitat elements for focal species	Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria.	180 m – Maximum distance travelled by Sugar Glider and Eastern Yellow Robin from bushland 300 m – Maximum distance travelled by Black Wallaby and Blue-tongued Lizard	See Appendix 5

3.5. A review of the Melbourne Water investigation into habitat connectivity

In 2011, Melbourne Water published an extensive investigation of landscape connectivity within the Port Phillip and Western Port region, focusing on Melbourne Water-managed areas (O'Malley *et al.* 2011). The goal of this work was to 'identify and prioritise biodiversity corridors across the Melbourne Water region to assist in improving and restoring structural and functional ecological connectivity'. The Melbourne Water study was focused on a much larger landscape and sub-regional scale compared to the scale of this study (i.e. KCC), and while many of the findings have broad relevance to the Knox municipality, the lack of fine-scale resolution in the analysis means results are not directly transferable to the smaller area. Nevertheless, the MW study identified a number of broad corridors or areas of higher-levels of connectivity of importance to the Knox LGA, namely the waterways and Rural Land Precincts. Below, we briefly summarise the methods and results from that study as they relate to the present report.

3.5.1. Methods used in the Melbourne Water habitat connectivity investigation

Surrogate species selection

Initially, surrogate species or species groups were selected to represent the full suite of species occurring in the study area, namely the Port Phillip and Western Port catchments. Factors considered in the selection of these surrogates were to ensure that:

- A range of habitat and connectivity requirements were present;
- Selected species were broadly representative of other species or species groups;
- Sufficient information was known to accurately estimate parameters required for subsequent modelling;
- A range of responses to landscape features were present (e.g. roads, urbanisation); and,
- Sufficient spatial data and resolution was available for landscape elements important to that surrogate.

On the basis of these selection criteria, five surrogate species or species groups were chosen: ground-dwelling mammals, woodland birds, frogs, fish and the Platypus *Ornithorhynchus anatinus*.

Assessing connectivity

The MW study adopted two approaches to calculating landscape connectivity. For the first, a composite map of landscape permeability for faunal movement was developed for each surrogate species or species group, which presented visually how easy it would be for that group to move across the landscape (Figure 10). This composite map comprised all the spatial layers considered relevant to determine movement for that surrogate group (e.g. EVCs, roads, waterways). For each spatial layer a permeability or resistance score was allocated to each attribute of that layer based on behavioural or ecological attributes of the surrogate group as determined from a review of relevant literature. An example of a resistance map is shown

For some surrogate groups these landscape permeability maps were used to determine corridors between pre-designated important habitat areas (a 'least-cost path analysis') (Figure 11). For a detailed explanation of the analysis methods see O'Malley *et al*. (2011).

3.5.2. Results of Melbourne Water connectivity investigation

Results from the modelling were primarily presented visually, with maps showing permeability / resistance across the whole Port Phillips and Western Port catchment and connectivity between important habitat for each surrogate group, and for all surrogate groups combined (Figure 10). Broadly, the study found that the highest restriction to faunal movement and occupation were urban landscapes for terrestrial surrogate groups, and for waterways within urban landscapes for aquatic surrogate groups. Furthermore, large areas of land supporting native vegetation had the lowest resistance to terrestrial faunal movement, followed by land adjoining natural and man-made watercourses. Resistance for aquatic surrogate groups was highest in urban landscapes, lower in agricultural landscapes, and lowest at higher elevation and in forested areas, while channels and modified watercourses had a higher resistance than natural waterways. All results are summarised from O'Malley et al. (2011).

The MW analysis confirms that the three main waterways within the Knox municipality (Dandenong Creek, Blind Creek and Corhanwarrabul Creek) and the Rural Land Precincts are critical to maintaining landscape connectivity for wildlife across Knox and into adjacent LGAs. This analysis demonstrates the importance of the existing 'corridors' as well as highlighting the difference in functional connectivity among the three waterways. For example, the section of Dandenong Creek that flows in a southerly direction from the northwest corner of Knox has the highest levels of relative importance compared to all other waterways, primarily due to its width and lack of development that increases relative resistance. Figure 10 and Figure 11 also clearly demonstrate how increased development and intensity of land-uses that reduce landscape permeability, such as major roads, residential and industrial development will increase landscape resistance and reduce movement of wildlife.

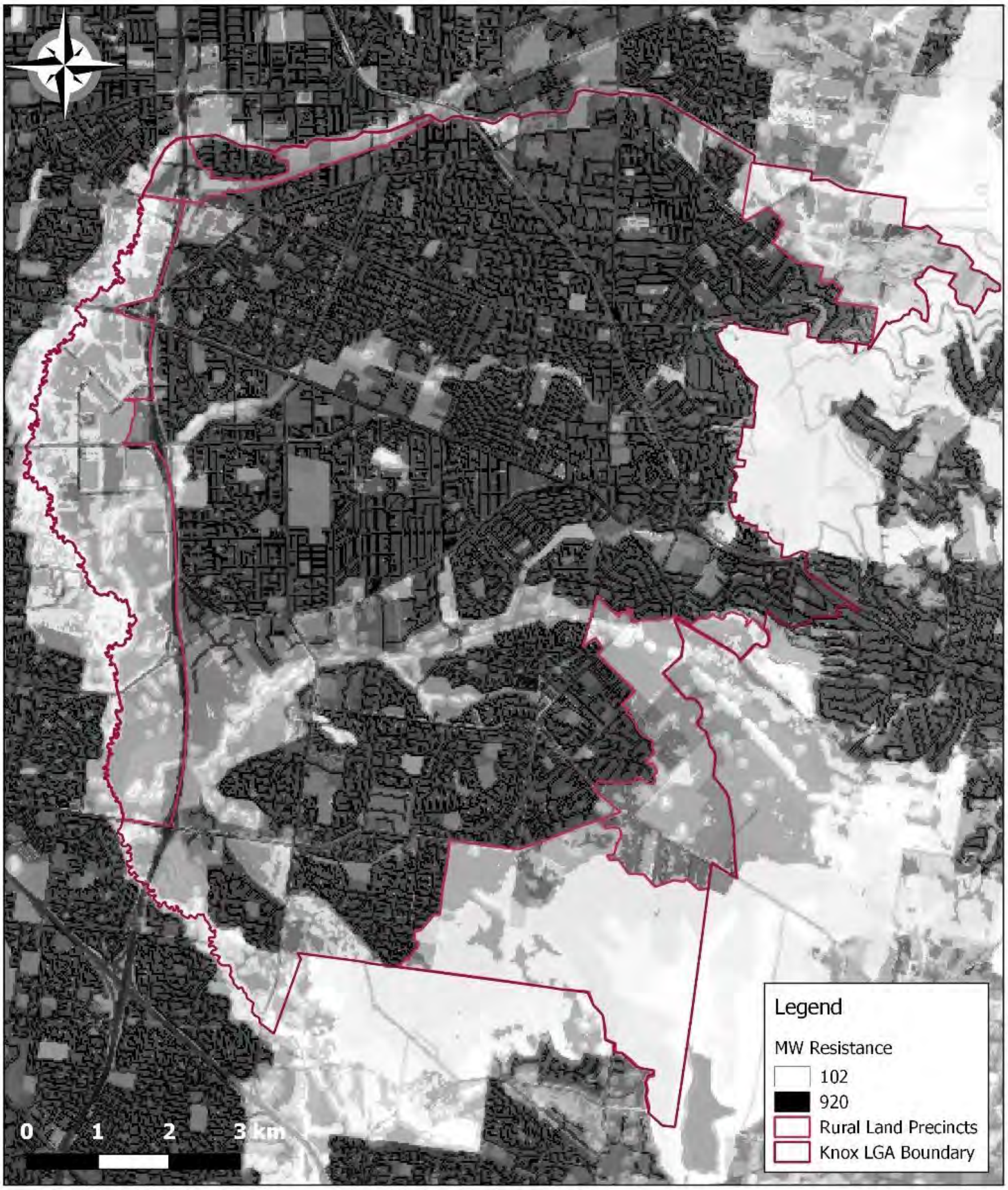


Figure 10. Relative resistance of the Knox municipality summed for all surrogate species and species groups combined. Areas with lighter colours have the lowest levels of resistance to faunal movement and darker colours increased resistance. The boundary of Knox City Council and the Rural Land Precincts are shown in red. (Source: O'Malley et al 2011a, b)

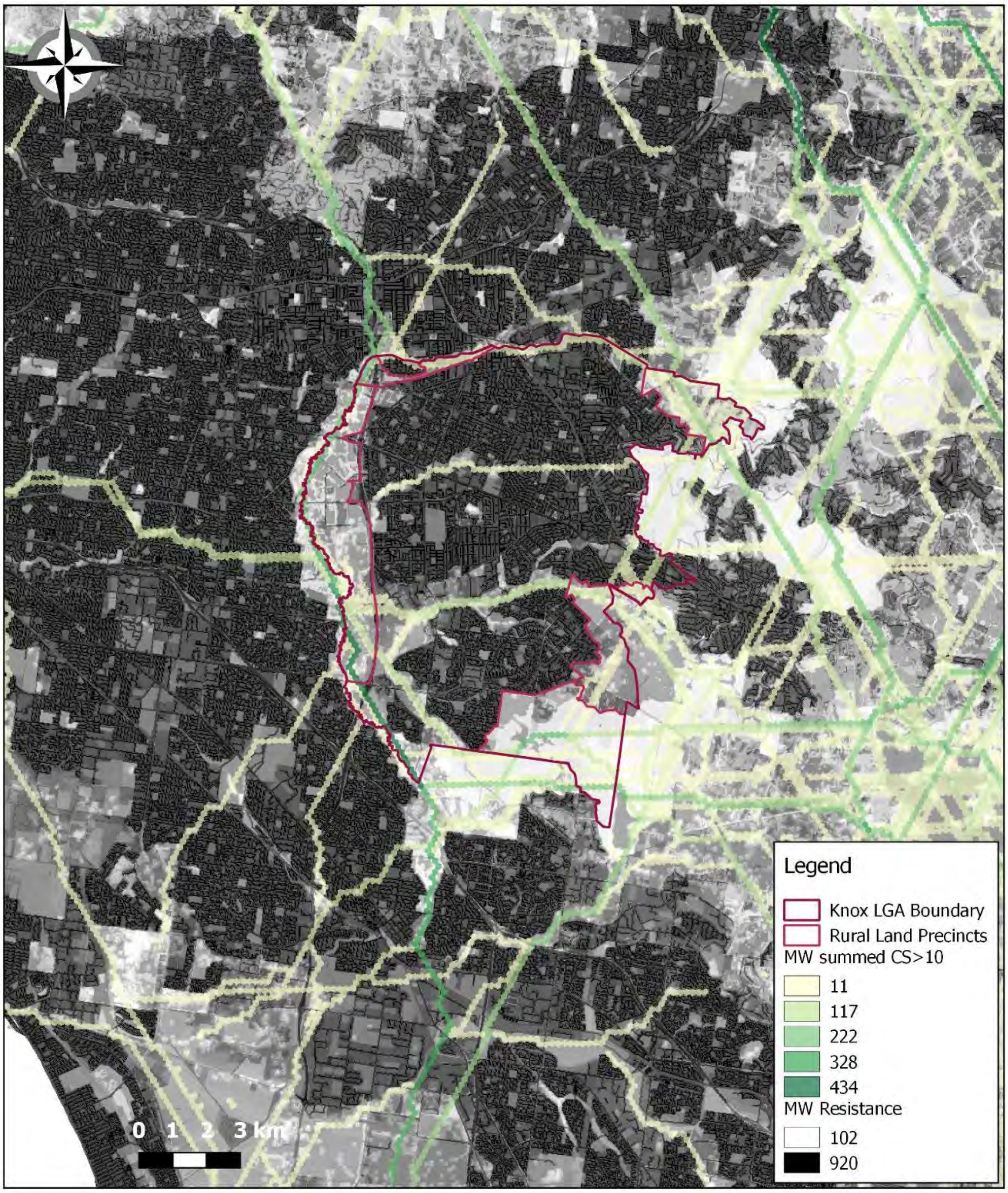


Figure 11. Relative resistance of the Knox and adjacent local government areas for all surrogate species and species groups and corridors for all terrestrial species and species groups with a corridor score > 10 (i.e. MW summed CS>10).

Greatest resistance is shown in black and least resistance in white, and darker greens represent higher order corridors suitable for more species. The Knox boundary and Rural Land Precincts are shown in red and highlights how connectivity within Knox is partially reliant on corridors outside the Knox municipality. Data derived from O'Malley et al (2011a, b).

4.0 Results

4.1. Wildlife in Knox

Since 1995, a total of 237 species of wildlife, namely amphibians, birds, mammals, and reptiles, have been recorded within the municipality of Knox, with a total of 228 occurring just within the 1km buffer around the outside of the Knox municipal boundary (Table 4). Not surprisingly, the species group with the highest diversity within Knox was birds with 192 species, including 176 native species and 16 introduced species. Twenty-five species of mammals have been recorded in Knox since 1995, including 18 native species and 7 introduced species. Eleven species of amphibian and nine species of reptile have also been observed in Knox (Table 4). Interestingly, the number of species recorded within the 1 km buffer outside the municipal boundary of Knox is not that dissimilar to the total number of species recorded within the municipality, highlighting the importance of those areas along the municipal boundary for both the conservation and movement of wildlife. On the eastern border of Knox, this buffer extends into the Dandenong Ranges National Park, to the south it includes Lysterfield and Churchill National Park and to the west and north it includes parkland along the Dandenong Creek.

Table 4. Number of native and introduced species per taxonomic group recorded in Knox since 1995, and in the area adjacent to Knox City Council boundary extending 1km into the surrounding LGAs.

	Knox LGA			Surrounding 1km around Knox Municipal Boundary		
	Native	Introduced	Total	Native	Introduced	Total
Amphibians	11	-	11	7	-	7
Bats	4	-	4	8	-	8
Birds	176	16	192	169	14	183
Terrestrial and semi-aquatic mammals	14	7	21	17	6	23
Reptiles	9	-	9	7	-	7
TOTAL	**214**	**23**	**237**	**208**	**20**	**228**

4.2. The vegetation, wildlife and landscapes of the Rural Lands Precincts and the remainder of Knox

The five RLPs within Knox are unique from each other and the remainder of Knox (Table 5). The precincts and the remainder of Knox vary significantly in overall area, average property size, amount of open space, road density and extent of native vegetation cover (Table 5, Figure 12). Because the RLPs differ so significantly from each other and the remainder of the Knox municipality, they are not substitutable. In other words, each precinct provides different values and functions from each other and each is valuable in its own right. The unique role of each RLP in supporting different EVC Groups is described in Section 4.2.1 to 4.2.5 and the role of each RLP in supporting each of the focal species is described in Section 4.3.2.

Table 5. Characteristics of each Rural Land Precinct and the remaining non-rural lands within Knox City Council

	Rural Land Precincts					
	1: The Basin Rural Landscape	2a: Lysterfield Valley and Hills	2b: Lysterfield quarries & surrounds	3: Dandenong Creek Valley	4: Healesville Freeway Reservation & surrounds	Non-Rural Land
Total Area (ha)	383.0	496.8	876.9	975.3	127.5	8542.8
Average Property Size (ha)	7.3	7.3	30.4	21.5	1.8	0.6
Standard Deviation Property Size (ha)	61.7	50.1	113.7	41.1	4.2	8.2
Number of Gardens for Wildlife properties	12	3	0	0	0	686
% of area comprising:						
*Road Class Codes 0 – 5	2.0%	2.0%	0.3%	3.4%	3.7%	7.0%
€ARCUE Public Open Space	8.6%	2.2%	65.4%	57.7%	31.8%	16.3%
Farm Dams/ Billabongs	1.3%	1.1%	0.4%	6.4%	0.6%	1.0%
ǀNative Vegetation	64.2%	15.5%	82.4%	31.6%	20.8%	5.3%
#Knox City Council Sites of Biological Significance	97.6%	63.4%	92.2%	54.8%	47.0%	24.4%
Bushland management areas	2.9%	1.4%	1.4%	0.3%	13.5%	1.1%
Knox Reserves	6.6%	2.0%	63.4%	19.4%	9.3%	11.3%
¥VEAC Metropolitan Melbourne open space	5.2%	2.4%	59.2%	63.3%	6.7%	11.9%

*Road class: 0=freeway, 1=highway, 2=arterial, 3=sub arterial, 4=collector, 5=local.
€Public Open Space mapped by the Australian Research Centre for Urban Ecology in 2002.
ǀNative vegetation mapped using the NV2005 spatial data layer from DELWP (see Appendix III for more detail).
#Sites of Biological significance from (Lorimer 2010a, b).
¥Open space mapped as part of the Metropolitan Melbourne Investigation (VEAC 2011).

Table 6. Total number of species per taxonomic group recorded in different precincts around Knox since 1995. The value in brackets is the % of species that are considered to be native.

	Rural Land Precincts					Non-Rural Land
	1: The Basin Rural Landscape	2a: Lysterfield Valley and Hills	2b: Lysterfield quarries & surrounds	3: Dandenong Creek Valley	4: Healesville Freeway Reservation & surrounds	
Amphibians	2 (100%)	9 (100%)	5 (100%)	2 (100%)	4 (100%)	9 (100%)
Bats	0	1 (100%)	2 (100%)	2 (100%)	1 (100%)	0
Birds	71 (92%)	71 (92%)	114 (91%)	142 (92%)	61 (89%)	176 (91%)
Mammals	10 (60%)	8 (88%)	13 (69%)	11 (64%)	1 (100%)	16 (63%)
Reptiles	5 (100%)	6 (100%)	2 (100%)	1 (100%)	0	2 (100%)

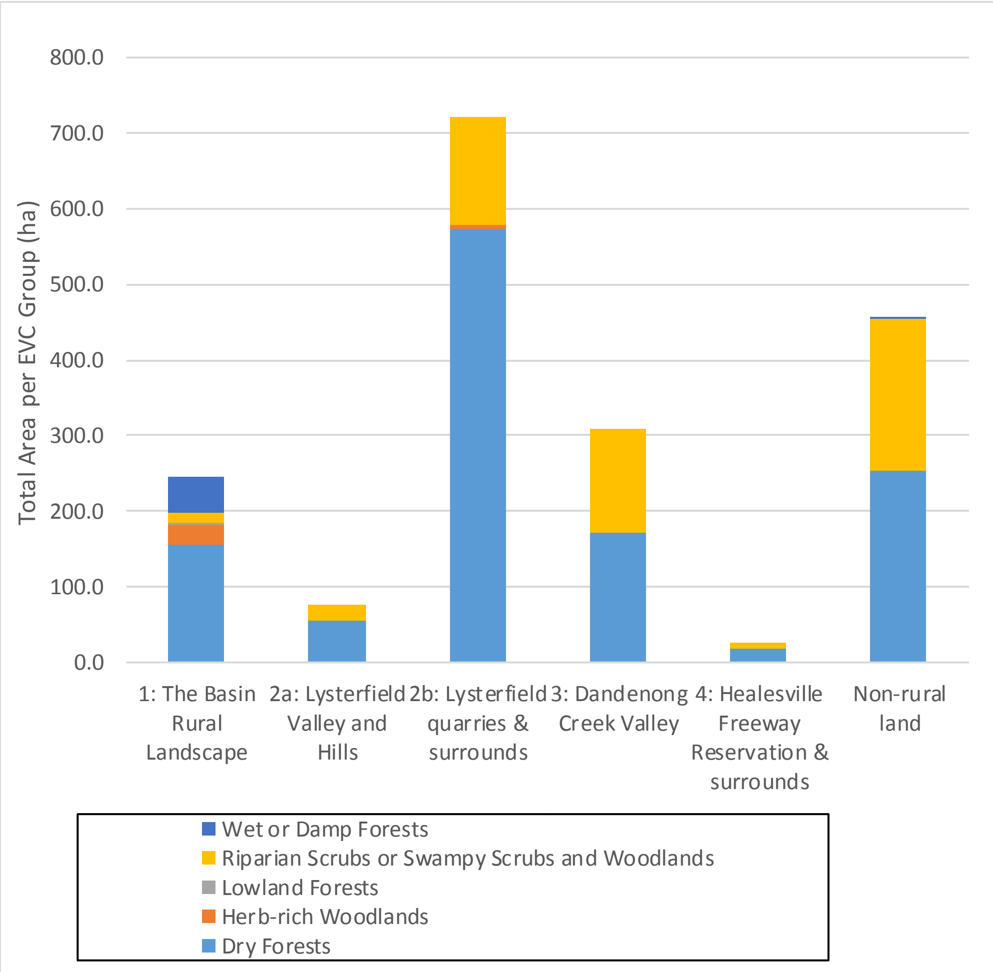


Figure 12. Extent of EVC Group in each of the Rural Land Precincts and the Non-Rural Land in Knox.

4.2.1. Precinct 1 – The Basin Rural Landscape

The Basin Rural Land Precinct is 383 ha in size and is dominated by the Dry Forests EVC type and cleared farmland (Figure 13), and is characterised by large allotment sizes. Importantly, almost two-thirds (64.2%) of this RLP supports native vegetation, and 97.6% of the area has been classified as Sites of Biological Significance for Knox, based primarily on the occurrence of native vegetation (Table 5). The Basin RLP is largely owned by a single land-owner, the Salvation Army, who purchased 219 acres (88 ha) in 1897 to develop a reform centre for youths who had committed crimes. Focussed around the benefits of farming, the Salvation Army had variously leased up to 700 acres (283 ha) in the area, teaching farming skills, including growing crops, raising livestock, a bakery and dairy. The past and present involvement of the Salvation Army in The Basin is a major contributor to its current rural outlook. Off all the RLPs, this precinct also has the largest number of residential properties, which is reflected in the largest number of Gardens for Wildlife Members of any precinct, with 12.

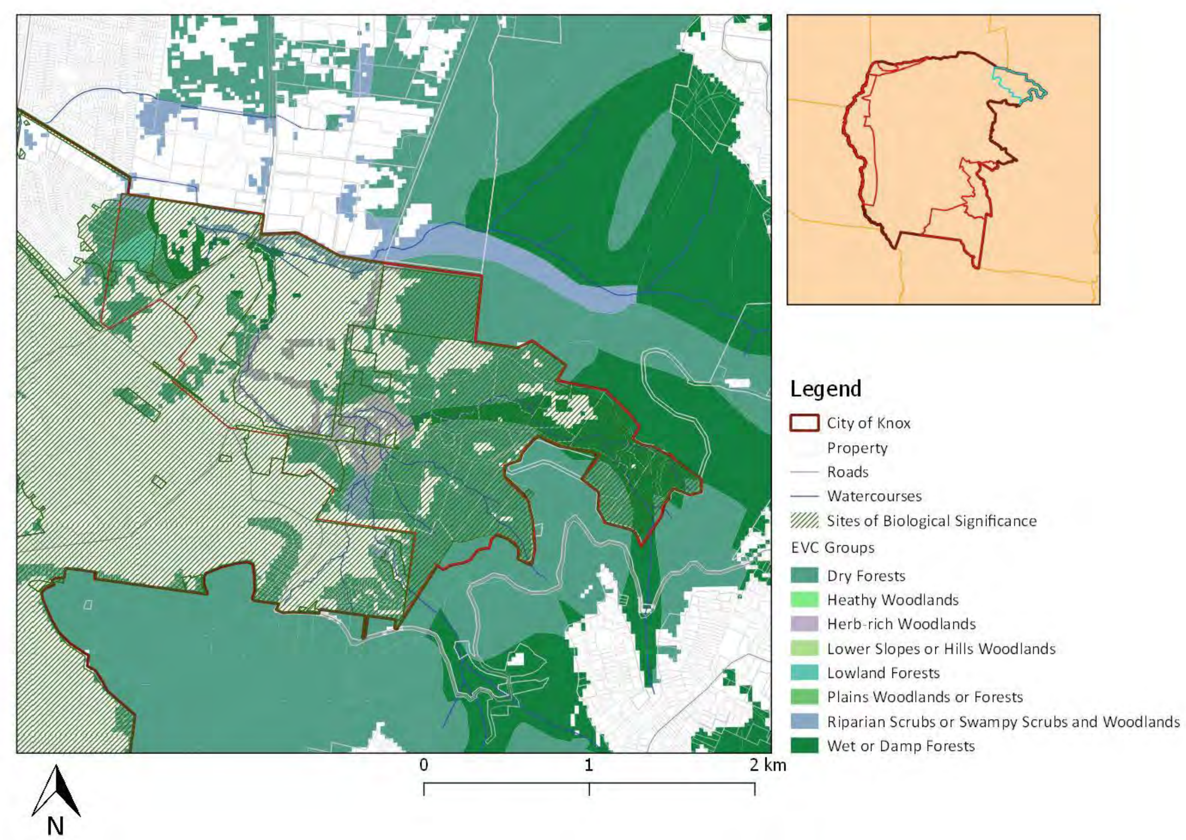


Figure 13. Distribution of EVC Groups within the Basin Rural Land Precinct, City of Knox.

The location of the precinct within the City of Knox is delineated in light blue on the inset map and by thin red line on main map. Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria. Waterways shown in dark blue.

4.2.2. Precinct 2a – Lysterfield Valley and Hills

The Lysterfield Valley and Hills RLP is almost 500 ha in area and supports the lowest percentage of area containing native vegetation (15.5%) compared to the other RLPs (Table 5, Figure 14). The most abundant broad EVC type is Dry Forests, with Riparian Scrubs and Swampy Scrubs and Woodlands patchily distributed along the waterways. The primary land uses within this precinct are agricultural, with market gardening and grazing currently dominating, along with hobby farming, horse agistment and larger lifestyle residential allotments. Monbulk Creek runs through this precinct, before joining up with Ferny Creek and becoming Corhanwarrabul Creek. The majority of this precinct appears to be privately owned, with just 2.2% (ARCUE) to 2.4% (VEAC) of the area classified as open space, with Knox CC responsible for managing just 2% of the area through its reserve system (Table 5). Nevertheless, 63% of the precinct has been classified as a site of biological significance, and the precinct has three Gardens for Wildlife properties.

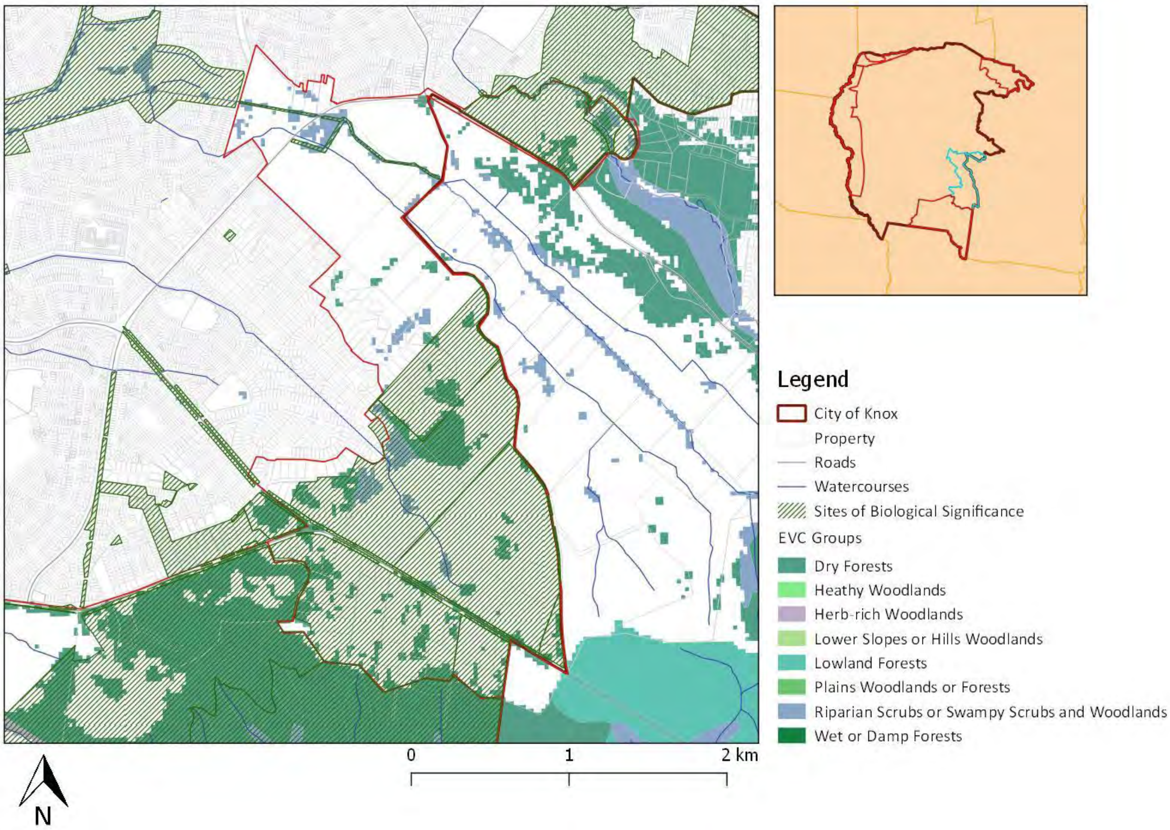


Figure 14. Distribution of EVC Groups within the Lysterfield Valley and Hills Rural Land Precinct within the City of Knox.

The location of the precinct within the City of Knox is delineated in light blue on the inset map and by thin red line on main map. Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria. Waterways shown in dark blue.

4.2.3. Precinct 2b – Lysterfield Quarries and Surrounds

The Lysterfield Quarries and Surrounds RLP at 877 ha is located to the south of the Lysterfield Valley and Hills RLP and supports the highest percentage cover of native vegetation of all the rural land precincts, with 82.4% (Table 5, Figure 15). The majority of this native vegetation is Dry Forests, with Riparian Scrubs and Swampy Scrubs and Woodlands occurring along most of the waterways that pass through this precinct. A number of quarries and cleared farmland dominate the eastern portion of the RLP, with Lysterfield National Park comprising the east and southeast portion of the precinct. While outside the precinct, Churchill National Park forms the southern boundary to the precinct with large areas of Dry Forests (Figure 15). There are no Gardens for Wildlife Properties within this RLP.

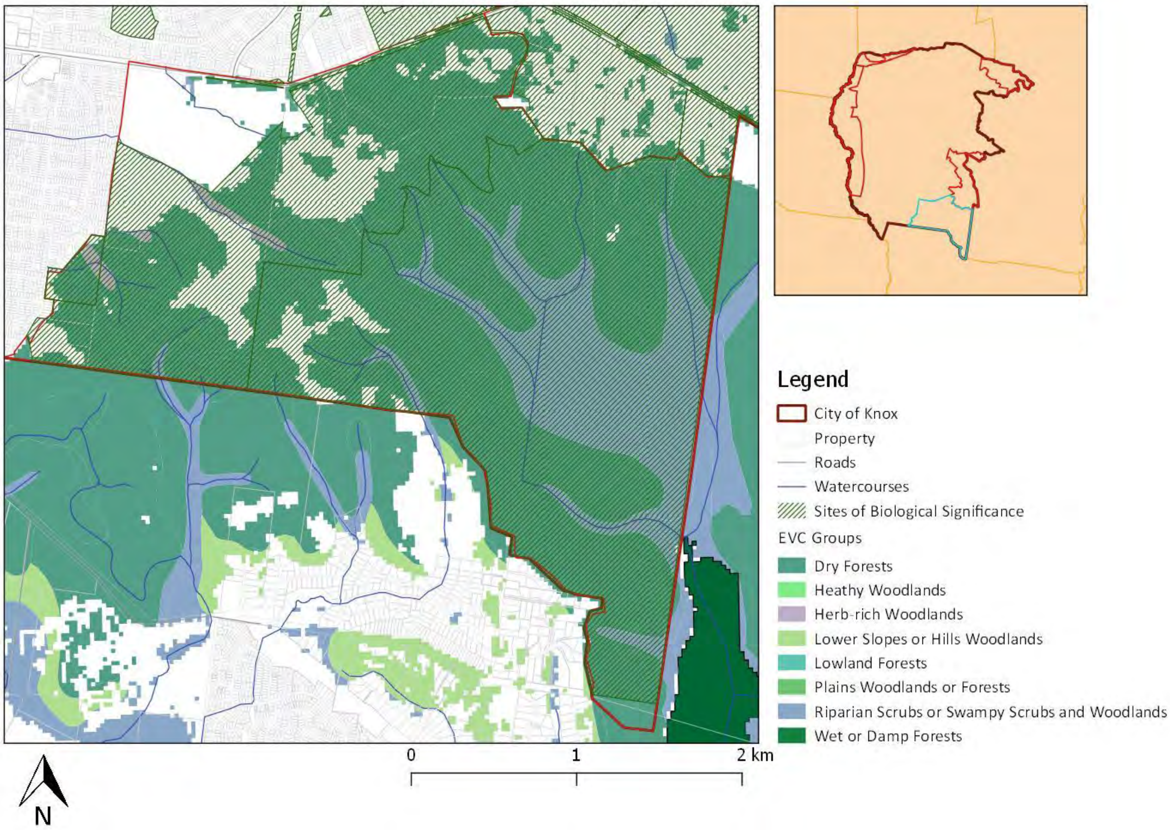


Figure 15. Distribution of EVC Groups in the Lysterfield Quarries and Surrounds Rural Land Precinct within the City of Knox.

The location of the precinct within the City of Knox is delineated in light blue on the inset map and by thin red line on main map. Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria. Waterways shown in dark blue.

4.2.4. Precinct 3 – Dandenong Creek Valley

The Dandenong Creek Valley Rural Land Precinct is the largest precinct (975 ha), forms the western boundary of the Knox municipality and is dominated by large tracts of cleared farmland, orchards and native vegetation (Figure 16, Figure 17, Table 5). Unlike the other RLPS, there are many more individual landowners in this precinct, with Parks Victoria and Melbourne Water responsible for a relatively large amount of this precinct due to its proximity to Dandenong Creek. Almost two-thirds of the Dandenong Creek Valley (58% [ARCUE] to 63% [VEAC]) is comprised of public open space, including sports fields, walking and cycling trails and water treatment and retention facilities. A little over half of the precinct (55%) has been classified as a site of Biological Significance (Table 5), and 6.4% of the precinct supports waterbodies, significantly more than all the other precincts, which averages 0.85%. Given the lack of residential properties in this precinct, there are no Gardens for Wildlife properties within the Dandenong Creek Valley precinct.

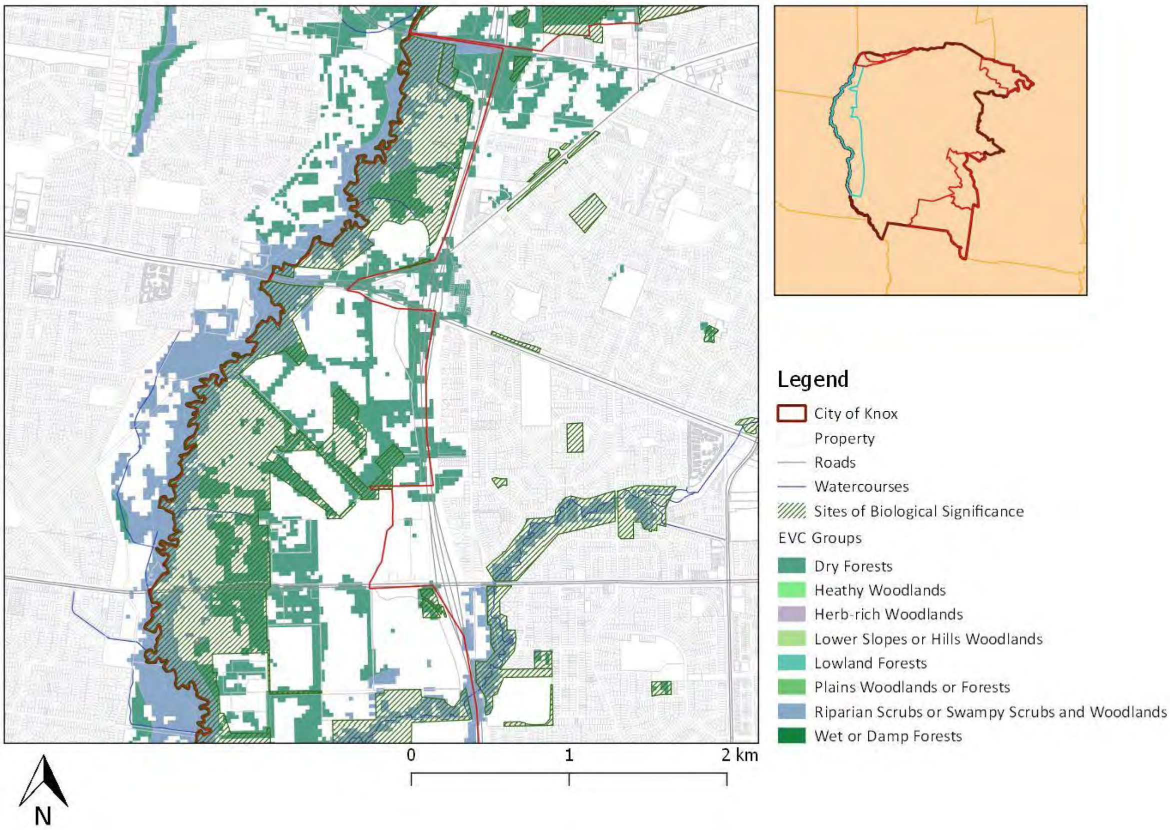


Figure 16. Distribution of EVC Groups in the northern section of the Dandenong Creek Valley Rural Land Precinct.

The location of the precinct within the City of Knox is delineated in light blue on the inset map and by thin red line on main map. Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria. Waterways shown in dark blue.

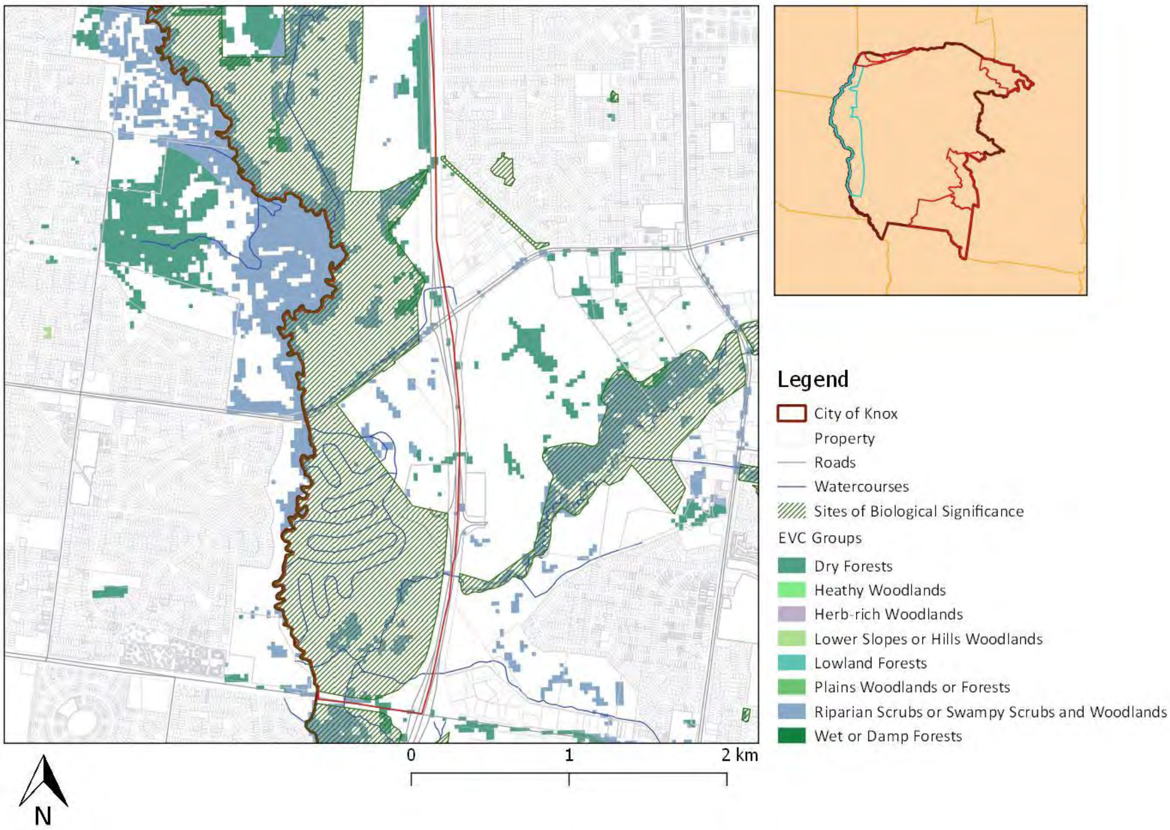


Figure 17. Distribution of EVC Groups in the southern section of the Dandenong Creek Valley Rural Land Precinct.

The location of the precinct within the City of Knox is delineated in light blue on the inset map and by thin red line on main map. Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria. Waterways shown in dark blue.

4.2.5. Precinct 4 – Healesville Freeway Reservation and Surrounds

The Healesville Freeway Reservation and Surrounds RLP is the smallest of the four precincts at 127.5 ha and supports 21% native vegetation cover, primarily Dry Forests and a small amount of Riparian Scrubs and Swampy Scrubs and Woodlands patchily distributed along Dandenong Creek (Figure 18, Table 5). Originally reserved for the 'Healesville Freeway' in 1969, the reservation east of Eastlink has been retained for possible future development. Much of the Healesville Freeway Reservation has been cleared and is used for a myriad of uses, including horse agistment, sports fields and pedestrian and cycling paths. Despite high levels of habitat clearing, approximately half of the precinct (47%) has been classified as sites of Biological Significance by Lorimer (2010a, b). Measures of open space in this precinct varies considerably between ARCUE (31.8%) and VEAC (6.7%), primarily because VEAC did not includes the actual freeway reservation in its calculations. This precinct has a few residential properties in the north-eastern corner of the precinct, and no Gardens for Wildlife properties.

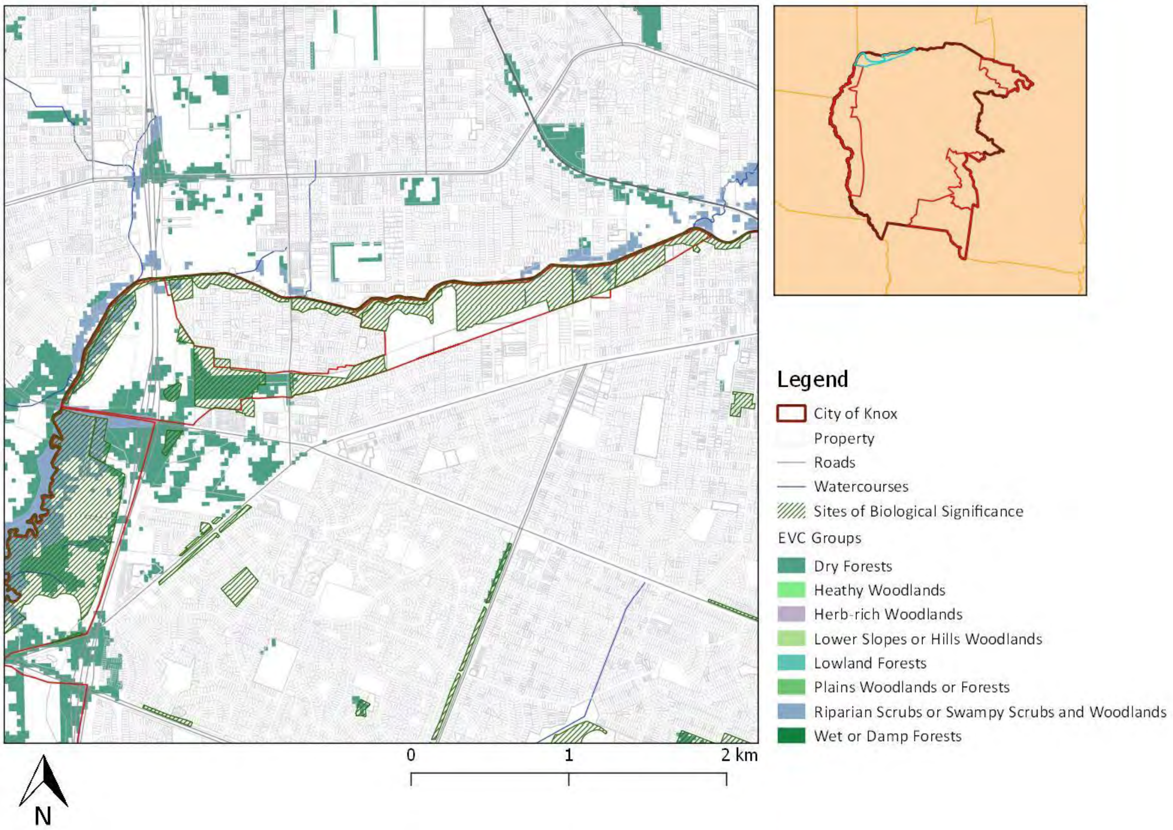


Figure 18. Distribution of EVC Groups in the Healesville Freeway Reservation and Surrounds Rural Land Precinct.

The location of the precinct within the City of Knox is delineated in light blue on the inset map and by thin red line on main map. Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria. Waterways shown in dark blue.

4.3. Focal species

4.3.1. Summary of each focal species

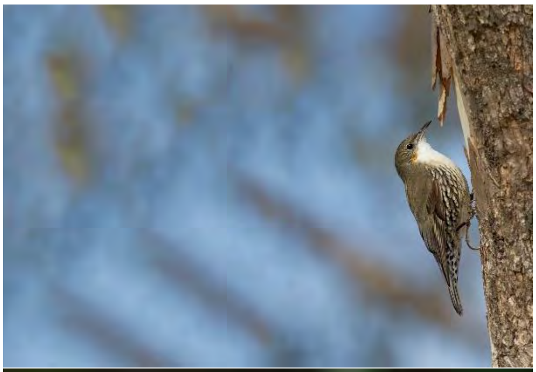
Ten focal species were selected (Figure 19, Table 7) using the process described in Section 3.3, and cover a range of faunal groups, habitat preferences and ecological characteristics (Figure 20). Each species is described more fully in Appendix 5, with summary fact sheets to share with the community and council staff provided in Appendix 6. The number of records of each focal species within Knox was variable (Table 8), with the birds being the most frequently recorded species within the municipality.

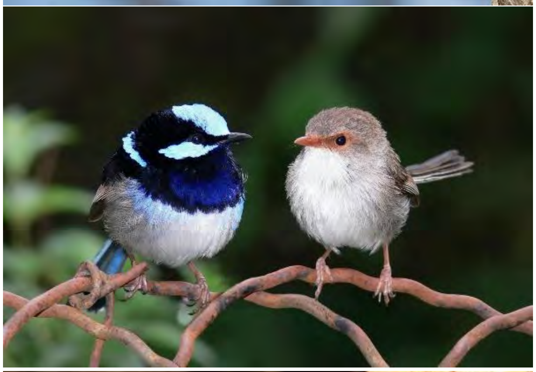
Table 7. Focal species used in this study to capture the habitat requirements of all species and their relevant key attributes.

Species	Fauna Group	Habitat type	Strata	Key habitat requirements	Movement capability
Australian Reed-warbler *Acrocephalus stentoreus*	Bird	Wetland / Riparian	Aquatic / Terrestrial	Thick vegetation around wetlands and riparian areas	Low
White-throated Treecreeper *Cormobates leucophaeus*	Bird	Woodland	Arboreal	Hollows for breeding Remnant woodland	Medium
Eastern Yellow Robin *Eopsaltria australis*	Bird	Woodland	Arboreal / Terrestrial	Woodlands	Medium
Superb Fairy-wren *Malurus cyaneus*	Bird	Generalist	Terrestrial	Open areas for feeding Thick vegetation for nesting	Low
Black Wallaby *Wallabia bicolor*	Mammal	Woodland / Riparian	Terrestrial	Thick undergrowth	Medium
Sugar Glider *Petaurus breviceps*	Mammal	Woodland	Arboreal	Tree hollows for shelter and breeding and trees within gliding distance for connectivity	Low
Short-beaked Echidna *Tachyglossus aculeatus*	Mammal	Generalist	Terrestrial	Lots of ants	High
Blue-tongue Lizard *Tiliqua sp.*	Reptile	Generalist	Terrestrial	Generalist	High
Eastern Snake-necked Turtle *Chelodina longicollis*	Reptile	Wetland / Riparian	Aquatic / Terrestrial	Wetlands and rivers	High
Southern Bullfrog *Limnodynastes dumerilii*	Frog	Wetland	Aquatic / Terrestrial	Wetlands	Low

Figure 19. (Next page) Photos of the 10 focal species selected to represent the ecological and biological requirements of most species of wildlife in Knox.

Clockwise from top left: Australian Reed-warbler, White-throated Treecreeper, Superb Fairy-wren, Sugar Glider, Eastern Snake-necked Turtle, Southern Bullfrog, Blue-tongue Lizard, Echidna, Black Wallaby, and Eastern Yellow Robin.







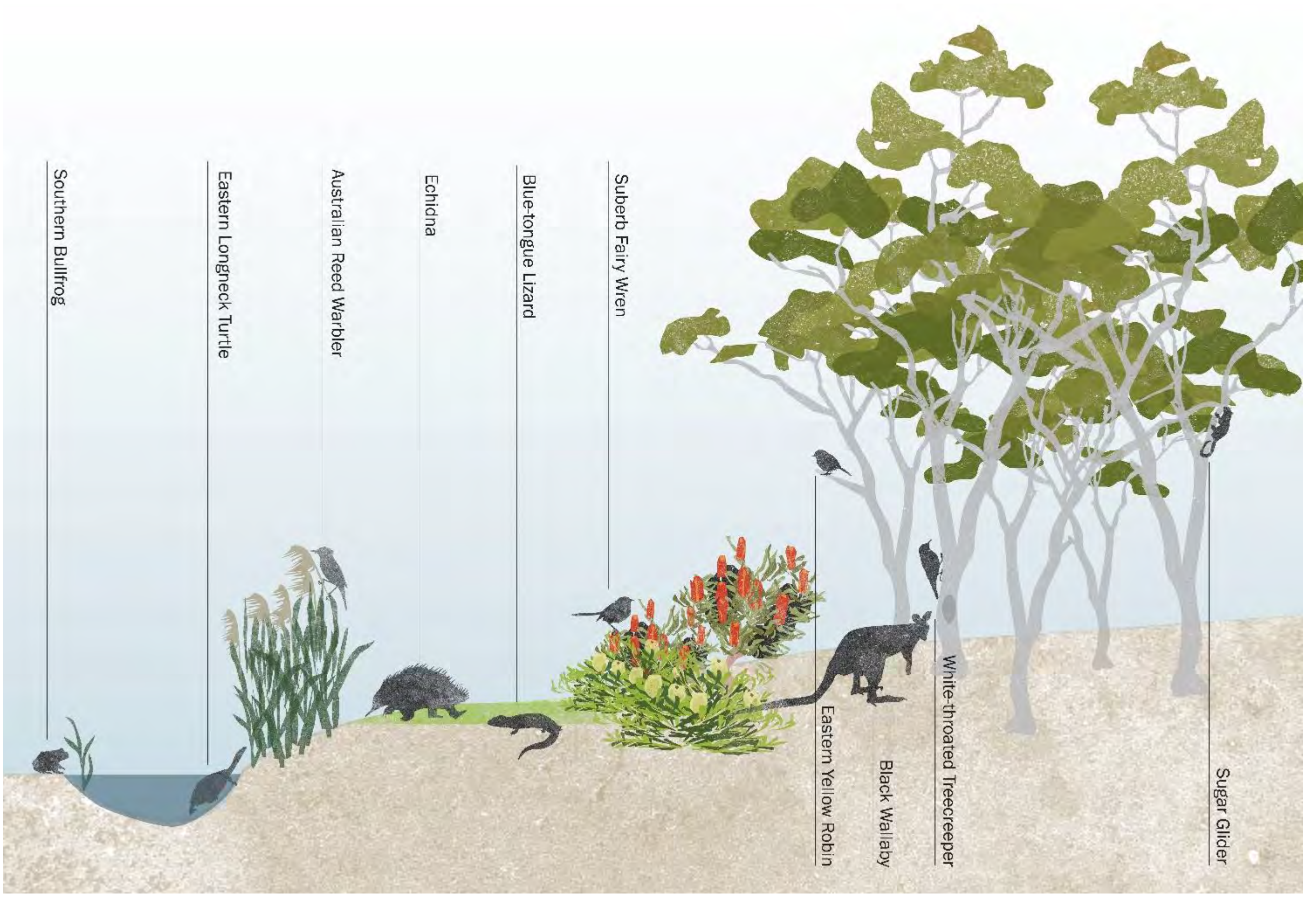


Figure 20. Schematic diagram showing the different ecological niches that each of the ten focal species occupy.

4.3.2. Distribution of each focal species in Knox

The ten focal species were initially selected according to their ecological and biological requirements and to ensure they 'represented' other species of wildlife within Knox. Because we selected species with some degree of specialisation (i.e. they were not generalists capable of surviving solely in the residential matrix), they were not widely distributed across Knox, nor do they appear to be super-abundant or ubiquitous across the municipality (Table 8). It is clear however, that the majority of all records of the ten focal species occur within the RLPs or just outside them (Figure 21) with 68.2% of all records of the focal species within the Knox LGA occurring within the RLPs. Without the RLPs, these focal species, and many other species that have similar traits, would not exist within the Knox municipality.

The most commonly observed and reported focal species are the Superb Fairy-wren, Australian Reed-Warbler and Eastern Yellow Robin, while the least commonly observed and reported species are the Short -beaked Echidna, Black Wallaby and Sugar Glider (Table 8). While there is likely a reporting and detection bias behind these results due to a relatively large and engaged group of volunteer bird observers, the reporting trends are likely reflective of the general abundance and distribution of these focal species, as well as their detectability. Birds are generally more mobile and detectable (colourful, vocal, active during the day) than the three focal species of mammal, with the exception being the Black Wallaby. However, the Black Wallaby has the largest spatial requirements of all our focal species and is also the least cryptic and unobtrusive, meaning it will regularly come into contact with people and dogs in smaller bushland reserves. In contrast, the birds are able to shelter in smaller patches of dense reeds and thick shrubs.

The Rural Land Precincts were variously important for different focal species, depending on the habitat provided within each precinct (Table 9). For example, RLP1 and RLP3 were important for sightings of Australian Reed Warbler, Eastern Yellow Robin and Superb Fairy-wren, while RLP2a had many independent locations with records of the Eastern Snake-necked Turtle. RLP2b was important for the White-throated Treecreeper, Short-beaked Echidna and the Superb Fairy-wren. Finally, RLP2a and 2b were important areas supporting many locations with records of the Southern Bullfrog, both species of Blue-Tongued Lizard, the Black Wallaby and the Sugar Glider.

Table 8. Number of records of focal species with a locational accuracy <300 m within Knox and each Rural Land Precinct and within 1 km of the municipal boundary in the surrounding local government areas since 1995.

A record is defined as a single observation of a species at one discrete point in time and space (i.e. duplicate records of the same species for that location included).

	Knox LGA						Within 1km	Grand Total
	RLP1	RLP2a	RLP2b	RLP3	RLP4	Non-RLP		
Australian Reed-warbler	46	5	8	206	3	149	461	878
White-throated Treecreeper	6	5	28	1		41	55	136
Eastern Yellow Robin	22	7	62	198	3	62	752	1106
Superb Fairy-wren	45	16	66	713	17	292	1769	2918
Black Wallaby		1	23			13	79	116
Sugar Glider			3	4	2	6	14	29
Short-beaked Echidna	3	5	14			20	21	63
Blue-tongued Lizard		1	1			6	4	12
Eastern Snake-necked Turtle	1	17		1		24	2	45
Southern Bullfrog		10	11	2	2	38	20	83
Grand Total	**123**	**67**	**216**	**1125**	**27**	**651**	**3177**	**5386**

Table 9. Number of locations with at least one observation of a focal species (i.e. presence only) with a locational accuracy < 300m within Knox, each Rural Land Precinct and within 1km of the municipal boundary in the surrounding local government areas since 1995.

	Knox LGA						Within 1km	Grand Total
	RLP1	RLP2a	RLP2b	RLP3	RLP4	Non-RLP		
Australian Reed-warbler	6	2	2	42	2	31	90	175
White-throated Treecreeper	5	3	16	1		15	25	65
Eastern Yellow Robin	12	5	31	46	3	29	162	288
Superb Fairy-wren	15	9	34	112	8	92	290	560
Black Wallaby		1	23			6	72	102
Sugar Glider			3	2	1	5	13	24
Short-beaked Echidna	2	3	11			12	21	49
Blue-tongued Lizard		1	1			6	4	12
Eastern Snake-necked Turtle	1	2		1		10	2	16
Southern Bullfrog		6	7	2	1	17	17	50
Grand Total	**41**	**32**	**128**	**206**	**15**	**223**	**696**	**1341**

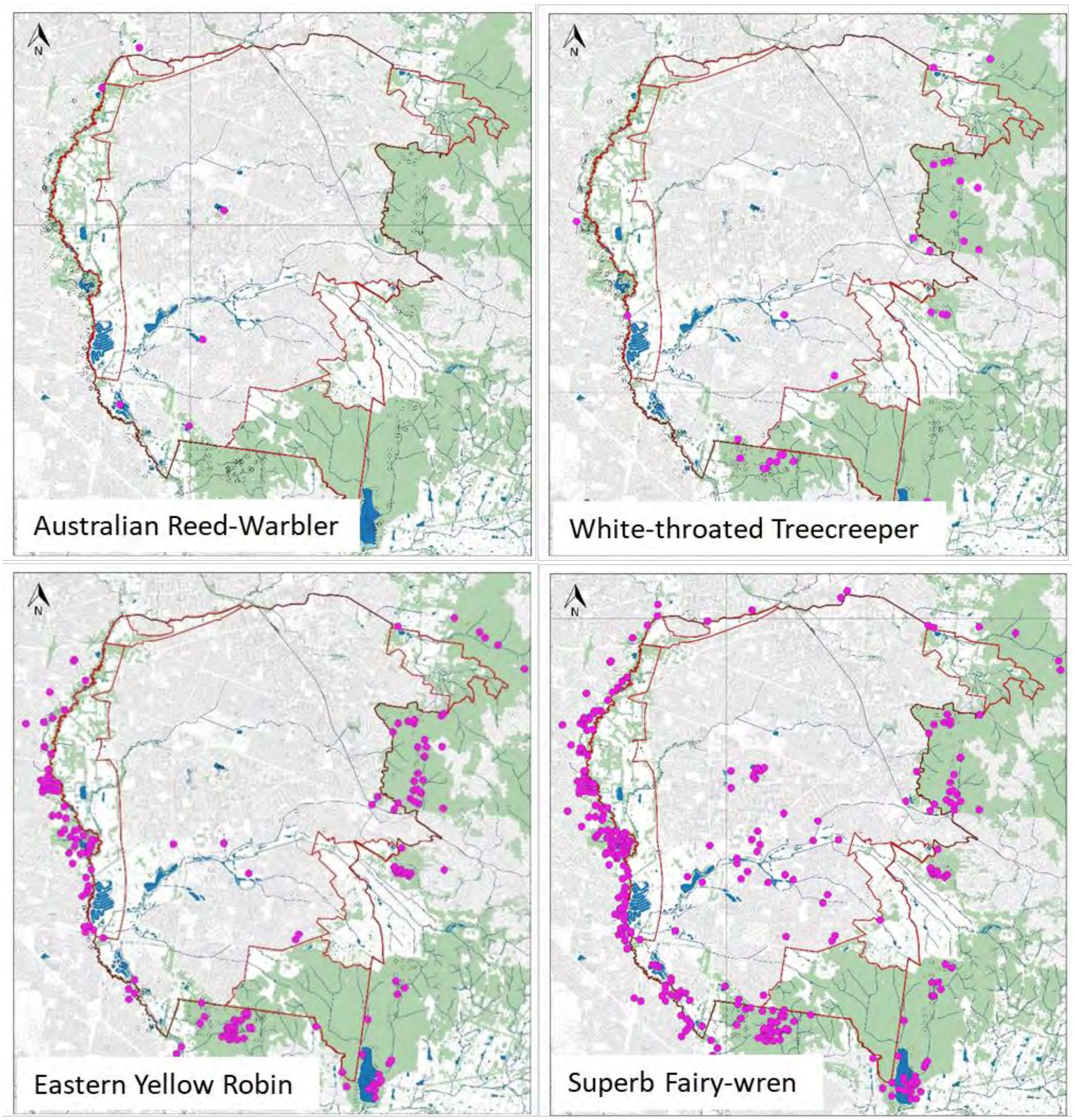


Figure 21. Distribution of the ten focal species within the City of Knox and up to 1 km into neighbouring LGAs.

Each map shows a different focal species, with presence-only records for each species shown in pink and presence-only records for the remaining nine species shown with open circles. Data Source: Native Vegetation (shown as green) - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria and waterways shown as dark blue.

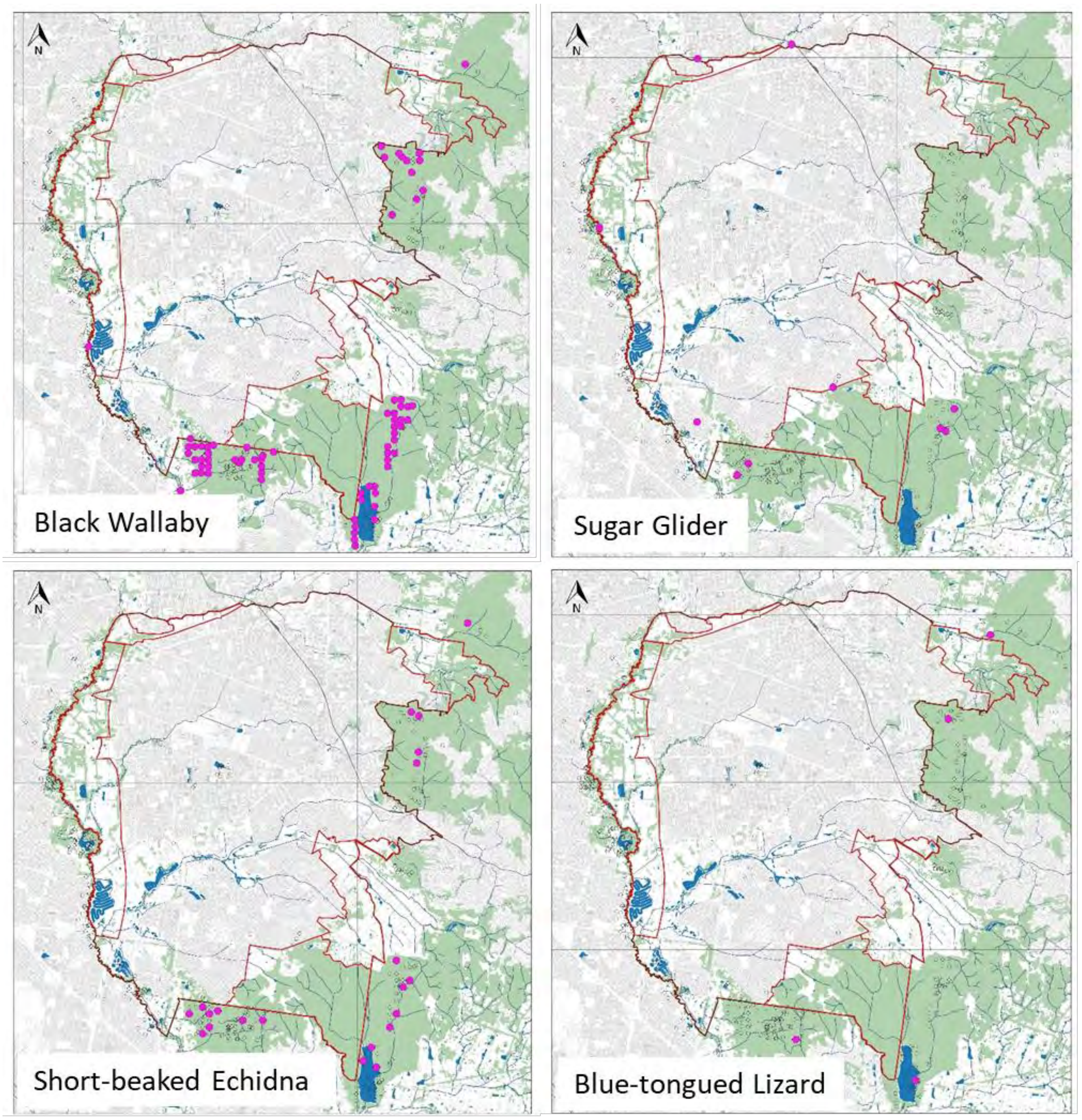


Figure 21 continued.

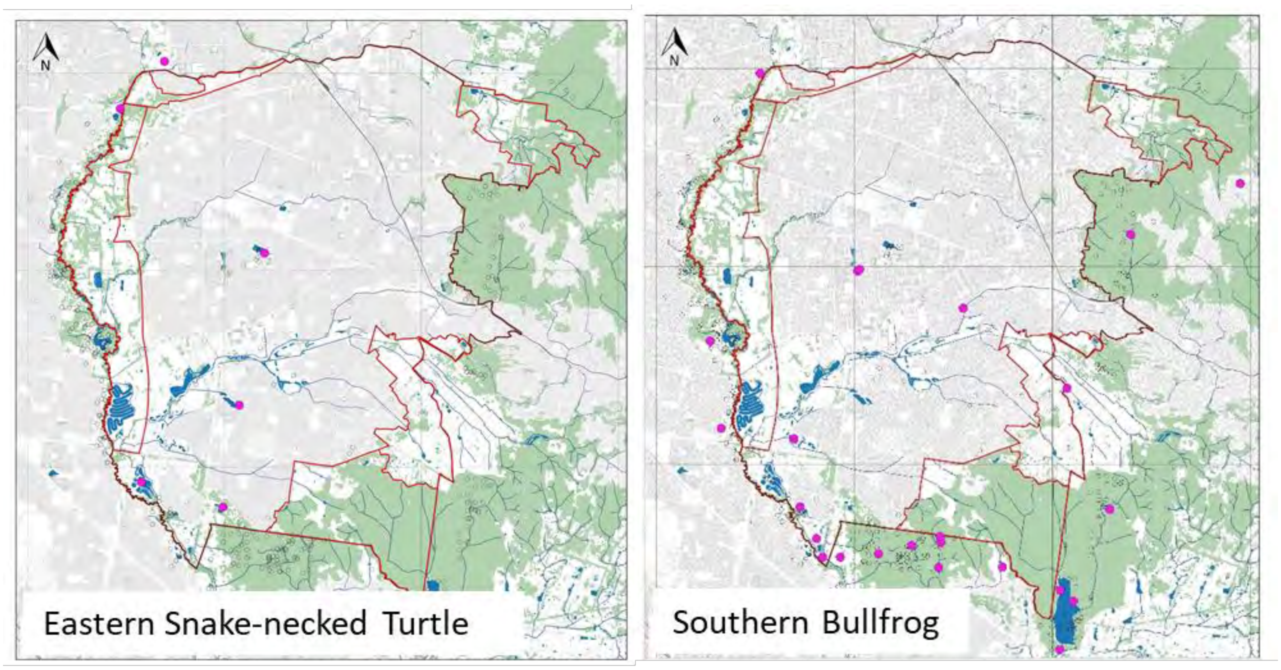


Figure 21 continued.

4.3.3. Characteristics of habitat associated with recent records of the focal species.

The importance of remnant vegetation

Scrub or Swampy Scrubs and Woodlands are the two most common EVC Groups within the municipality (Figure 22) and provide important resources for conserving the associated plant and animal communities. The White-throated Treecreeper and Black Wallaby were most commonly associated with larger areas of Dry Forests, and the Eastern Snake-necked Turtle was associated with the smallest extent of these EVC Groups. Larger areas of Lowland Forests appear to be important areas for Sugar Gliders, and also support Eastern Yellow Robin, Superb Fairy-wren, Black Wallaby and the Short-beaked Echidna. The White-Throated Treecreeper, Eastern Yellow Robin, Superb Fairy-wren, Black Wallaby and the Short-Beaked Echidna were also associated with Wet/Damp Forests. Within the City of Knox, these latter two EVC Groups are only found within The Basin RLP.

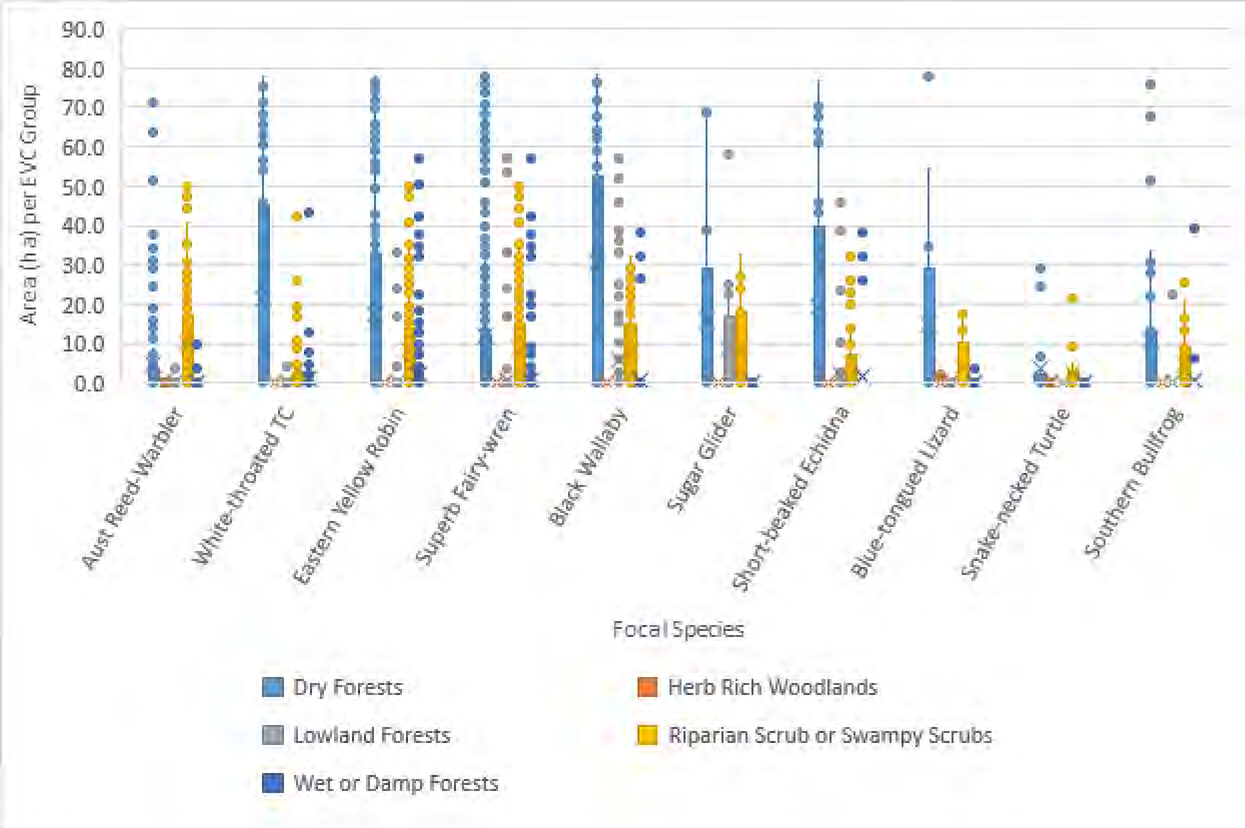


Figure 22. Extent of Ecological Vegetation Class groups found within a 500 m buffer around each record of each focal species within the City of Knox and for records up to 1 km into adjacent LGAs from the Knox municipal boundary.

Refer to Text Box 3 for instructions to interpret this graph.

Text Box 3: Interpreting the box-plots in Figures 21 to 24 and Figure 26

Each colour represents a different variable that may be of importance to a focal species, such as area of EVC group, farm dam or billabong, or specific types of open space within a 500 m radius of each location of a focal species. Each graph shows the median value (denoted by the X) for that variable across all location records for that focal species, the colored column is the interquartile range (i.e. showing the middle 50% of records) and the dots the upper and lower 25% of records (i.e. outliers or extreme values). In most cases, the lower 25% of records are close to zero. No colored column is shown for species that have insufficient records for that species.

The importance of wetlands, waterways and farm dams

The area or extent of wetlands, namely farm dams, billabongs and waterways, was a strong influence on the occurrence of the four focal bird species (Figure 23).

The Australian Reed-Warbler was associated with the highest extent of Farm Dams/Billabongs, while the Sugar Glider and Blue-tongued Lizard sites rarely included these features. The water-dependent Eastern Snake-necked Turtle and the Southern Bullfrog were generally associated with small extents of Farm Dams or Watercourses, but for all except two sites there was at least 0.5 ha of Farm Dam/Billabong or 0.25 km of Watercourse. As the daily movements for these species are relatively restricted, this may be sufficient to provide for their day-to-day needs.

It is unclear if some species are actually relying on the waterbody per se, or simply responding to the type of habitat that occurs around waterways. For example, dense understory vegetation is very important for the Superb Blue-wren, and much of the dense understory vegetation within Knox is probably associated with waterways. Nevertheless, it demonstrates the importance of the waterway areas within Knox for the persistence of many species of wildlife.

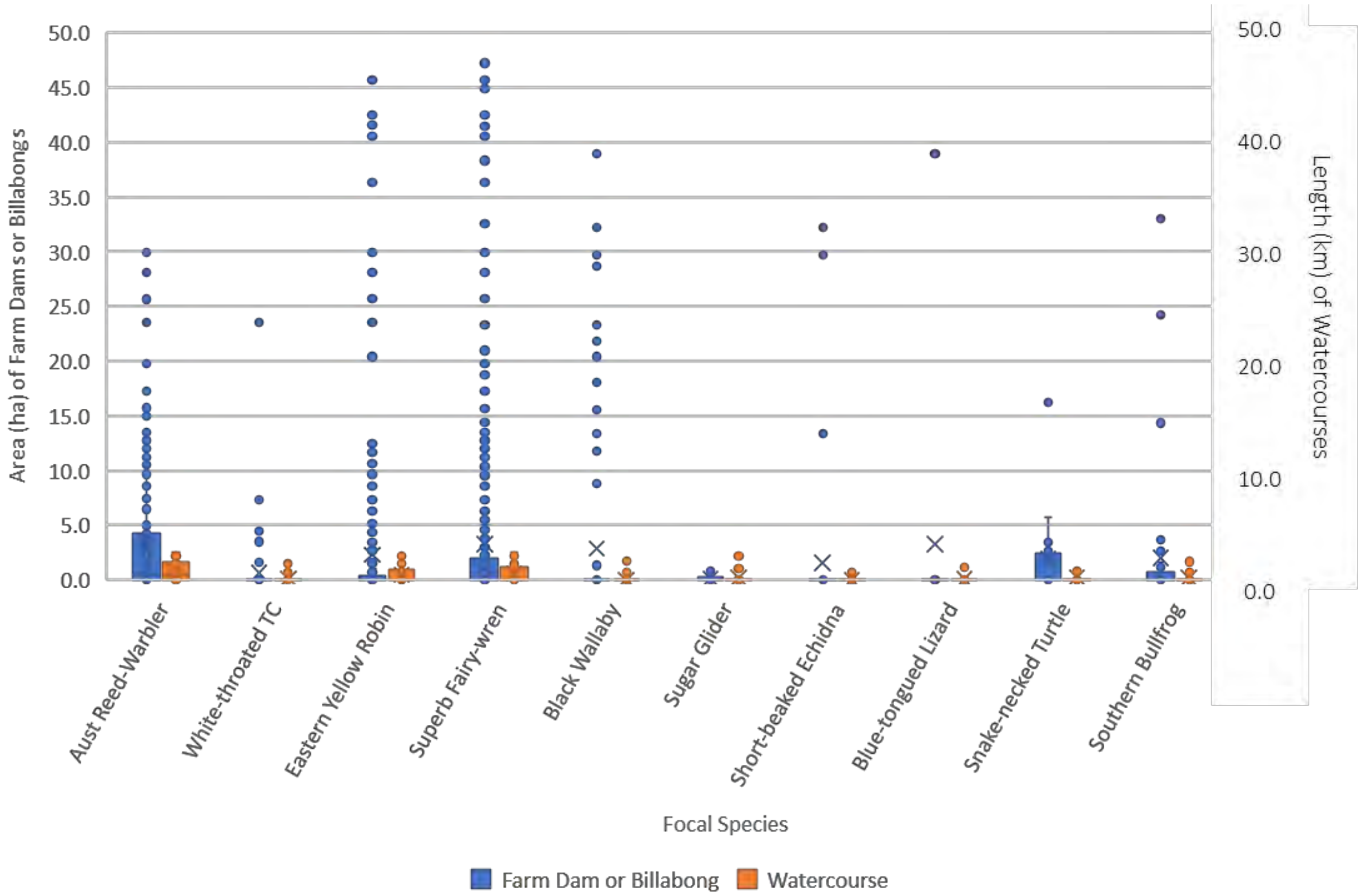


Figure 23. Extent of farm dams and billabongs (ha) or length of Waterways (km) within 500 m of records of each focal species. Refer to Text Box 3 for instructions to interpret this graph.

Importance of public open space

All focal species were most strongly associated with Natural/Semi-Natural areas or Protected Areas (i.e. national park or other formal conservation reserves), the Black Wallaby in particular appears to be associated with a minimum of 10 ha protected areas (Figure 24). The Black Wallaby, Sugar Glider and Short-beaked Echidna in particular appear to be associated with Natural- or Semi-Natural areas, while the White-throated Treecreeper and Black Wallaby are often associated with larger areas of Protected Area open space. The Blue-tongued Lizard and Eastern Snake-necked Turtle were associated with the smallest extent of VEAC open space. This may reflect the species relatively small daily movement distances, and the ability to persist in relatively small areas provided the required habitat elements are present.

Several species were associated with Organised Recreation areas, and this may reflect their presence around golf courses, or in vegetated areas surrounding sports grounds.

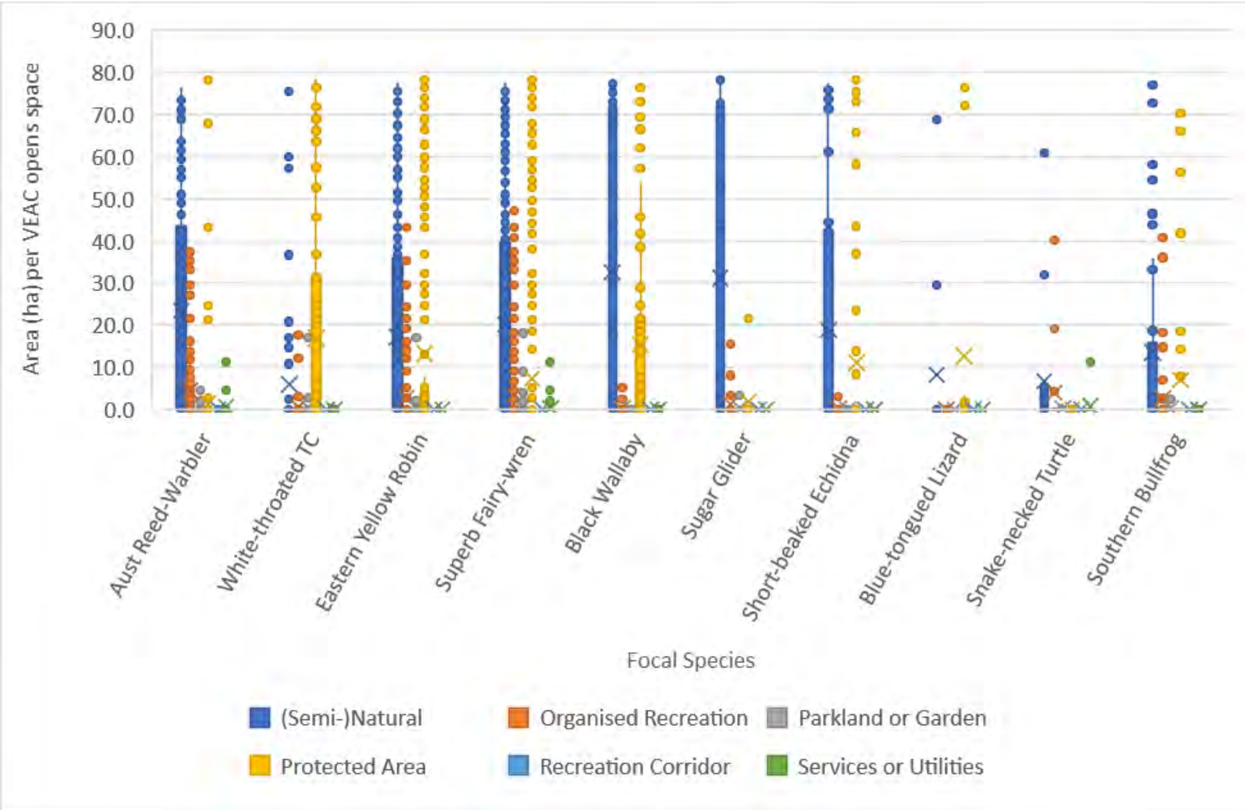


Figure 24. Extent of VEAC Open Space categories (ha) found within 500 m of location for each focal species. Refer to Text Box 3 for instructions to interpret this graph.

Importance of roads and urban density

Most species were recorded in sites with higher densities of local roads (Class 5), compared to the major or connector Roads (Classes 0 – 4) (Figure 25). However, all of the bird species were recorded in locations with higher densities of all road classes compared to the other focal species. This is likely to reflect their lower reliance on connectivity at ground level due to their ability to fly across landscapes, and their high mobility which gives the option of using these areas as part of their home range which they can move into and out of with relative ease.

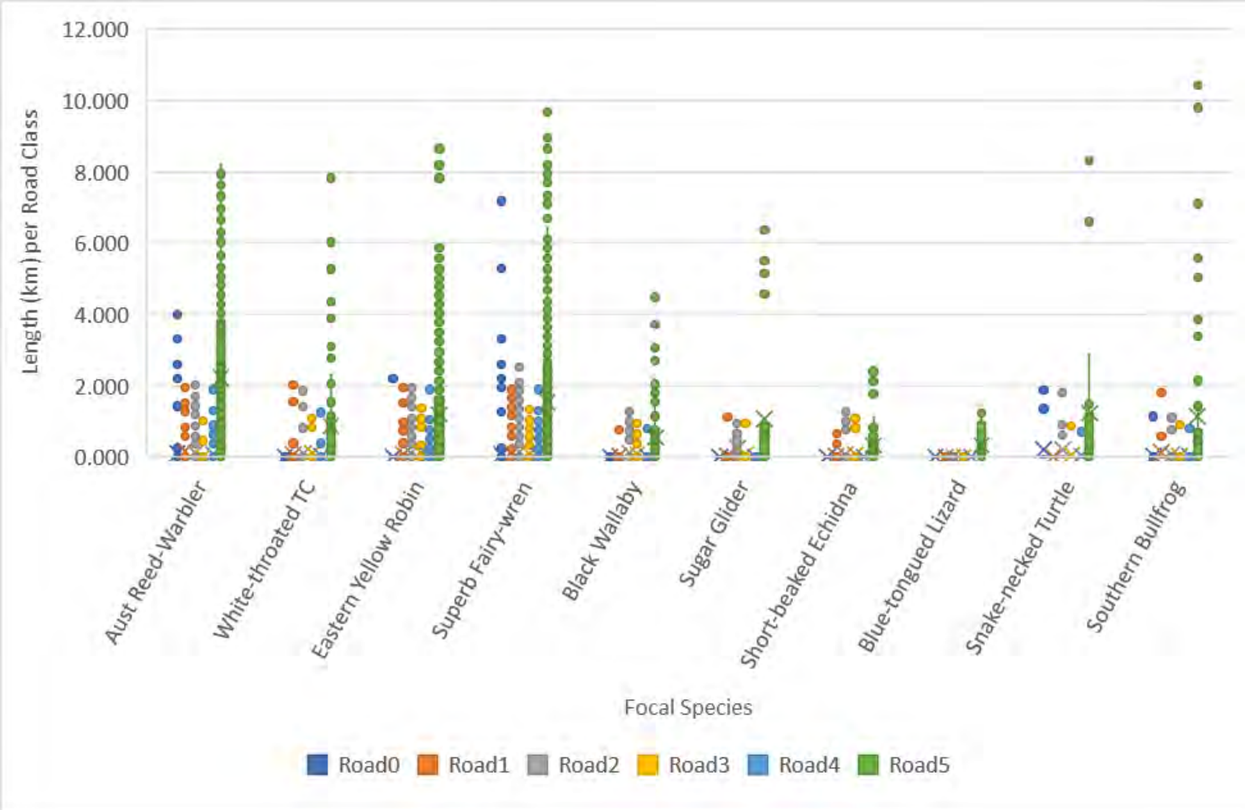


Figure 25. Length of Roads (km) in different road classes found within 500 m of locations for each focal species.

Road class is: 0 = freeway, 1 = highway, 2 = arterial, 3 = sub arterial, 4 = collector and 5 = local roads. Refer to Text Box 3 for instructions to interpret this graph.

Another measure of urbanisation is average property size. For all ten focal species, they were most likely to be associated with larger property sizes of more 8 hectares (Figure 26), which equates to the minimum property size permitted in the Green Wedge Zone – Schedule 1. This is particularly the case for Black Wallaby, Short-beaked Echidna and Blue-tongued Lizards which were only observed in proximity to this size property parcel. All four bird species were regularly observed in sites with average property sizes of 4.0 to 8.0 hectares, which equates to the minimum size permitted in Green Wedge Zone - Schedule 2.

The only species with records in areas where property sizes were less than 0.4 ha (1 acre) were the Australian Reed-Warbler, Easter Yellow Robin, Superb Fairy-wren, Sugar Glider and Eastern Snake-necked Turtle. However, of these four species, only the bird species were found in areas where property sizes matched the traditional residential house-block size of 0.2 ha (1/2 acre) or less. For the birds and the Sugar Glider, this is likely to reflect either the species' ability for movement above ground level by flying or gliding. For the Eastern Snake-necked Turtle this is more likely to reflect their ability to persist in relatively isolated locations, possibly enhanced by human-assisted migrations through the release of pet turtles into nearby ponds or dams.

These findings suggest that the ten focal species are quite sensitive to urbanization, particularly the larger animals and those which move at ground level (Black Wallaby, Short-beaked Echidna and Blue-tongued Lizard), and any additional development that introduces smaller average property sizes or increases the density of roads is likely to have a negative impact on the ability of these focal species to persist in that area of the landscape. While not designed to identify thresholds in land parcel sizes beyond which they are unable to persist, the analysis presented in Figure 26 suggests that the threshold is likely between 4 and 8 ha.

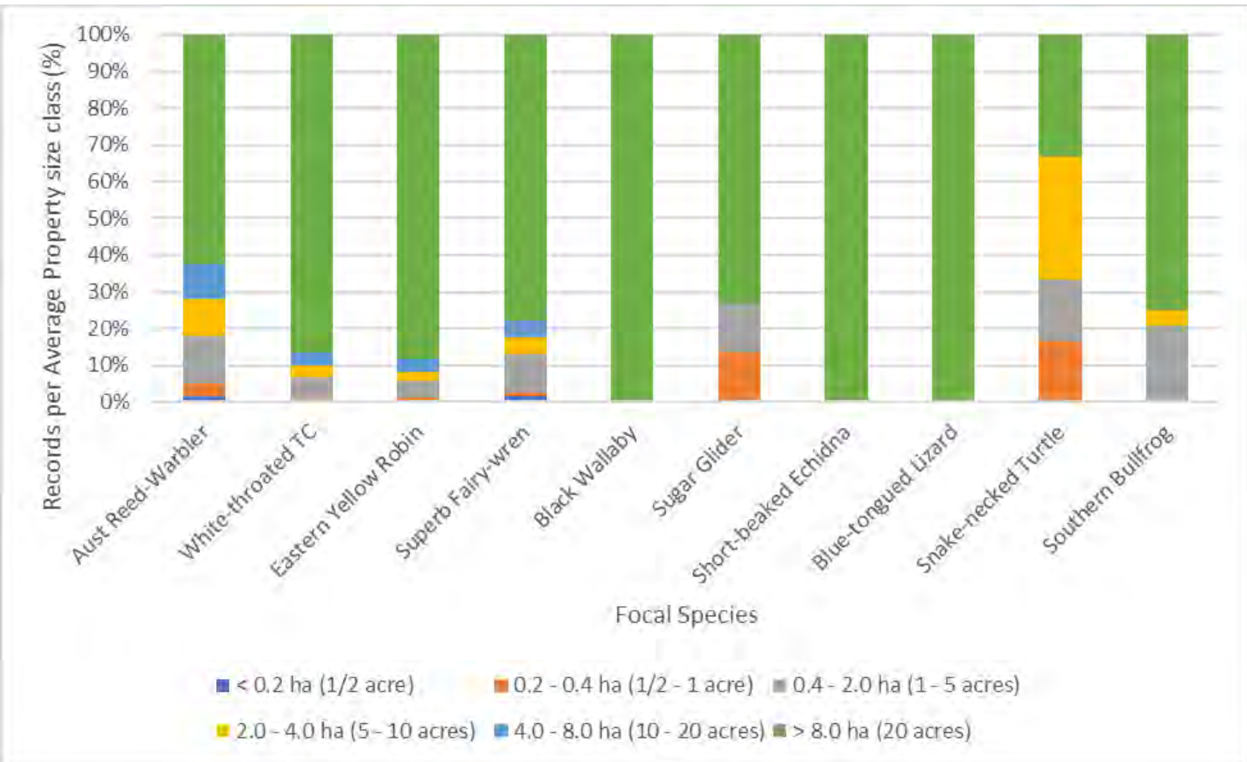


Figure 26. Number of records within different average size classes for property parcels found within 500 m of location for each focal species.

Importance of planning zones

Planning zones provide a useful indication of the types of urban land-use and associated activities that are likely to be occurring in an area. The majority of our focal species were associated with greenspaces in Public Parks and Recreation and Urban Flood Zones (Figure 27). All four bird species and the Southern Bullfrog were often associated with larger areas of Conservation zones (Public Conservation Zones or Rural Conservation Zones) and Rural, Farming or Green Wedge Zones. The Black Wallaby was also regularly associated with larger areas in the Rural, Farming or Green Wedge Zones. These affiliations highlight the dependence of these focal species on access to large extents of green space containing relatively little built infrastructure.

The Australian Reed-Warbler, Eastern yellow Robin, Superb Fairy-wren and Eastern Snake-necked Turtle were regularly recorded in sites containing larger areas of residential landuses, (General, Neighbourhood and Low-Density Residential Zones). While the ten focal species most likely rely on natural areas and green space, they can also use residential areas when the conditions are favourable, and initiatives that seek to make residential areas more compatible with biodiversity can have a beneficial outcome for our focal species and other wildlife in these areas. This concept is supported by anecdotal feedback collected from the Knox's Gardens for Wildlife participants who responded to the request for sightings of focal species that we sent out during the data-collection phase of this project.

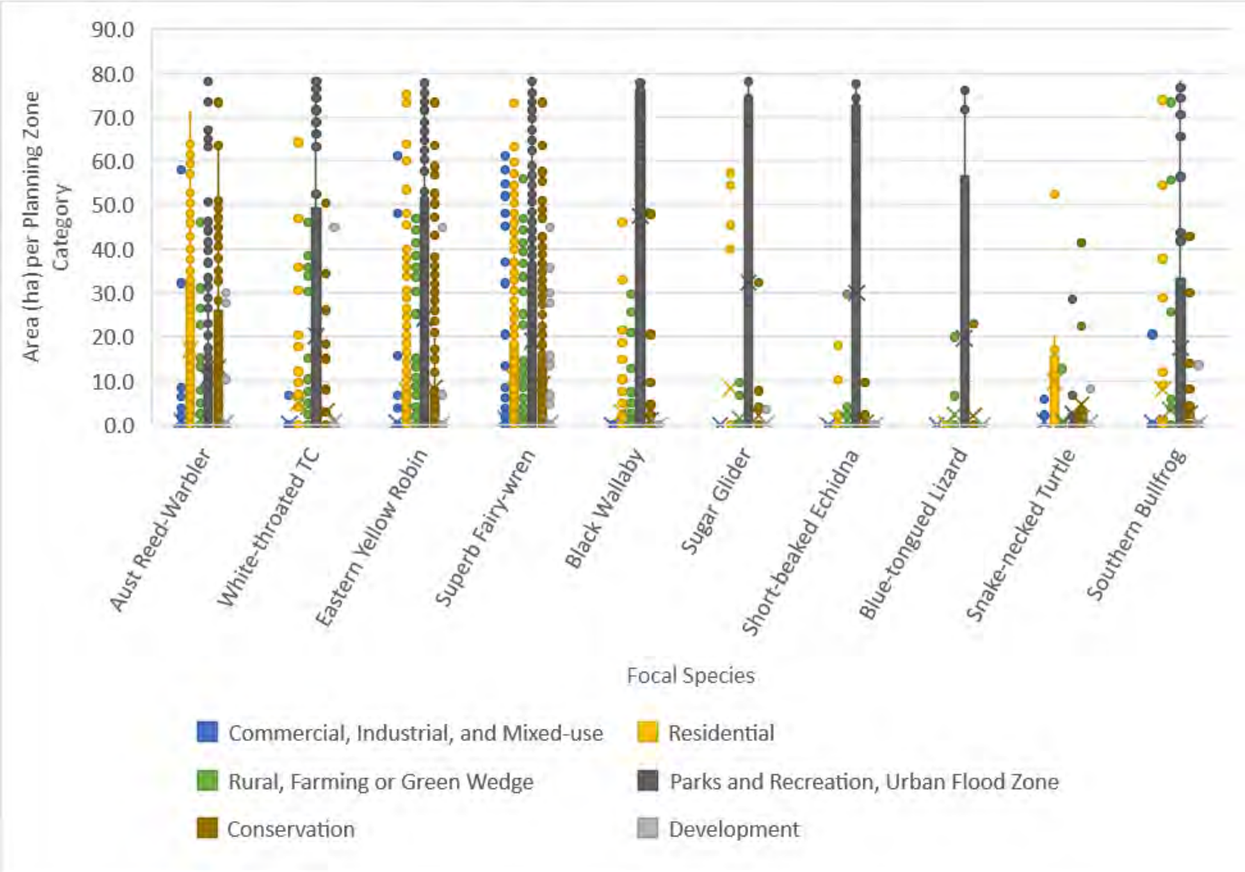


Figure 27. Extent of generalized Planning Zone categories (ha) found within 500 m of location for each focal species. The development category is composed of land parcels slated for major development. Refer to Text Box 3 for instructions to interpret this graph.

4.4. Barriers to movement of wildlife along Knox corridors and suggestions for improvement

A total of 37 existing and five future potential barriers along the three major waterways in Knox were identified from maps and aerial photography: these were inspected and their likely effect on the movement of the ten focal species assessed. In all cases except one, the identified barriers were associated with roads, with the remaining barrier being the Belgrave train line across Dandenong Creek. The location of each potential barrier / road crossing is given in Figure 28, and detailed in Appendix 7. The primary factors affecting wildlife movement along the waterways across the roads were road width, traffic volume, extent of native vegetation around and leading up to the road and the type and size of the underpass. Appendix 7 also provides a range of concept-level improvements to enhance connectivity for the focal species, and thus other species of wildlife as well.

The most effective enhancements to wildlife connectivity across the Knox municipality is to daylight the sections of creek that are currently piped under the various roads and replace the culverts with open-span bridges. This action and many others are major investments and these significant and expensive retrofits should be considered in combination with other road or structure maintenance or enhancement works, such as bridge or culvert replacement and road widening. Partnerships with Melbourne Water should be investigated to daylight the creeks and restore natural flow regimes, because piped creeks are a barrier themselves to the movement of fish, platypus and other aquatic species. Other works are more minor in nature. Irrespective of the scale of works, all should be considered and prioritised as part of an overall "wildlife connectivity enhancement program" to be implemented over a 10 – 20 year period, taking into account the occurrence of target species at each location, cost, urgency and opportunity. These recommendations encompass a range of site-specific actions, including:

- Undertaking strategic revegetation at the approaches to each structure to reduce the size of the open gap that wildlife must traverse in order to reach the underpass.
- Planting trees along the road edge and within the median to provide connectivity for gliders in the medium term.
- Installing rope bridges across wide roads which are beyond the gliding capability of Sugar Gliders (approximately 40 to 50 m), with on-site measurements conducted to confirm estimates provided in Appendix 7. Rope bridges can also be installed under tall bridges, such as those under Eastlink.
- Replacing culverts with open span bridges during road upgrades and other works in the years ahead.
- Raise the floor level of outer culverts to provide dry passage for most of the year or install shelves on the sidewall of culverts where flow can't be restricted.
- Re-contouring the creek channel to provide flat or gently sloping banks to allow the movement of wildlife under bridges.
- Removing large rocks (also known as rip-rap) that provide scour protection under bridges and replace with poured concrete to provide stable, flat passage for animals. If scour protection can't be removed, fill the gaps between the rocks with poured concrete or gravel to provide a less 'wobbly' surface.

There are a number of approved and mooted future road projects that have the potential to further decrease wildlife connectivity across the municipality (locations 38 to 42 in Figure 28). These projects include extensions of Dorset Rd and Stud Rd, the Healesville Freeway and the Henderson Rd bridge over Corhanwarrabul Creek. Of these projects, only the Henderson Rd bridge has been confirmed and is currently being designed.

In all cases, future crossings of waterways or open space have the potential to incrementally add another barrier or filter to the movement of wildlife in that area, potentially fragmenting an existing population into two smaller sub-populations, each with an increased risk of local extinction. In addition, the road may also result in the mortality of wildlife and reduce the quality of habitat within the vicinity of the road. Where possible, new roads should not be placed in areas important for wildlife. If unavoidable, the road and bridges should be designed to (i) facilitate unimpeded movement of wildlife; (ii) include strategies to prevent the mortality of wildlife and (iii) be designed to limit the amount of noise and light entering adjacent habitats. These strategies are often species- and location-specific but may include such things as fencing, overpasses and underpasses, noise and light walls and reduced speed limits (van der Ree et al. 2015).

Barrier Locations

1 Dandenong Creek- Liverpool Rd
2 Dandenong Creek- Dobson Ln
3 Dandenong Creek- Colchester Rd
4 Dandenong Creek- Dorset Rd
5 Dandenong Creek- Bayswater Rd
6 Dandenong Creek- Train Line
7 Dandenong Creek- Wantirna Rd
8 Dandenong Creek- EastLink (North)
9 Dandenong Creek- Boronia Rd
10 Dandenong Creek- Burwood Hwy
11 Dandenong Creek- High St
12 Dandenong Creek- Ferntree Gully Rd
13 Dandenong Creek- Wellington Rd
14 Dandenong Creek- Stud Rd
15 Corhanwarrabul Creek- Stud Rd 1
16 Corhanwarrabul Creek- Stud Rd 2
17 Waterford Valley Lake- Karoo Rd
18 Monbulk Creek- Bunjil Way
19 Monbulk Creek- Blackwood Park
20 Monbulk Creek- Napoleon Rd
21 Monbulk Creek- Lysterfield Rd
22 Ferny Creek- Brennock Park
23 Ferny Creek- Glenfern Rd
24 Ferny Creek- Hancock Dr
25 Ferny Creek- Bunjil Way
26 Blind Creek- EastLink
27 Blind Creek- High St
28 Blind Creek- Timmothy Dr
29 Blind Creek- Stud Rd
30 Blind Creek- Burwood Hwy
31 Blind Creek- Lewis Rd
32 Blind Creek- Scoresby Rd
33 Blind Creek- Manuka Rd
34 Blind Creek- Rankin Rd
35 Blind Creek- Wattletree Rd
36 Blind Creek- Dorset Rd
37 Dandenong Creek – EastLink (South)
38 Corhanwarrabul Creek- Henderson Rd
39 Ferny Creek- Dorset Rd Extension
40 Monbulk Creek- Dorset Rd Extension
41 Drainage Channel- Dorset Rd Extension
42 Drainage Channel- Lysterfield Rd

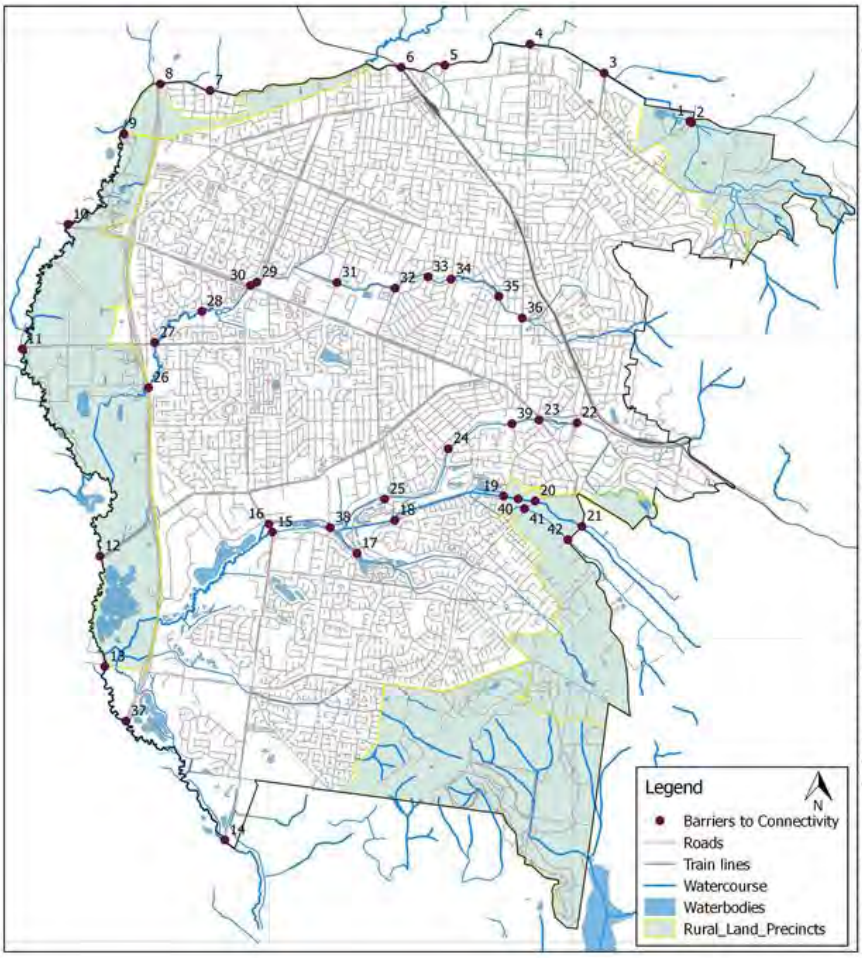


Figure 28. Location of potential barriers across the three major waterway corridors within the City of Knox.

Numbers correspond to specific road and railway crossings over the creeks (sites 1 to 37), current (site 38) or mooted future road projects (sites 39 – 42). Detailed descriptions of each crossing and recommended improvements for sites 1 - 37 are provided in Appendix 7. Data sources: Watercourse Network 1:25,000 - Vicmap Hydro (HY_WATERCOURSE/) © State of Victoria; Road Network - Vicmap Transport (TR_ROAD/) © State of Victoria. Grid overlay 5 km x 5 km.

4.5. Important areas for the conservation and movement of wildlife in Knox

We mapped a number of buffers over different landscape elements to identify the important areas for conservation and movement of wildlife in Knox (see Table 3 for more details). In summary, we used a 180 m buffer around treed EVCs to represent the distance that Sugar Gliders (Caryl et al. 2013) and Eastern Yellow Robins have been recorded travelling outside bushland and a 300 m buffer to represent distances travelled by Black Wallabies and Blue-tongued Lizards. Farm dams were buffered by 375 m as a study of Eastern Long-necked Turtles found that 95% of all records were within this distance from the nearest dam (Roe & Georges 2007). As per State Government guidelines, watercourses were buffered by 200 m to support Growling Grass Frogs (Heard et al. 2010), which we adopted for this study. Melbourne Water also recommend that the 1 in 100 year flood level be protected, and they also provide a minimum buffer width of water courses depending on stream order, ranging from 50 m along Dandenong Creek to a minimum of 20 m for the smallest creeks (Melbourne Water 2013)

The following figures and discussion clearly demonstrates that the RLPs play a critically important role in both the conservation and movement of wildlife within Knox. By overlaying the various buffers, we have identified the location and extent of areas that are likely critical for the conservation of the focal species that we selected a-priori for this study. And as the focal species are moderately sensitive, they are likely to represent the needs of a whole suite of other sensitive species that will be unable to persist in Knox if the EVC's, open space and other wildlife habitats is not maintained within the RLPs or along the major waterway corridors.

4.5.1. The importance of the major waterways in Knox as habitat and corridors for movement

The RLPs offer large and consolidated areas with high natural values and minimal development. Large extents within the RLPS contain multiple overlapping ecological values for wildlife, highlighting the critical importance of these areas for maintaining viable and diverse populations of wildlife.

This analysis also confirmed the importance of Blind Creek and Corhanwarrabul Creek as important habitat and connectors across the municipality of Knox, connecting the foothills of the Dandenongs to Dandenong Creek (Figure 29), and the importance of Dandenong Creek on and around the northern and western boundaries of the municipality as critical habitat and corridor for wildlife movement (Figure 29).

General types of locations within Knox with high values for wildlife conservation and connectivity are shown in Figure 29 and described in Table 10. Specific cases of these location types are also identified in the finer scale maps of the respective Rural Land Precincts (Figure 30 to Figure 37).

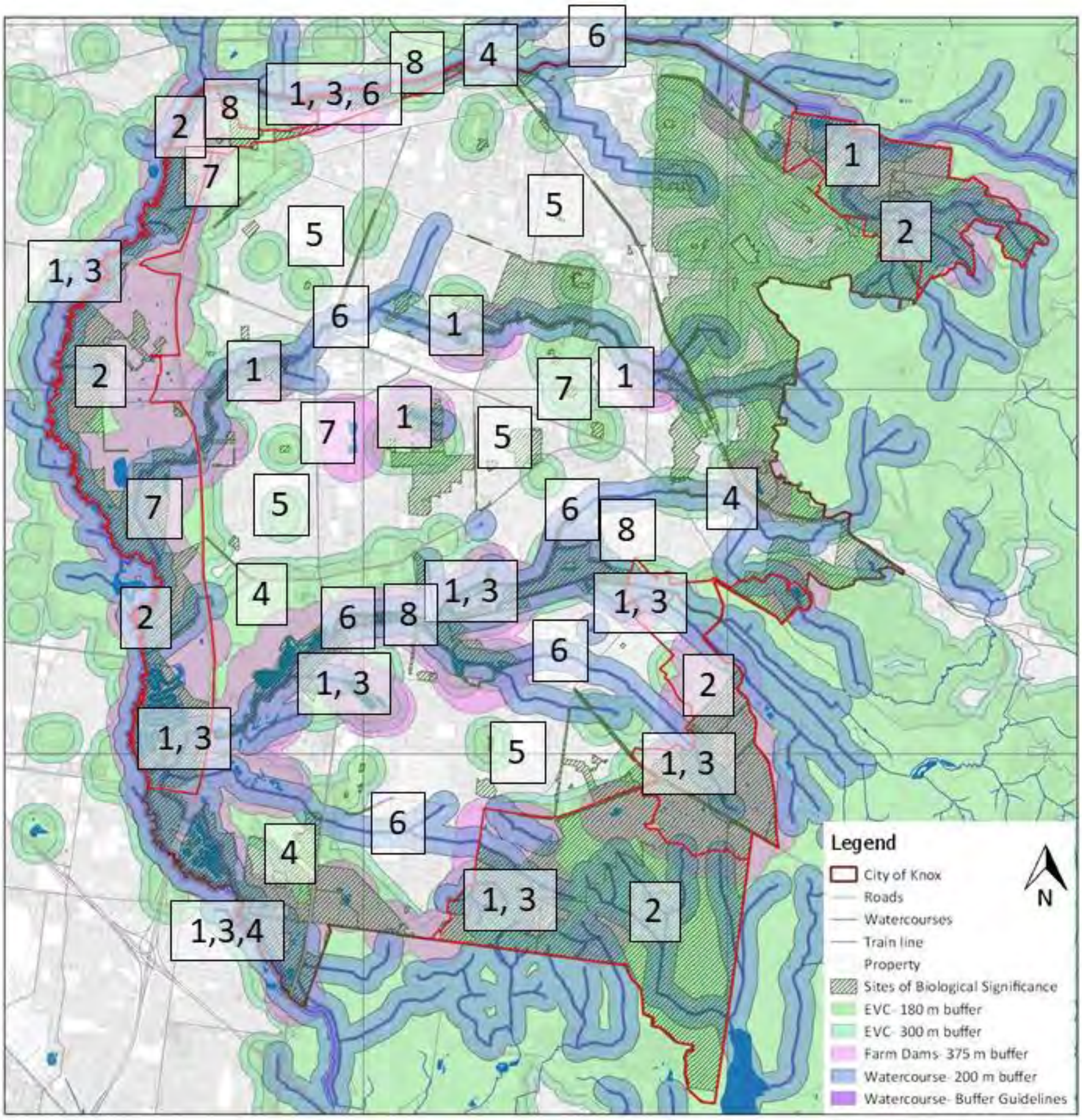


Figure 29. Important areas for protecting habitat quality and movement opportunities for wildlife within the City of Knox.

Increasingly darker shading indicates a larger number of overlapping values, and hence greater importance for wildlife conservation. For interpretation of numbered labels see Table 10. Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria; Farm Dams and Billabongs – Draft layer from Melbourne Water. Grid overlay 5 km x 5 km.

Table 10. General types of areas with high ecological value for wildlife conservation and connectivity in Knox. Specific locations associated with some of these types are discussed in more detail at the Rural Land Precinct scale.

Type	Important ecological value for wildlife conservation and connectivity	Actions to retain and enhance ecological values
1	Locations with multiple overlapping ecological values, where remnant vegetation, riparian areas and farm dams or other waterbodies exist in close proximity to each other. These areas provide a diversity of habitat values and are likely to be hotspots for biodiversity as they will support not only the habitat specialists (e.g. riparian species), but will also provide a critical opportunity for species with multiple and diverse habitat needs	• Protect and conserve the multiple ecological features that provide these values • Minimize any potential barriers to movement in these areas, including linear infrastructure (e.g. roads), large buildings, and fences at ground level • Mitigate the barrier effect for any essential infrastructure that cannot be placed elsewhere • Actively manage environmental weeds, predators or other threats to habitat quality • Augment the vegetation in these areas and apply appropriate vegetation management practices to increase the habitat value
2	Large consolidated areas of greenspace with ecological values are largely restricted to the Rural Land Precincts. Maintaining the continuous cover of natural vegetation is critical to the long-term viability of wildlife as more they will support larger populations and offer greater opportunities for movement and dispersal in multiple directions	• Preserve and protect large consolidated areas of greenspace, such as those in the Rural Land Precincts • Protect against incremental habitat loss in these areas by restricting development of built structures, such as buildings and roads • Protect against reduction in habitat condition by minimising degrading processes such as decreasing minimum lot sizes, or allowing additional impacts such as artificial light at night or noise pollution to intrude on these areas • Pro-actively augment and enhance existing ecological values through restoration and revegetation activities and controlling environmental weeds, introduced predators and other species that have detrimental effects on wildlife communities
3	High density of farm dams, offering opportunity for wetland species (turtles, frogs) to move in search of food, nesting sites or mates. Higher density of farm dams support larger populations, with more individuals and greater genetic diversity and therefore a higher likelihood of surviving future challenges	• Allow activities that retain continuous areas of longer grass, trees and shrubs between ponds. These provide cover and protection while animals move between ponds (e.g. low to medium density stocking of livestock grazing) • Support and encourage activities that improve the quality of the water and vegetation surrounding farm dams, potentially through Knox's Gardens For Wildlife program, or by linking in with other initiatives that have a stronger rural focus (e.g. Land for Wildlife, Landcare Australia, Greening Australia) • Limit intensive activities (increased building densities, market gardens, heavy stock grazing) that drastically alter the intensity of human activity and impact on the quality of the farm dams or surrounding vegetation • Locate septic tanks and animal manure collection areas away from farm dams to reduce risk of nutrient impacts during leaching, seepage or overflow events • Minimize water runoff from impermeable surfaces directly entering farm dams to reduce risk of erosion and pollution impacts
4	Areas with very high ecological values for wildlife connectivity outside of Rural Land Precinct zones provide important connections	• Protect existing connections along Dandenong Creek and inland connections from Corhanwarrabul Creek to Waverley Golf Club via Kingston Links Golf Club by limiting new roads and buildings in these areas in favour of compatible land uses

	between large areas of remnant vegetation (e.g. National Parks) which can act as source populations for areas that may not support viable populations of wildlife on their own, but which play a crucial role in adding additional habitat and thus supporting a larger population in the region	such as golf-courses, community farms, outdoor recreational uses and other nature-based activities • Enhance and augment existing ecological values through bushland restoration efforts and other initiatives that add ecologically import habitat features to the area
5	Developed areas with small, isolated locations with one or two high ecological values for wildlife. The scarcity of these ecological features within a landscape confers extra importance to any locations where they are still present	• Protect and conserve the native vegetation and other ecological features that provide these values • Complementary planting in the surrounding streetscapes and encouraging strong uptake of Gardens For Wildlife participation, particularly within the buffer areas surrounding the ecological features will enhance their long-term viability and increase their ecological impact • Adding new habitat in the areas between isolated features will increase the ability of wildlife to move through those landscapes and recolonise patches following local extinction events
6	Areas within high ecological value buffer zones where development has already occurred still offer important opportunities for wildlife connectivity and conservation (e.g. along Blind Creek and Corhanwarrabul Creek, and Dandenong Creek between RLP1 and 4)	• Incorporate habitat elements into nature strips and other areas in surrounding streetscapes. Habitat elements include connected tree canopy, multi-story vegetation (ground cover, mid-level shrubs, tree canopy) drawing from indigenous plant species found in remnant. • Encourage similar actions on private land through initiatives such as Gardens for Wildlife. • Place stronger requirements for green cover on private land in these areas as wildlife will use backyards as supplementary habitat (e.g. limit infill development, mandate a minimum 30% green space per property) • Encourage wildlife friendly fences that allow wildlife to go over or under them, whilst still functioning as fences for human purposes (e.g. keeping pets in yards) • Encourage consolidation of private greenspaces e.g. neighbours coordinate planting so that small plantings on each block form part of a larger ecological feature • Encourage "city as a catchment" approaches to water management
7	New developments in areas containing or adjacent to features of ecological value (e.g. golf courses, hobby farms, horse agistment) provide a critical opportunity to retain and enhance ecological values in the area while also meeting the needs for an increasing human population	New locations for residential development are critical to the long-term prosperity of Knox. However, where future large-scale developments are planned for largely natural sites, such as golf courses, opportunities should be sought to: • Protect and retain existing ecological features, such as large old trees, remnant vegetation, natural wetlands and connections among nearby features. • Engage and encourage the developer to consider working with existing ecological features on site and incorporating them into the planning, design, construction and ongoing liveability phases for that development
8	Construction of linear infrastructure (e.g. roads, bridges) in locations that are currently held as reserves has the potentially to significantly decrease connectivity and habitat values for wildlife in those	• Wherever possible, (re)align the road or bridge so that it has the least impact on the existing ecological assets in the areas • If construction must proceed, design the new infrastructure such that it is compatible with the existing ecological values of the site through:

	locations, through both the loss of existing habitat, and the replacement of corridors with barriers	• Use of part of the reserve to create parallel corridors for wildlife and/or people (e.g. Appendix 8) • Add wildlife crossing structures such as those identified in Appendix 7

4.5.2. The importance of each Rural Land Precinct for habitat and connectivity of wildlife

Rural Land Precinct 1 – The Basin

The Basin Rural Land Precinct (RLP 1) contains large extents of EVC Groups (Herb-rich Woodlands and Wet or Damp Forests) that rarely occur in other areas of Knox (Figure 12). It is also surrounded on the southern, eastern and north-eastern boundaries by the Dandenong Ranges National Park, and provides an important consolidated link between Doongalla Forest and the Upper Ferntree Gully blocks. The current landscape has a high density of watercourses, farm dams and remnant vegetation (Figure 30), and a large diversity of native wildlife species have been recorded in the precinct (

Table 6).

The eastern half of the precinct contains the largest consolidated areas of native vegetation, as well as many of the headwater streams that feed into Dandenong Creek via Dobson's Creek. The Salvation Army Site (Special Use Zone - Schedule 1) is likely to play an important role in protecting the adjacent Rural Conservation Zone, as well as providing opportunities for connection to the Liverpool Rd Retarding Basin (Public Conservation Zone), and offers complementary and additional resources to wildlife in these areas. Any future development in this zone should be minimal and restricted to non-intensive and ecologically-compatible activities, such as grazing or perennial horticulture as outlined in the Assessment of Agricultural Potential of Rural Land in Knox Report (RMCG Environment 2016).

Throughout the remainder of this RLP, maintaining high levels of connectivity will be critical to retaining high quality conservation outcomes in this landscape. Opportunities for additional development are limited, and should be restricted to complementary land-uses, with any sub-division limited to minimum lot sizes of > 8.0 hectares (20 acres). Complementary land-uses include enterprises based around native vegetation such as the establishment of commercial seed growing properties, or native plant cut-flowers or nurseries, or sites for nature-based education or experiences.

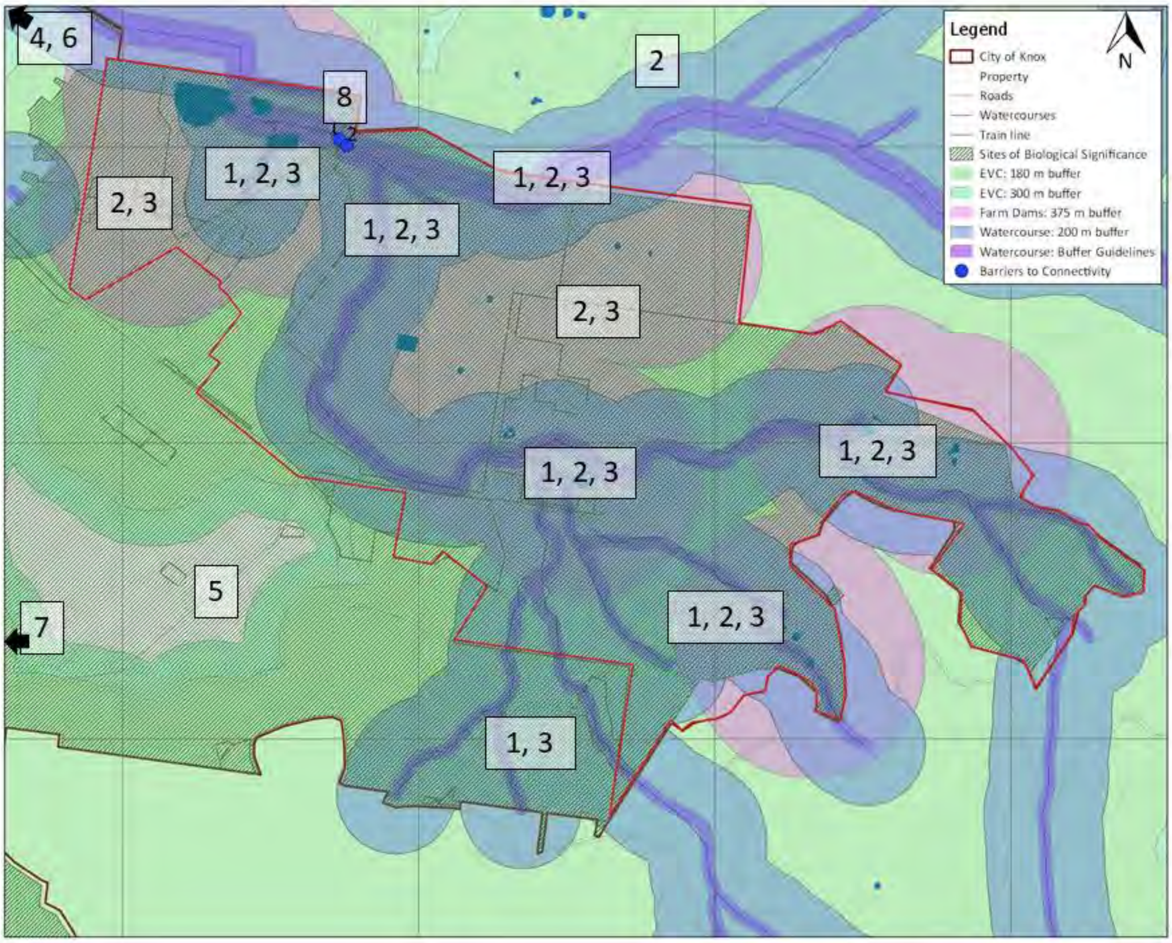


Figure 30. Important areas for protecting habitat quality and movement opportunities for wildlife within The Basin Rural Land Precinct (RLP 1).

Increasingly darker shading indicates a larger number of overlapping values, and hence greater importance for wildlife conservation. For interpretation of numbered labels see Table 10. For overview of location within Knox see Appendix 11. Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status)

(NV2005_EVCBCS/EVCBCS) © State of Victoria; Farm Dams and Billabongs – Draft layer from Melbourne Water. Grid overlay 1 km x 1 km.

Rural Land Precinct 2a- Lysterfield Valleys and Hills

Rural Land Precinct 2a- Lysterfield Valleys and Hills provides an important connection for wildlife movement between Lysterfield National Park and the Upper Ferntree Gully block of the Dandenong Ranges National Park (Figure 31). The southern two-thirds of this precinct contains well connected farm dams and is likely to provide important overland connections for meta-populations of water-dependent species such as the Southern Bullfrog and Eastern Snake-necked Turtle, as well as other ground dwelling amphibians such as the EPBC-listed Growling Grass Frog *Litoria raniformis*, which was historically recorded in this area. The Green Wedge Zone- Schedule 2 and the Rural Conservation Zones currently protect and support wildlife connectivity and conservation outcomes. Further protection and enhancement in the northern section of this precinct could help strengthen the resilience of this area. For example, habitat restoration activities within the 200 m zone adjacent to Monbulk Creek are likely to reduce the risk of flooding in the downstream Urban Flood Zones. This is something that will become increasingly important once construction has been completed in the Comprehensive Development Zone to the north-west of this precinct and when the future climate includes more extreme rainfall events.

The northern section of RLP 2a is a critical junction point for connectivity, with this analysis showing it is currently a relatively narrow connection between the Green Wedge to the Corhanwarrabul Creek Corridor. As many ground-dwelling animals, such as Short-beaked Echidna, Blue-tongued Lizards, Eastern Snake-necked Turtle and Southern Bullfrog use riparian corridors to facilitate movement between sub-populations, protecting this area of the landscape will maximise the probability that these species are able to persist and support viable populations in the western side of Knox (e.g. Rural Land Precinct 3- Dandenong Valley Parklands).

The proposed Dorset Road Extension is likely to have an impact on the wildlife conservation and connectivity values of this precinct, as it currently acts as an informal connector between RLP 2a and Ferny Creek. However, there are opportunities to approach this road extension project in ways that also deliver improved connectivity benefits for wildlife and people. A case study example of how this extension project might be undertaken to deliver both a transport and a wildlife corridor is presented in Appendix 8.

The current minimum property size for the Green Wedge Zone - Schedule 1 is 8.0 hectares (20 acres), and this should be protected wherever possible to ensure that the wildlife conservation and connectivity opportunities in this landscape remain at their current level. There are also opportunities to work with land-holders of these properties to undertake actions that will augment the ecological value of this landscape for wildlife, similar to the Gardens for Wildlife initiative that has been well received by the urban residents of Knox. Any future development in this precinct should be restricted to clusters along a narrow zone adjoining major roads (e.g. Wellington Rd), in combination with wildlife crossing structures in the sections between clusters to ensure there are minimal impacts on wildlife in this landscape. Other compatible land-uses for this precinct are: existing annual horticulture in the northern section, livestock grazing, nature-based or open air sports and recreation, bush playgroups, and community gardens.

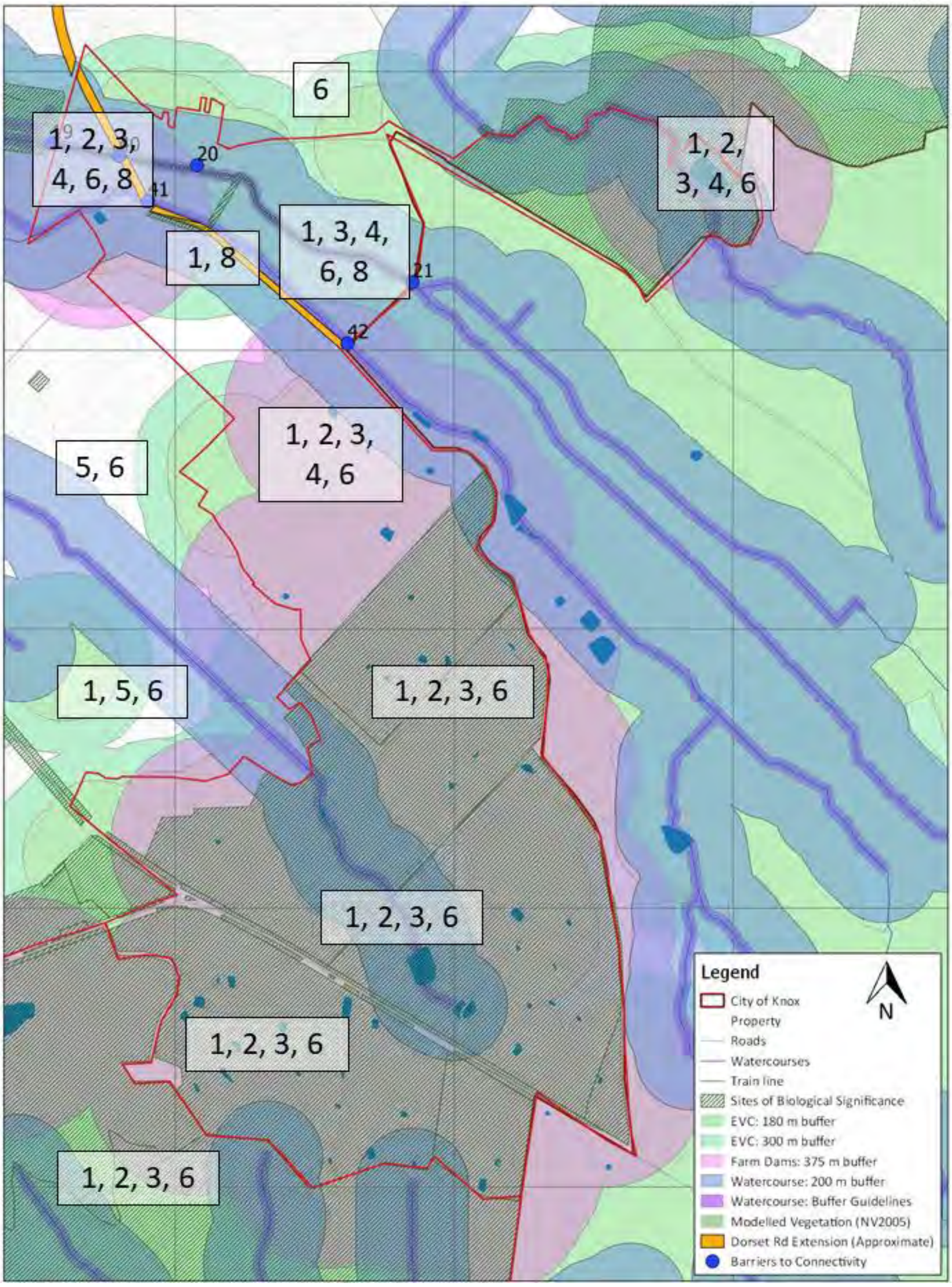


Figure 31. Important areas for protecting habitat quality and movement opportunities for wildlife within the Lysterfield Valleys and Hills Rural Land Precinct (RLP 2a).

Increasingly darker shading indicates a larger number of overlapping values, and hence greater importance for wildlife conservation. For interpretation of numbered labels see Table 10. For overview of location within Knox see Appendix 11. Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria; Farm Dams and Billabongs – Draft layer from Melbourne Water. Grid overlay 1 km x 1 km.

Rural Land Precinct 2b - Lysterfield Quarries and Surrounds

The southern and eastern areas of Rural Land Precinct 2b - Lysterfield Quarries and Surrounds contains a significant section of Lysterfield National Park, and much of the catchment for the streams which feed into Lysterfield Lake (Figure 32). These features are currently within areas designated as Public Conservation Zone and as Public Parks and Recreation Zone. There are a small number of areas designated as Green Wedge Zones - Schedule 2, in which the minimum property size is 1.6 hectares (or 4 acres), and these largely coincide with the areas of lower conservation and connectivity value within this Precinct. However, future development of these areas or a reduction in the minimum property size is likely to exert a negative influence on the extensive areas of native vegetation and other habitat options in this landscape.

The north-east section of this precinct abuts Rural Land Precinct 2a, with the many farm dams and the adjacent catchment of Monbulk Creek. Maintaining this connection between the native vegetation and the adjacent agricultural lands will help preserve the populations of Short-beaked Echidna, Southern Bullfrog, Black Wallaby, and the four bird focal species that occur in this landscape.

The eastern section of this Precinct offers the closest point for connection across to Rural Land Precinct 3- Dandenong Valley Parklands (Figure 36), and any development that occurs in this area should consider the implications for these important wildlife connections. Land-uses that help retain the rural and natural landscape characteristics of this area would be the first priority, followed by moderate impact land uses (e.g., ecologically sensitive small scale residential developments) located adjacent to already developed lands, particularly when these moderate land uses can help secure long-term protection of dedicated habitat corridors nearby.

As much of the northern boundaries of this precinct are adjacent to residential development, they offer an important buffer against negative impacts from human activities or associated disturbances such as domestic cats and dogs. To protect the value of this buffer habitat, initiatives that encourage responsible pet ownership, or which restrict the number of domestic cats and dogs in the area will help to ensure that the biodiversity of this area remains high.

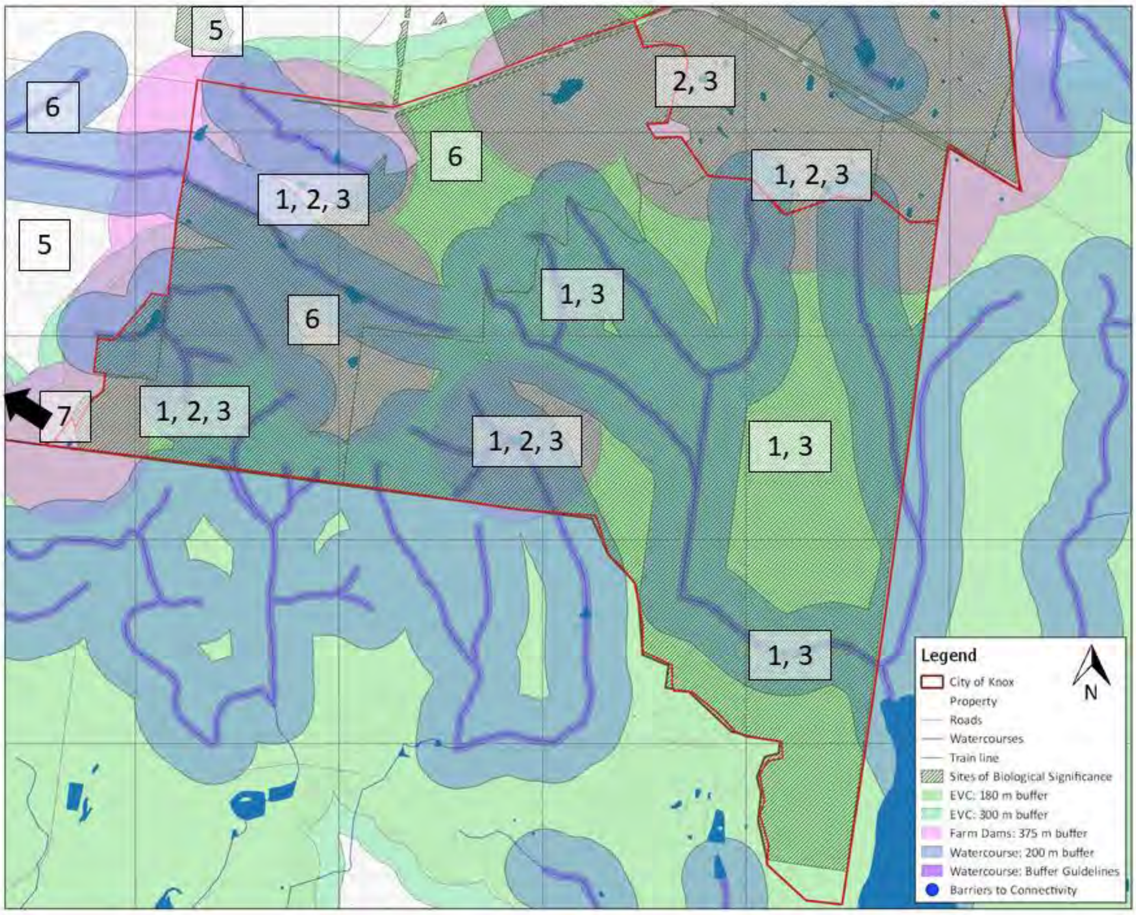


Figure 32. Important areas for protecting habitat quality and movement opportunities for wildlife within the Lysterfield Quarries and Surrounds Rural Land Precinct (RLP 2b).

Increasingly darker shading indicates a larger number of overlapping values, and hence greater importance for wildlife conservation. For interpretation of numbered labels see Table 10. For overview of location within Knox see Appendix 11. Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria; Farm Dams and Billabongs – Draft layer from Melbourne Water. Grid overlay 1 km x 1 km.

Rural Land Precinct 3 – Dandenong Creek Valley

Rural Land Precinct 3 contains many well-connected billabongs, the widest core riparian zones, large extents of 1 in 100 year flood plains, as well as a relatively consistent spread of remnant vegetation along the length of the precinct (Figure 33, Figure 34). Significant investment into the natural assets in this precinct were made by a number of agencies during the construction of the EastLink Tollway, and any development in this precinct has the potential to significantly compromise the returns on that investment unless it is undertaken very carefully.

The Assessment of Agricultural Potential of Rural Land in Knox Report (RMCG Environment 2016) identified poor maintenance of orchards and weed control as factors that could detract from the amenity value of this landscape. These also have the potential to reduce the wildlife connectivity and conservation values of this precinct if they encroach upon areas of native vegetation or other areas of habitat. However, in some cases areas of existing weeds may provide habitat values for wildlife. For example, Southern Brown Bandicoots have been recorded using blackberry bushes along fencelines as they offer protection against predators. Therefore, any actions to remove or reduce weed cover should be undertaken in a staged basis, alongside active planting of native vegetation as replacement habitat.

Compatible land uses within this precinct would be for passive and active recreation-based activities (e.g. cycling, walking, birdwatching), and associated infrastructure (e.g. small cafes, amenity stations), nature-based education programs, continuance of low intensity farming practices, and enterprises based around native vegetation such as the establishment of commercial seed growing properties, or native plant cut-flowers or nurseries. These land-uses were also identified as compatible with the Agricultural potential of this precinct in the Assessment of Agricultural Potential of Rural Land in Knox Report (RMCG Environment 2016).

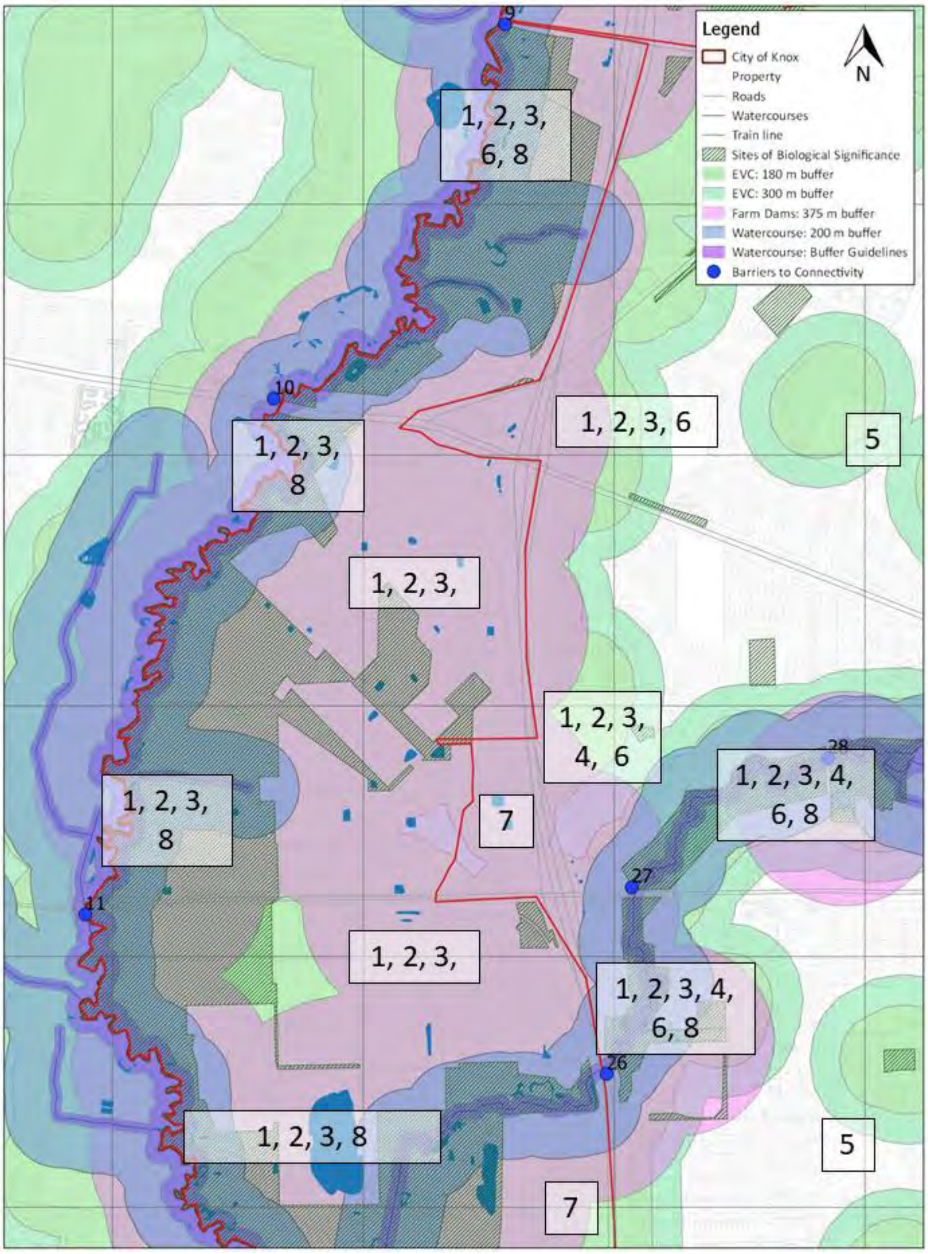


Figure 33. Important areas for protecting habitat quality and movement opportunities for wildlife within the northern half of the Dandenong Creek Valley Rural Land Precinct (RLP 3).

Increasingly darker shading indicates a larger number of overlapping values, and hence greater importance for wildlife conservation. For interpretation of numbered labels see Table 10. For overview of location within Knox see Appendix 11. Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria; Farm Dams and Billabongs – Draft layer from Melbourne Water. Grid overlay 1 km x 1 km.

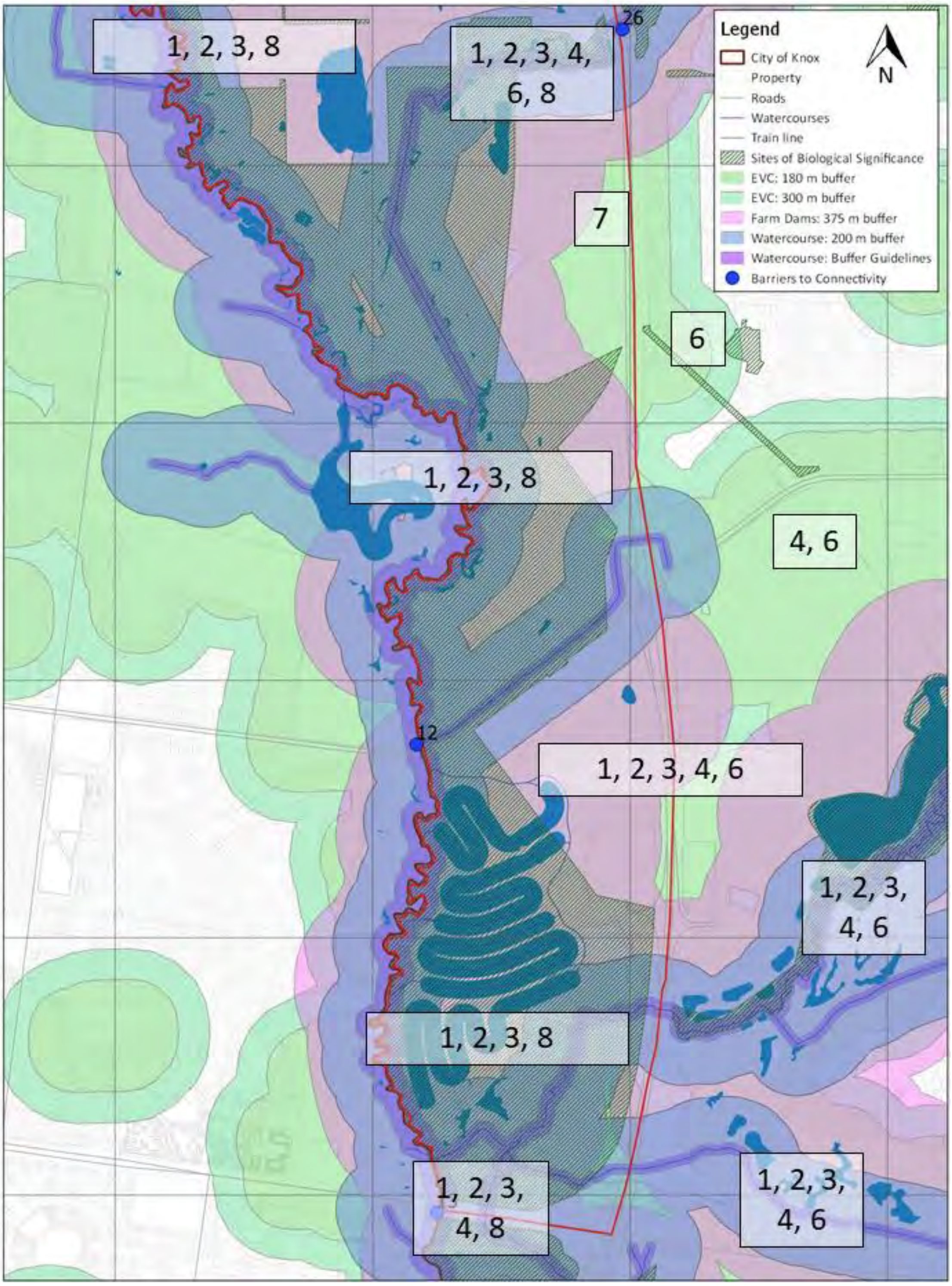


Figure 34. Important areas for protecting habitat quality and movement opportunities for wildlife within the southern half of the Dandenong Creek Valley Rural Land Precinct (RLP 3).

Increasingly darker shading indicates a larger number of overlapping values, and hence greater importance for wildlife conservation. For interpretation of numbered labels see Table 10. For overview of location within Knox see Appendix 11. Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria; Farm Dams and Billabongs – Draft layer from Melbourne Water. Grid overlay 1 km x 1 km.

Rural Land Precinct 4 – Healesville Freeway Reservation and Surrounds

The eastern and western ends of RLP4 contain remnant vegetation, while the central area contains areas with billabongs in close proximity to the Dandenong Creek. The remnant vegetation in the western section forms part of a larger consolidated area of remnant vegetation, some of which will be affected by the Wantirna Health Development Precinct between Mountain Highway and Boronia Road. This provides an important opportunity to consider integrating space for biodiversity into the development of this precinct, particularly given the increasingly prominent recognition of the health and wellbeing benefits delivered by the opportunity to view and interact with nature (e.g. Kaplan 1986 & more recent studies).

Within the Wantirna Health Development Precinct, focussing built infrastructure in the eastern portion close to the Wantirna Road intersection would allow the retention of larger areas of consolidated open space in proximity to the Dandenong Creek Valley RLP. This would have benefits for wildlife connectivity and conservation by providing larger, consolidated areas of vegetation rather than isolated or fragmented patches, and would allow for more continuous and immersive nature experiences for people visiting and using services within the Wantirna Health Precinct. This spatial arrangement would also allow more direct links between transport and the built infrastructure, therefore minimising the risk of wildlife exposure to vehicle traffic and reducing the journey time for people visiting the Wantirna Health precinct. Aligning the Healesville Freeway extension along the norther boundary of the Health Precinct would help reduce travel times to the precinct, protect the Batemans Bush conservation area, and allow the natural values within RLP4 to be retained along with the associated opportunities to provide improved health benefits through increased connection to nature.

Recent revegetation and restoration efforts by the Knox and Maroondah City Council Bush crews along Dandenong Creek in and around RLP4 have greatly added to the wildlife habitat and dispersal opportunities in this precinct. Any future development in this precinct should ensure that the precinct continues to provide adequate habitat and movement opportunities for wildlife as well as protect investments in bushland restoration elsewhere along Dandenong Creek. Compatible land-uses for this precinct are: nature-based health activities to complement and strengthen health outcomes at the Wantirna Health Precinct; nature-based or open air sports and recreation, bush playgroups, community gardens, along with continuance of current agistment activities identified in the Assessment of Agricultural Potential of Rural Land in Knox Report (RMCG Environment 2016), particularly when they include the management of environmental weeds using the approach outlined in the previous section (Rural Land Precinct 3 – Dandenong Creek Valley).

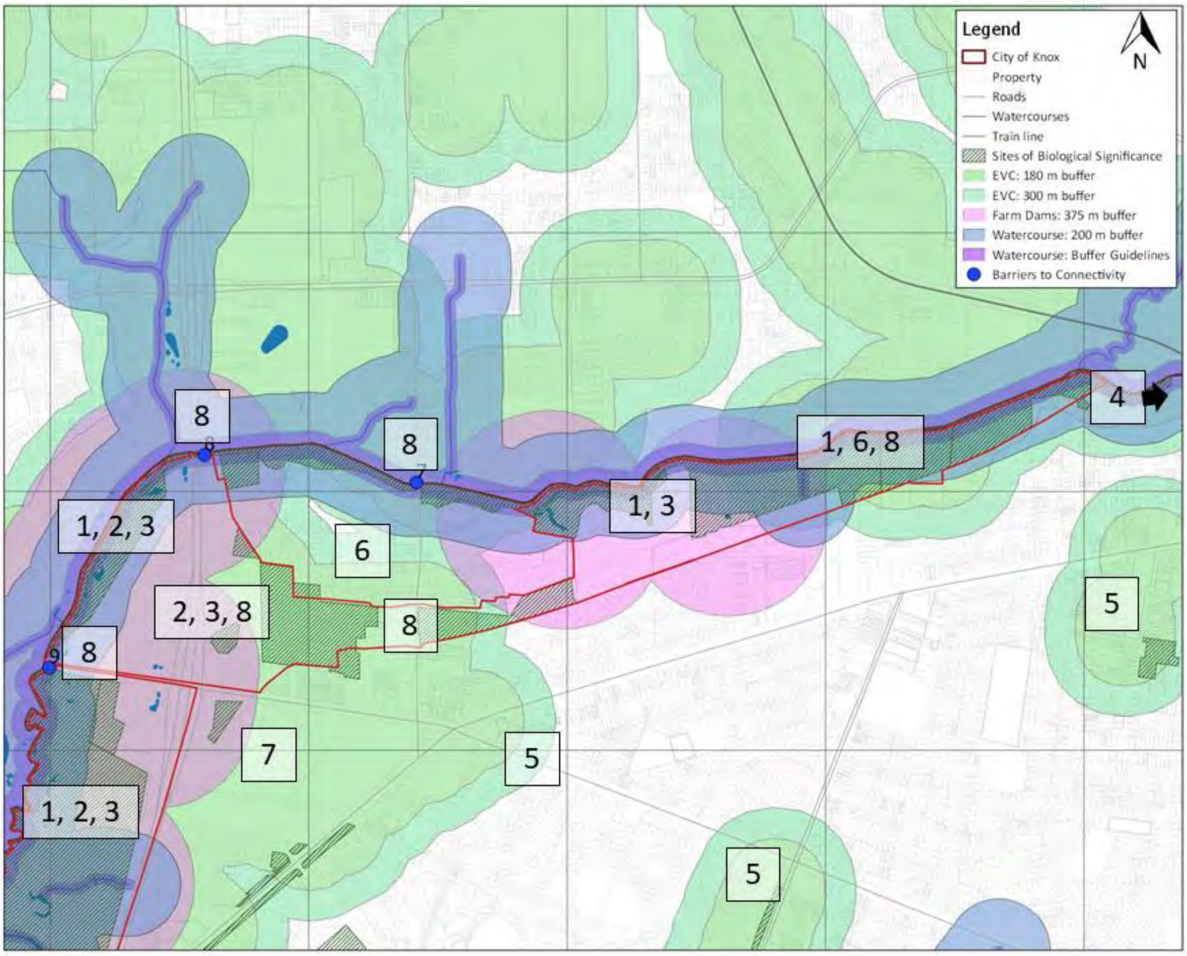


Figure 35. Important areas for protecting habitat quality and movement opportunities for wildlife within the Healesville Freeway and Surrounds Rural Land Precinct (RLP 4).

Increasingly darker shading indicates a larger number of overlapping values, and hence greater importance for wildlife conservation. For interpretation of numbered labels see Table 10. For overview of location within Knox see Appendix 11. Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria; Farm Dams and Billabongs – Draft layer from Melbourne Water. Grid overlay 1 km x 1 km.

Important areas of the municipality of Knox outside the Rural Land Precincts for wildlife conservation and connectivity

The south-west corner of Knox is not being examined directly as part of the Rural Land Precincts investigation, although it was included as a precinct in the Assessment of Agricultural Potential of Rural Land in Knox Report (RMCG Environment 2016). As it forms a critical link between the Dandenong Valley Parklands (RLP 3) and Lysterfield National Park (RLP 2b), it was important for this report to highlight the role it plays in wildlife connectivity and conservation (Figure 36). The links include a riparian connection along the Dandenong Creek corridor, as well as an important terrestrial link from Corhanwarrabul Creek to Lysterfield National Park via the Kingston Links Golf Club and Waverley Country Club.

By working with the major landholders in this area there is an opportunity to create major positive outcomes for wildlife habitat and movement by establishing wildlife linkages through the coordination of activities under formal or informal partnerships. Rezoning Waverley Country Club to residential purposes is likely to have a significant impact on wildlife connectivity and would need to be compensated with additional protections and habitat enhancements to retain connectivity along the Dandenong Creek Valley. Any residential or other high impact land-use in this area should include strict controls over minimum lot sizes, densities of residents, intensities of uses and urban de sign guidelines to minimize the impact of human activity, impermeable surfaces, and artificial light at night on the quality of the remaining natural areas.

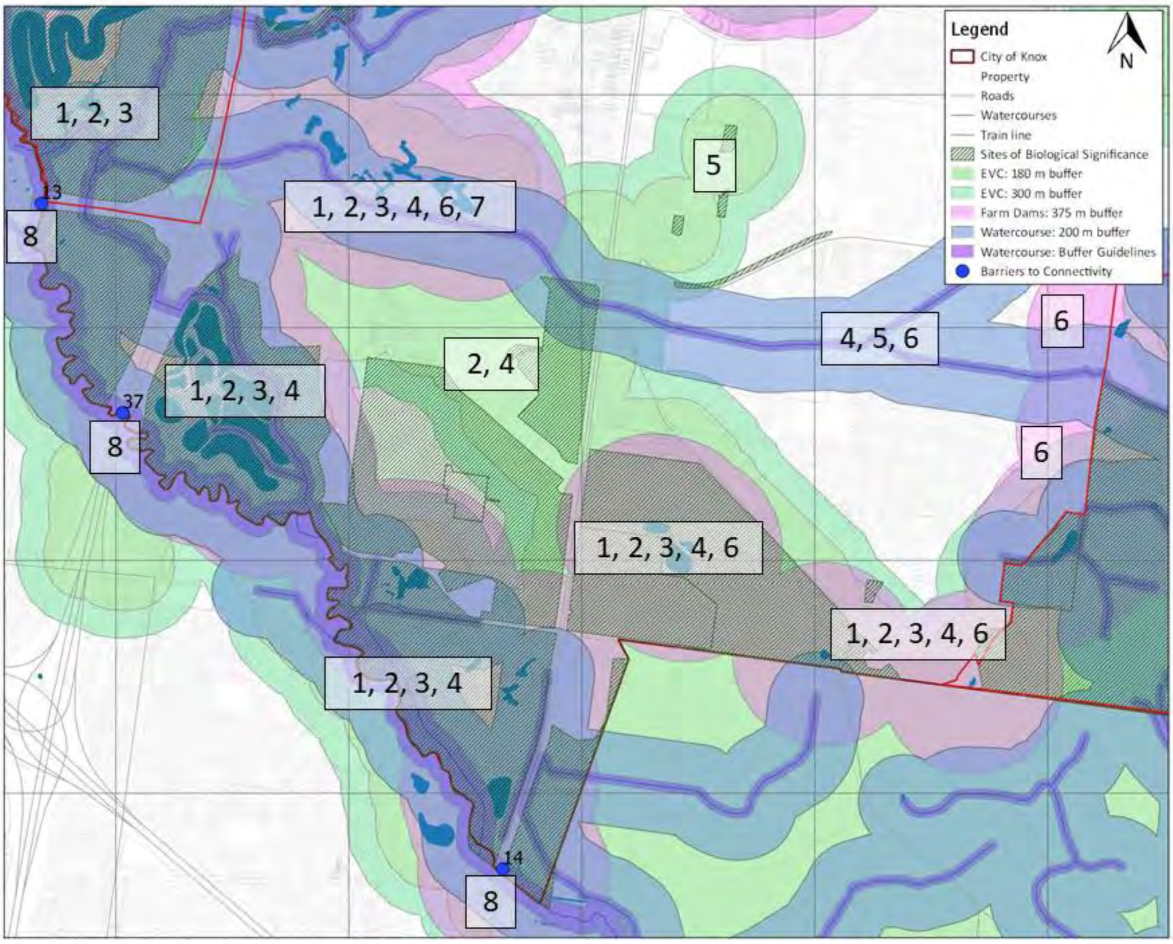


Figure 36. Important areas for protecting habitat quality and movement opportunities for wildlife in the south-west corner of Knox, as a connection between Rural Land Precinct 2b and Rural Land Precinct 3.

Increasingly darker shading indicates a larger number of overlapping values, and hence greater importance for wildlife conservation. For interpretation of numbered labels see Table 10. For overview of location within Knox see Appendix 11. Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria; Farm Dams and Billabongs – Draft layer from Melbourne Water. Grid overlay 1 km x 1 km.

The northern boundary of Knox is not being examined as part of the Rural Land Precincts investigation, but it forms a crucial link between the headwaters of Dandenong Creek and the Dandenong Ranges National Park, and Rural Land Precinct 4 and the remainder of the Dandenong Valley Parklands (Figure 37). While this area has already largely been developed, it is important to retain and protect the existing landscape features which are critical to wildlife connectivity and conservation values of the area.

These actions include protecting the integrity of the Dandenong Creek corridor by minimizing any new road extensions or other linear infrastructure wherever possible, and mitigating the impacts of those which do proceed using some of the solutions identified in Appendix 7.

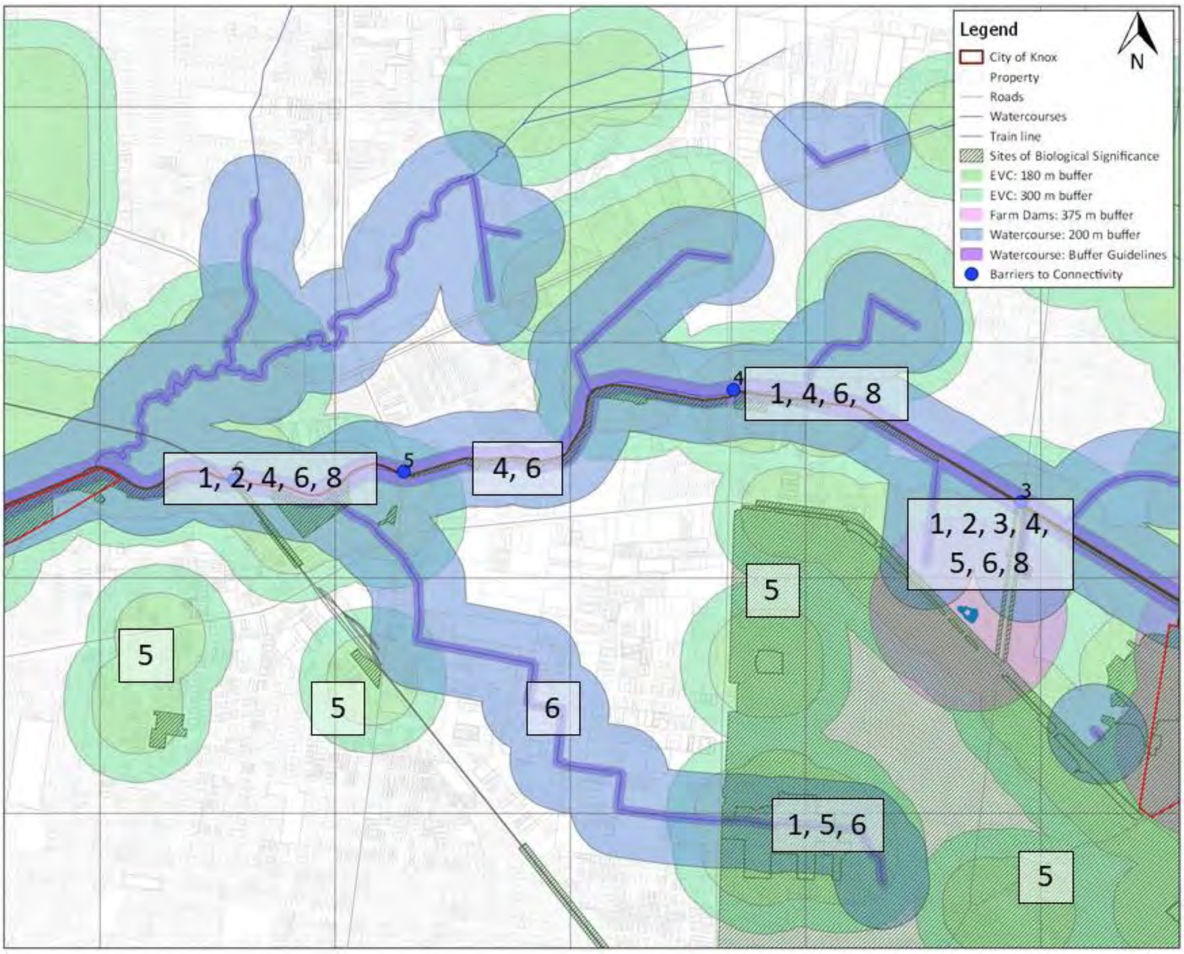


Figure 37. Important areas for protecting habitat quality and movement opportunities for wildlife in the northern area of Knox, as a connection between Rural Land Precinct 1 and Rural Land Precinct 4.

Increasingly darker shading indicates a larger number of overlapping values, and hence greater importance for wildlife conservation. For interpretation of numbered labels see Table 10. For overview of location within Knox see Appendix 11. Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria; Farm Dams and Billabongs – Draft layer from Melbourne Water. Grid overlay 1 km x 1 km.

The eastern boundary of Knox between Rural Land Precinct 1 and Rural Land Precinct 2a is not being examined directly as part of the Rural Land Precinct, but is addressed here due to the importance as a relatively short connector between Lysterfield National Park at the southern end of RLP 2a and the Dandenong Ranges National Park to the north (Figure 38). There are a number of important connections for wildlife movement and conservation in this area, particularly the links to Ferny Creek along Monbulk Creek, the upper reaches of Ferny Creek, and along the parcel of land reserved for the Dorset Road Extension. Protecting these valuable linkages will be important for retaining vital connectivity for wildlife to move between Lysterfield National Park, and the Dandenong Valley Parklands and Dandenong Ranges National Park along the Ferny Creek/Corhanwarrabul Creek corridor.

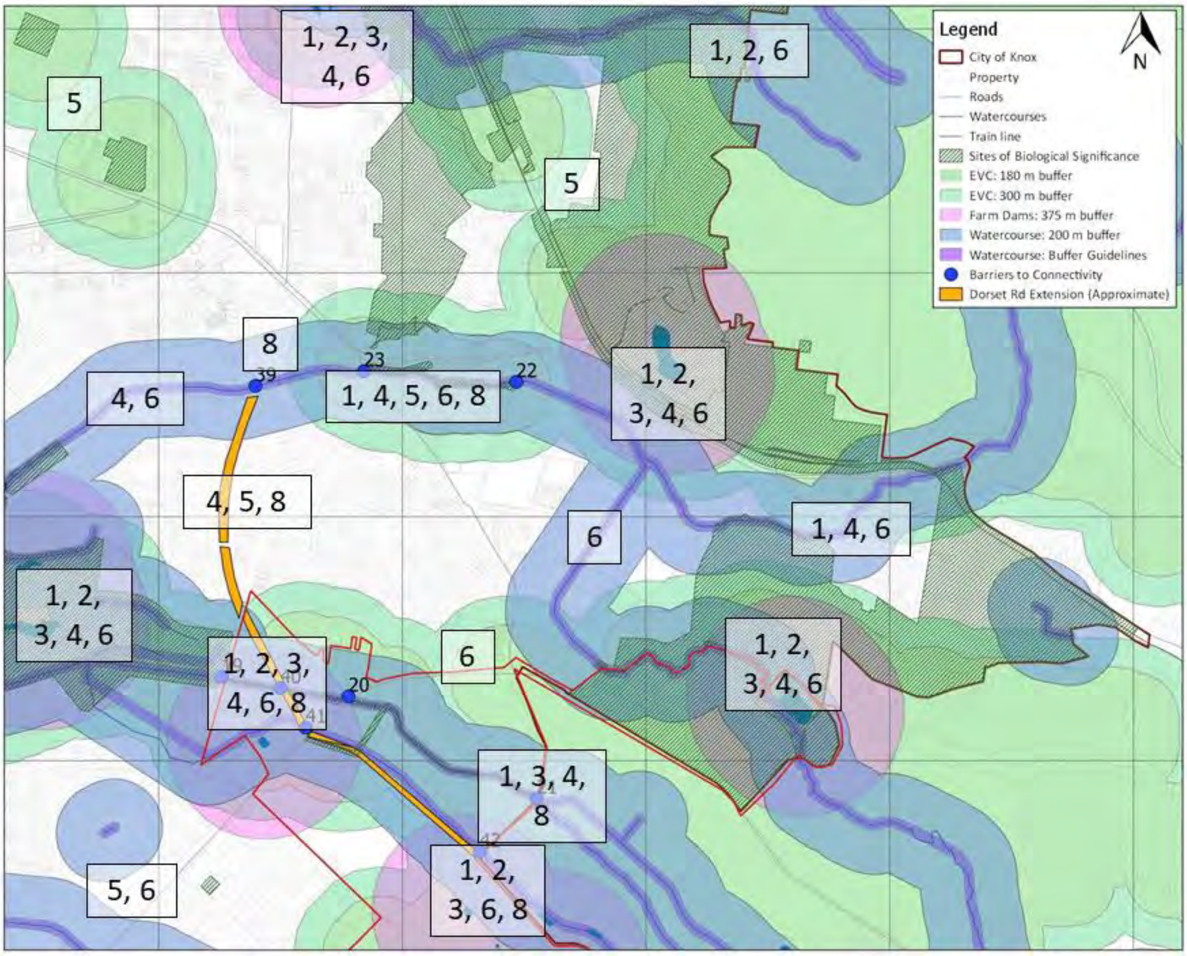


Figure 38. Important areas for protecting habitat quality and movement opportunities for wildlife in the eastern area of Knox, as a connection between Rural Land Precinct 1 and Rural Land Precinct 2a.

Increasingly darker shading indicates a larger number of overlapping values, and hence greater importance for wildlife conservation. For interpretation of numbered labels see Table 10. For overview of location within Knox see Appendix 11. The proposed Dorset Road extension is shown in orange. Data Source: Native Vegetation - Modelled 2005 Ecological Vegetation Classes (with Bioregional Conservation Status) (NV2005_EVCBCS/EVCBCS) © State of Victoria; Farm Dams and Billabongs – Draft layer from Melbourne Water. Grid overlay 1 km x 1 km.

5. Discussion and recommendations

Broader context

There are a number of high-level plans and strategies relating to habitat connectivity at national, state and regional spatial scales, however it is unclear how successfully these are being implemented and their applicability to the spatial scale of KCC. A consistent theme, however, throughout these documents is that stakeholder involvement and project ownership is critical to the success of every program. Private land owners in particular have a critical role to play in facilitating connectivity for fauna and flora species and communities, as much biodiversity exists outside of areas formally managed for conservation. The Gondwana Link project (http://www.gondwanalink.org/) demonstrates a *best-practise* approach that could be replicated even at a local scale, and has a wealth of publicly-available support resources. Of the regional and local plans reviewed, Melbourne Water's Waterway Corridors Guidelines can be applied immediately and integrated with the Knox corridor plan, while other LGA corridor / connectivity plans are not sufficiently developed to determine their usefulness as a model for KCC.

The Knox City Council area

Previous work has highlighted that the Knox municipality contains natural landscapes that are significant at metropolitan, regional and local levels, and that Knox supports approximately 450 species of flora. There are also around 120 sites across Knox that support remnant or restored indigenous vegetation, including 77 sites that are significant at the State level, primarily because of the occurrence of two ecological vegetation classes that are listed as 'Endangered', namely Valley Heathy Forest (EVC 127) and Swampy Woodland (EVC 651). These sites primarily occur in the four Rural Land Precincts that were a focus of this report. We found that vegetation within the RLPs and along major waterways are critical for the 'across Knox' movements and faunal interchange with adjacent LGAs, while the shorter roadsides, scattered trees and native gardens are critical for local, fine-scale movements. Additionally, RLPs are variously well connected with more extensive habitats outside of the KCC area, especially with areas to the east, providing strong connectivity with extensive areas of natural habitat. This linkage to large tracts of habitat is important because it can support larger populations of wildlife species, and therefore greater likelihood of these populations persisting into the future.

Our study found that the KCC area harboured a high diversity of fauna (237 species), and that each of the four RLPs had unique assemblage of faunal species (Table 4). These differences were related to both the EVCs present and the connectedness with larger areas of habitat outside the KCC. Importantly, KCC contains good numbers of some species which have declined, or disappeared, from more highly urbanised areas to the west. This abundance and diversity reflects the extinction debt from historic practices, and the impact of current practices, including continuing clearing of vegetation, urban densification, loss of tree cover in backyards and road widening. This is concerning because a recent analysis of wildlife records of a range of species within the VBA shows that the inner LGAs have lower species diversity than the outer LGAs, and that without intentional planning and improved management, the outer LGAs will, over time, similarly decline (van der Ree 2004; van der Ree & McCarthy 2005; Hamer & McDonnell 2010)

For native vegetation, the area of the Dry Forests group of EVCs was highly correlated with the occurrence of most of the ten focal species, while some species were primarily associated with Wet/Damp Forests, which within the City of Knox, only occurs within The Basin RLP. All areas of these EVC Groups should be a priority for protection across the KCC area. We also showed that riparian areas are important habitat for many fauna species, and often provide important connectivity between larger areas of suitable habitat. While riparian areas may not always correspond to a relevant EVC, they should also be a focus for protection and restoration activities.

Both measures of urbanisation that we used – road density and average property size – had a generally negative influence on our focal species. For roads, birds were likely to remain in proximity to higher road classes, however all other focal species clearly avoided areas with any roads other than local roads. For property sizes, focal species were most likely to be found in properties of more than two hectares (~5 acres), and no focal species were reported from areas with 0.1 hectare (¼ acre) blocks. Our analysis highlighted the importance of maintaining areas free of major roads, as we found this had a negative effect on the presence of most of our non-bird focal species. We also identified a series of barriers to wildlife movement, primarily along the three major waterways of the RLPs. The impact of each barrier will be species-specific, however improvements can readily be made to most of these barriers to make them less of an impediment to animal movements.

The four RLPs displayed unique and distinctive landscape character and wildlife opportunities. Therefore, while some planning and management actions can be applied at the scale of the municipality, others will need to be applied specifically to each RLP. The extent of the existing connectedness among the RLPs means that KCC has the potential to proactively prepare for climate change and reduce the predicted impacts on EVCs, and flora and fauna distributions in their management planning. Reducing the area and connectivity of RLPs would limit the ability of flora and fauna to move in response to climate change, and eventually this would lessen the biodiversity present within KCC. At particular risk are wetland EVCs (Meacher 2013) due to higher temperatures and increasingly variable rainfall patterns, therefore, ensuring that such habitats are maintained shouldbe a focus for KCC as these EVCs provide habitat for a large range of fauna that is currently present within KCC.

Here we provide a series of recommendations to maintain and increase the connectivity of wildlife habitat areas in the KCC area. These act at different scales, on different landscape elements and require varying levels of commitment (in terms of time, money and resources), however we have attempted to prioritise these where possible. When evaluating each recommendation, our primary consideration was the long-term impact on the survival of fauna species within the KCC area: we did not take into account the feasibility, resources or effort required to implement each recommendation.

High priority:

I) Ensure that the connectivity elements and important habitats we identified within and among RLPs (Section 4.2 and 4.5) are incorporated into KCC planning especially in the review of development applications and strategic planning of the RLPs. These include:
   a) Locations with multiple overlapping ecological values, where remnant vegetation, riparian areas and farm dams or other waterbodies exist in close proximity to each other.
   b) Large consolidated areas of greenspace.
   c) Areas with a high density of farm dams, offering opportunity for wetland species (turtles, frogs) to move in search of food, nesting sites or mates.
   d) Areas with very high ecological values for wildlife connectivity outside of the RLPs, particularly along Dandenong Creek, Blind Creek and Corhanwarrabul Creek and their tributaries.
   e) Small, isolated locations with one or two high ecological values for wildlife within developed areas, e.g. remnant patches of vegetation or isolated ponds.

II) Mandate an ecologically sensitive development approach in all applications for:
   a) Areas within high ecological value buffer zones where development has already occurred.

b) New greenfield developments adjacent to and replacing areas with features of ecological value (including Wantirna Health Development Precinct).
c) Construction of linear infrastructure (e.g. roads, bridges) in locations that currently hold strong existing ecological values (e.g. riparian corridors, or areas of native vegetation within RLPs).

III) Strengthen mechanisms to protect existing areas of native vegetation from future development, particularly in locations where they are relatively isolated as these critical resources can form stepping stones for future efforts to increase connectivity for wildlife.

IV) Create 300 m protection buffers around existing areas of native vegetation, and use these buffer areas to prioritize:
a) Habitat restoration and revegetation efforts.
b) Supplementation of habitat values of both remnant and restored vegetation through provision of additional hollows via nest boxes and chainsaw hollows in a systematic, co-ordinated manner.

V) Develop mechanisms to protect riparian buffer zones, particularly along Dandenong Creek, Blind Creek, Corhanwarrabul Creek and their tributaries, as these provide valuable corridors for wildlife movement, as well as critical areas for maintaining the quality of the waterways. Protections should:
a) Establish appropriate buffers around riparian areas and areas of EVCs in both planning schemes and on the ground. These should be based on existing industry best-practice (e.g. the Melbourne Water guidelines and Growling Grass Frog sub-regional strategy for riparian areas).
b) Prohibit any further development within the Melbourne Water Critical Riparian Zones and adjacent 10 m vegetation buffers.
c) Minimize any additional development in the remaining areas of the 200 m buffer zone identified by the Growling Grass Frog Sub-Regional strategy, which are not covered by the Melbourne Water Critical Riparian Zones and 10 m vegetation buffers.
d) Mandate Water Sensitive Urban Design interventions within the 200 m buffer zone to disconnect stormwater drains from natural waterways and help reinstate more natural water cycles.

VI) Develop mechanisms to protect and retain existing farm dams and augment their habitat value for wildlife. Habitat values can be protected and enhanced by:
a) Locating septic tanks and animal manure collection areas away from farm dams to reduce risk of nutrient impacts during leaching, seepage or overflow events.
b) Minimising water runoff from impermeable surfaces directly entering farm dams to reduce risk of erosion and pollution impacts.
c) Limiting intensive activities (increased building densities, market gardens, heavy stock grazing) that drastically alter the intensity of human activity and impact on the quality of the farm dams or surrounding vegetation.
d) Supporting and encouraging activities that improve the quality of the water and vegetation surrounding farm dams, potentially through Knox's Gardens For Wildlife program, or other initiatives that have a stronger rural focus (e.g. Land for Wildlife, Landcare Australia, Greening Australia).
e) Allowing activities that retain continuous areas of longer grass, trees and shrubs between ponds. These provide cover and protection while animals move between ponds (e.g. low to medium density stocking of livestock grazing).

VII) Where new or existing developments occur within the sensitive area buffer zones around waterways, farm dams or native vegetation, minimize the impact on wildlife by:

a) Controlling and limiting impacts of disturbances such as domestic pets, artificial light at night, negative human activities.
b) Mitigating barrier effects of linear infrastructure, fences and other built structures.
c) Supplementing existing habitat values by actively promoting planting of native species in backyards and public open spaces, especially understorey species. This vegetation element is especially important as shelter and nesting sites for small birds.

VIII) Establish mechanisms to identify and protect large old trees from removal in an effort to maintain permeability and retention of these critical wildlife habitats across the municipality. This may include the following actions:
a) Undertake targeted surveys of tree hollows in selected areas to both identify significant trees as well as identify areas with a lack of hollows that may be limiting the occurrence of hollow-dependent fauna, such as Sugar Gliders and hollow-nesting birds.
b) Create and maintain a database of 'significant habitat trees' on public and private land, with trees assessed on their trunk and crown diameter (which reflects their age), number of hollows, proximity to other significant trees, height, and historical significance.
c) Record the location and other data such as type, dimensions, date of installation etc, of all supplementary hollows (e.g. nest boxes and chainsaw hollows) to enable their use and effectiveness to be assessed over time.
d) Regularly measure tree canopy cover using satellite data to track changes in structural connectivity across the matrix.

IX) Reduce the barrier effects at the sites identified in Section 4.4 to increase connectivity for all fauna species, and strengthen the metapopulation and overall survival in KCC. Specifically, this includes:
a) Scoping the types of mitigation works relevant to each location, such as fencing, replacing underground pipes with open culverts or bridges, and installation of canopy bridges.
b) Developing detailed concept plans for each crossing location.
c) Prioritising timing of works, according to need and opportunity.

X) Maintain a minimum block size in the RLPs which is not less than that allowed by current controls, and seek opportunities to consolidate smaller blocks to four hectare parcels as the likely presence of focal species declines significantly when property sizes are below this threshold.

XI) Continue to support and grow the Gardens for Wildlife program, as it provides a valuable opportunity to link people to nature and involve the community in broader actions around land stewardship, in both residential and industrial landscapes.

XII) Maintain the newly created Knox Wildlife Atlas and pursue opportunities to increase the value of this asset by:
a) Creating a tailored user interface that allows it to be maintained and used more effectively within Knox CC.
b) Promoting a publicly accessible version of the Knox Wildlife Atlas as an interactive public engagement and communication tool.

Medium priority:

XIII) Undertake targeted surveys of focal species (and other high profile/charismatic/other focal species) outside their current apparent distribution within Knox and identify specific management actions to extend the known range of focal species.

XIV) Re-visit the sites of Biological Significance along roadsides and identify gaps and locations for habitat restoration to improve connectivity. Some of these gaps may be more important (and easier) to restore than the road barriers identified in Appendix 7 and Figure 28.

XV) Identify and map all sections of waterways throughout the municipality that have been piped and develop a prioritised plan to 'daylight' these in partnership with other relevant agencies.

XVI) Explore opportunities with Melbourne Water to:

a) Daylight the sections of creekline that are currently piped, including under roads.

b) Replace culverts with open-span bridges.

XVII) Extend supplemental habitat plantings beyond the sensitive area buffer zones, with a particular focus on areas within 500 m of waterways and RLPs.

XVIII) Identify and implement planning mechanisms and other tools that help reduce human impacts (e.g. noise, artificial light at night) in the remainder of the municipality.

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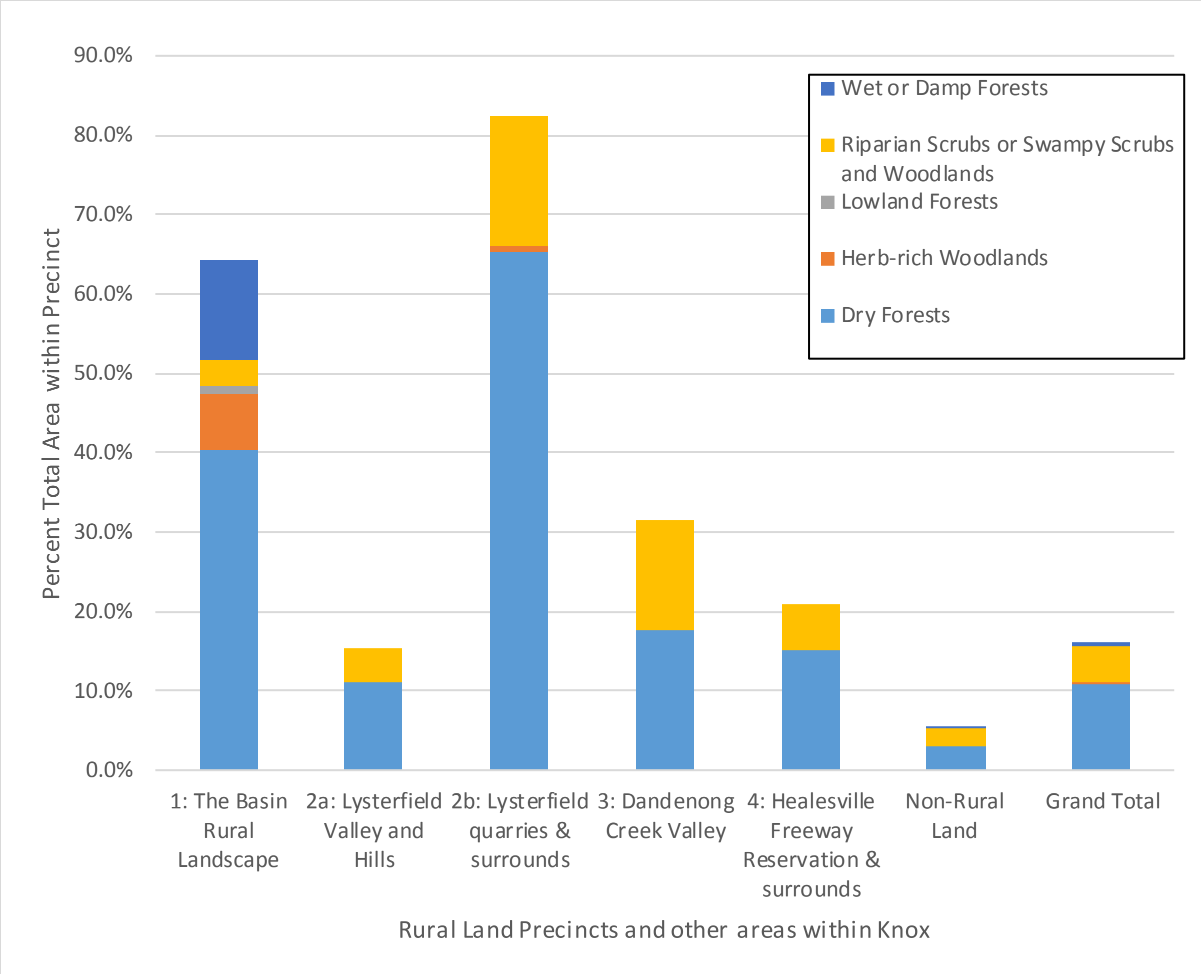
Appendix 1: Amount of each Ecological Vegetation Class Group in each Rural Land Precinct and the City of Knox.

EVC Group	1: The Basin Rural Landscape	2a: Lysterfield Valley and Hills	2b: Lysterfield quarries & surrounds	3: Dandenong Creek Valley	4: Healesville Freeway Reservation & surrounds	Non-Rural Lands	Entire City of Knox
Dry Forests (ha)	154.8	55.3	572.8	172.6	19.2	253.8	1228.5
Herb-rich Woodlands (ha)	26.3	-	7.0	-	-	0.0	33.3
Lowland Forests (ha)	4.5	0.2	-	-	-	0.2	4.9
Riparian Scrubs or Swampy Scrubs and Woodlands (ha)	12.4	21.4	142.8	135.4	7.4	199.2	518.6
Wet or Damp Forests (ha)	48.1	-	-	-	-	0.4	48.5
All EVCs Combined (ha)	*246.0*	*76.9*	*722.6*	*308.0*	*26.5*	*453.7*	*1833.7*
Total area of Precinct (ha)	**383.0**	**496.8**	**876.9**	**975.3**	**127.5**	**8542.8**	**11402.3**

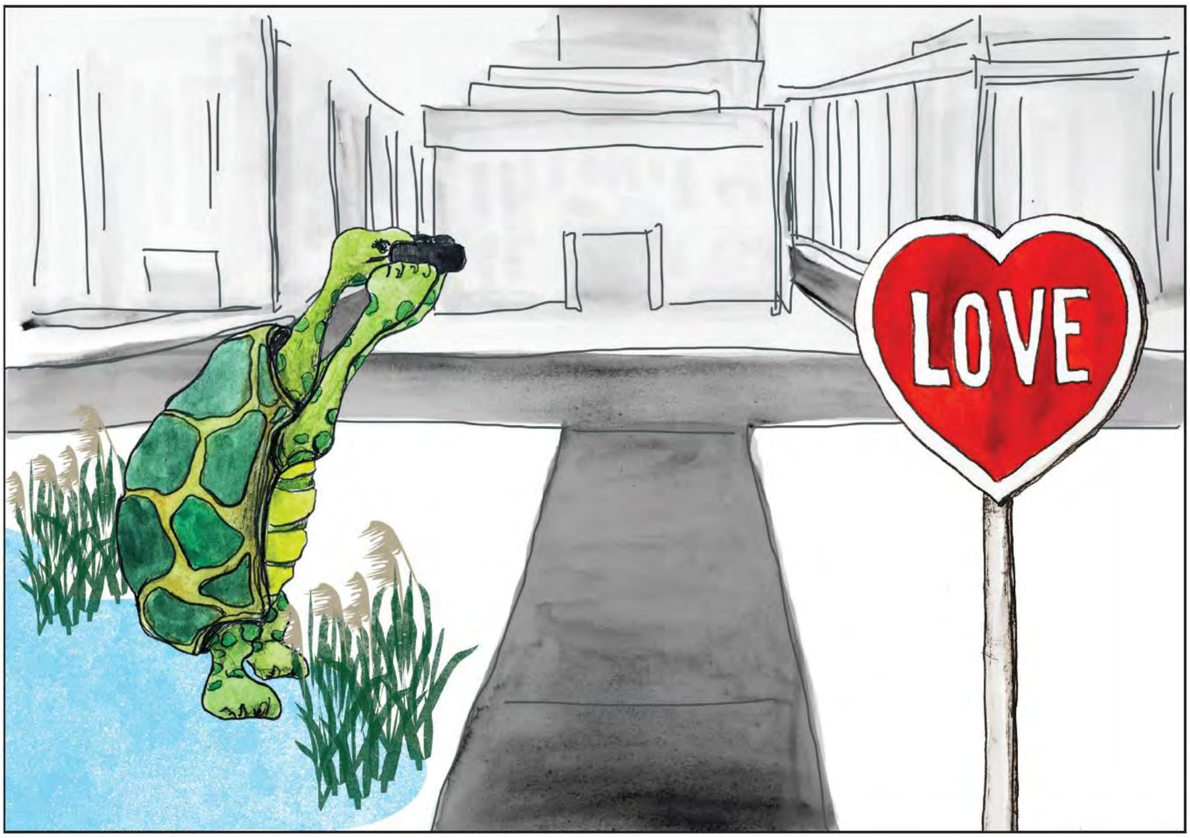


90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Percent Total Area within Precinct
Wet or Damp Forests
Riparian Scrubs or Swampy Scrubs and Woodlands
Lowland Forests
Herb-rich Woodlands
Dry Forests
1: The Basin Rural Landscape
2a: Lysterfield Valley and Hills
2b: Lysterfield quarries & surrounds
3: Dandenong Creek Valley
4: Healesville Freeway Reservation & surrounds
Non-Rural Land
Grand Total
Rural Land Precincts and other areas within Knox

In all areas of life – connectivity matters! Communities of people are more socially resilient and healthy when we are connected to our neighbours and when our social networks are broad and diverse. Business and industry functions more efficiently when suppliers and consumers are well-connected. Being connected to the global information super-highway is fundamentally essential in almost all areas of life. Globally, the world is shrinking dramatically as per capita travel is increasing rapidly - from 32 trillion passenger km per year in 2000 to 105 trillion passenger km per year in 2050 (Schafer & Victor 2000).

In many respects, wildlife operate similarly to us. Individual animals are distributed across the landscape and higher densities tend to occur in places where food and shelter is more abundant and where threats, such as predators, are less. High-school geography teaches us that humans also congregate in areas with fertile soils and reliable, adequate supplies of fresh water, as well as locations that offer defensive advantages against would-be invaders.

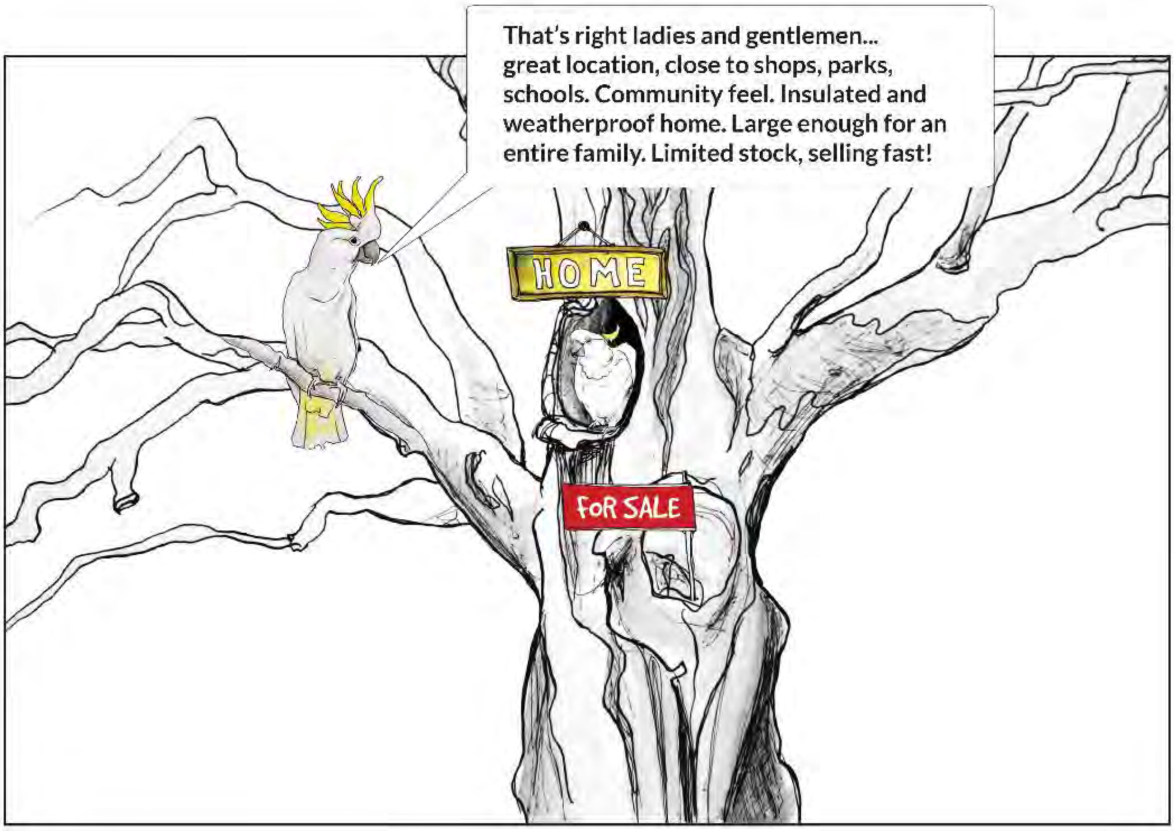
Juvenile wildlife also need to leave home when they start to annoy their parents through competition for food, shelter or mates. Unlike some human families, juveniles are often forced by their parents to disperse and they will search for vacant territories or for territories where they can outcompete the resident animals. Problems may arise when there are no suitable travel routes or there are no places for them to settle, often leading to conflict with humans or mortality along the way, such as when they attempt to cross roads.



When leaving home, wildlife may be a little less picky when choosing areas to move through compared to habitat where they choose to settle permanently, but it still needs to be mostly suitable. For example, fussy animals are unlikely to move through residential backyards or industrial allotments, but they might move through farmland.

When planning transport routes across a city, planners consider the resilience and efficiency of the network as a whole. Good planning encompasses multiple routes from A to B, in the knowledge that different people use different routes and modes of transport, as well as plan for contingencies when certain routes are 'out of action'. Identical considerations for wildlife connectivity are also required - landscape-scale planning of a network is essential to cater for all species and for the longer-term.

And then when they choose to start a family, wildlife also want to live in a good neighbourhood, with access to affordable housing (i.e. shelter, such as tree hollows, fallen logs, dense shrubs), local transport (they need to get around their habitat), shops (access to good food) and good neighbours (mates to fall in love with and have babies…). So the landscape-scale connections needs to link up the best quality habitats, as well as the poorer quality ones, so animals can find those vacant housing opportunities.



One of the biggest threats to economic growth is a poor transport network, such as inadequate road capacity or condition, a lack of affordable public transport options and long daily commutes. The equivalent for wildlife are corridors that are narrow, are dissected by numerous barriers to movement such as roads, have inadequate protection from predators or lack enough high-quality food to support them on their journey.

Landscape connectivity is fundamental to the survival of wildlife, just as it is fundamental to ours.

Appendix 3: List of biodiversity data sets collected and collated for this report

Dataset	Owner / Custodian	Coordinates	Taxonomic Group	Comment	Original Source File
Victorian Biodiversity Atlas	DELWP	DD	Amphibians, bats, birds, mammals, reptiles, fish,	Potentially duplicated records within ALA and BirdLife Australia	VBA_13km_Merged-xinverts_inclTaxaGroup.shp
Atlas of Living Australia	ALA	DD	All taxa	Potentially high amount of duplication with VBA	
Melbourne Water Frogwatch Census	Melbourne Water	DD, UTM	Frogs	Added sites within 5km of Knox City Council	Query2_Frogs.dbf
Earthwatch Frog survey	Andrew Hamer	UTM	Frogs	Added sites within 5km of Knox City Council	AHamer_frogs.xlsx
Earthwatch Turtles on the Move	Andrew Hamer	UTM	Turtles	Added sites within 5km of Knox City Council	AHamer_turtles.xlsx
BirdLife Australia	Birdlife Australia	DD	Birds	Potentially high duplication with VBA	Query3_BirdLifeAust_birds.dbf (provided by MW)
FNCV RV survey 2014-2016	Field Naturalists Club of Victoria (Robin Drury [robindrury6@gmail.com]; FSG)	UTM	Terrestrial fauna, bats, frogs, reptiles, (birds)	Spreadsheet with Parks, sites, species found and the co-ordinates of the sites. Also attached is a draft of the paper, which does not include Table 3. FSG could finalise if needed	RV Results.xlsx; DruryEastern Fauna Focus - Version Jan 17.docx
Tanja Straka PhD Bat data	Tanja Straka	DD	Micro-bats	Includes additional sites outside of proximity to Knox	Bats_Tanja_2012-2013.xlsx
Caroline Wilson PhD Bat data	Caroline Wilson	DD	Micro-bats	Includes additional sites outside of proximity to Knox	Earthwatch trapping 2010_2011_2012_LNG[updated].xlsx

Fiona Caryl Bat data	Fiona Caryl	UTM	Micro-bats	Includes additional sites outside of proximity to Knox	Melbourne_2010_bat_data_Fiona_caryl_theme_summary.xlsx
KNOX WILDLIFE ATLAS	Nadine Gaskell	(locations described but no coordinates assigned)	Birds, frogs, eels, reptiles, butterflies	**no co-ords, just reserve names for most sightings, some even lack reserve names.** This data is from the "KNOX WILDLIFE ATLAS" that Luke Murphy tried to set up at ~ 10 – 15 years ago.	knox wildlife records - species and location.xlsx
	Darren Wallace (March 6 to 15?th)	(locations described but no coordinate assigned)		Local revegetation specialist naturalist who has worked in Knox for 20+ years, (pers comm with RVDR)	Currently held as recording of conversation. Can be converted to records at a later date
Atlas of Living Australia	ALA	DD	All taxa	Potentially high amount of duplication with VBA	
Knox Gardens for Wildlife Participants	Rodney van der Ree and G4W coordinator at Knox	DD, UTM	10 focal taxa	Email request for sightings of focal taxa used for this report	

Appendix 4: Species lists by precincts, showing the year of last record within the various databases.

Species list			Knox LGA					Non-RLP	1km
Scientific	Common Name	Conservation Status	RLP1	RLP2a	RLP2b	RLP3	RLP4		
Amphibians									
Native									
Crinia signifera	Common Froglet		1999	2004	2009	2000	1997	2012	2014
Geocrinia victoriana	Victorian Smooth Froglet					1999	1998		
Limnodynastes dumerilii	Southern Bullfrog (ssp. unknown)			2005	2004			2008	
Limnodynastes dumerilii dumerilii	Pobblebonk Frog							2012	
Limnodynastes peronii	Striped Marsh Frog						1997	2012	2014
Limnodynastes tasmaniensis	Spotted Marsh Frog (race unknown)						1997	2012	2007
Limnodynastes tasmaniensis SCR	Spotted Marsh Frog SCR			2004	2004			2008	2014
Litoria ewingii	Southern Brown Tree Frog		2006	2004	2004			2007	2007
Litoria peronii	Peron's Tree Frog							2012	
Litoria raniformis	Growling Grass Frog	VU en L						2012	1999
Litoria verreauxii verreauxii	Verreaux's Tree Frog			2004	2004				
Pseudophryne semimarmorata	Southern Toadlet	vu							2007
Bats									
Native									
Chalinolobus gouldii	Gould's Wattled Bat			2004	2004				2007
Chalinolobus morio	Chocolate Wattled Bat								2007
Nyctophilus geoffroyi	Lesser Long-eared Bat						1998		2007
Pteropus poliocephalus	Grey-headed Flying-fox	VU vu L				2014			2014
Tadarida australis	White-striped Freetail Bat				2014	2014			2014
Vespadelus darlingtoni	Large Forest Bat								2001
Vespadelus regulus	Southern Forest Bat								2004
Vespadelus vulturnus	Little Forest Bat								2007
Birds- Non-Passerine									

Native									
Accipiter cirrhocephalus	Collared Sparrowhawk			2005	2005		2001	2006	2005
Accipiter fasciatus	Brown Goshawk				2004	2010		2010	2009
Accipiter novaehollandiae novaehollandiae	Grey Goshawk	vu L		2008					2005
Aegotheles cristatus	Australian Owlet-nightjar				2014			2008	2013
Alcedo azurea	Azure Kingfisher	nt							1998
Alisterus scapularis	Australian King-Parrot		2011	2002		2008		2010	2009
Anas castanea	Chestnut Teal			2000		2010		2012	2010
Anas gracilis	Grey Teal					2010		2012	2010
Anas rhynchotis	Australasian Shoveler	vu				2007		2009	2008
Anas superciliosa	Pacific Black Duck		2002	2005	2010	2013	2001	2012	2011
Anhinga novaehollandiae	Darter				2003	2010		2010	2010
Anser anser	Domestic Goose								1998
Apus pacificus	Fork-tailed Swift				2008				1998
Aquila audax	Wedge-tailed Eagle				2010	2013		2009	2014
Ardea ibis	Cattle Egret		2002			2010	1999	2005	2008
Ardea intermedia	Intermediate Egret	en L				2004		2009	
Ardea modesta	Eastern Great Egret	vu L	1999			2010		2009	2008
Ardea pacifica	White-necked Heron					2007		2007	2009
Aythya australis	Hardhead	vu				2009		2012	2009
Biziura lobata	Musk Duck	vu			2010			2001	2000
Botaurus poiciloptilus	Australasian Bittern	EN en L						2007	
Cacatua galerita	Sulphur-crested Cockatoo		2011	2005	2010	2013	2001	2010	2013
Cacatua sanguinea	Little Corella					2010		2011	2009
Cacatua tenuirostris	Long-billed Corella					2010		2006	2008
Cacomantis flabelliformis	Fan-tailed Cuckoo		2011	2004	2009	2010		2009	2011
Cacomantis pallidus	Pallid Cuckoo					2000		1999	2002
Cacomantis variolosus	Brush Cuckoo								2007
Callocephalon fimbriatum	Gang-gang Cockatoo		2002	2002	2005	2004		2010	2009

Calyptorhynchus funereus	Yellow-tailed Black-Cockatoo		2002	2002	2008	2010		2010	2013
Chenonetta jubata	Australian Wood Duck		2002	2005	2010	2010	2001	2012	2010
Chrysococcyx basalis	Horsfield's Bronze-Cuckoo				2007	2008		2009	2009
Chrysococcyx lucidus	Shining Bronze-Cuckoo				2004	2004		2009	2011
Circus approximans	Swamp Harrier				2003	2010		2009	2000
Coturnix ypsilophora australis	Brown Quail							2010	2010
Cygnus atratus	Black Swan				2010	2010		2012	2001
Dacelo novaeguineae	Laughing Kookaburra		2011	2004	2014	2013	2001	2010	2014
Egretta garzetta nigripes	Little Egret	en L			2004	2000		2004	
Egretta novaehollandiae	White-faced Heron		2002	2000	2010	2010	2001	2012	2014
Elanus axillaris	Black-shouldered Kite				2009	2007		2009	2009
Eolophus roseicapillus	Galah		2002		2007	2009	1999	2010	2010
Eudynamys orientalis	Eastern Koel								2005
Falco berigora	Brown Falcon			2002		2006		2001	2004
Falco cenchroides	Nankeen Kestrel					2008		2003	2009
Falco longipennis	Australian Hobby				2009	1999		2005	2007
Falco peregrinus	Peregrine Falcon			2005	2008	2008		2009	2008
Fulica atra	Eurasian Coot		1999	2004	2010	2010	2001	2012	2011
Gallinago hardwickii	Latham's Snipe	nt				2006	2001	2010	2013
Gallinula tenebrosa	Dusky Moorhen			2000	2001	2013	2001	2012	2011
Gallirallus philippensis	Buff-banded Rail		2012			2013		2006	2006
Glossopsitta concinna	Musk Lorikeet					2008		2014	2010
Glossopsitta porphyrocephala	Purple-crowned Lorikeet							1999	2004
Glossopsitta pusilla	Little Lorikeet					2005		2007	2009
Haliastur sphenurus	Whistling Kite					2010		2002	
Hieraaetus morphnoides	Little Eagle				2004			2003	2010
Hirundapus caudacutus	White-throated Needletail	vu			1999			2010	2013
Malacorhynchus membranaceus	Pink-eared Duck					2010		2010	1999
Microcarbo melanoleucos	Little Pied Cormorant		1999		2010	2010	2001	2010	2010
Ninox connivens connivens	Barking Owl	en L		2005					

Ninox novaeseelandiae	Southern Boobook		2002		2014	1999		2009	2009
Ninox strenua	Powerful Owl	vu L	2011		2002	2005	1999	2009	2014
Nycticorax caledonicus hillii	Nankeen Night Heron	nt				2014		1999	2009
Nymphicus hollandicus	Cockatiel							2010	1999
Ocyphaps lophotes	Crested Pigeon				2009	2008		2012	2009
Oxyura australis	Blue-billed Duck	en L				2008		2012	2004
Pelecanus conspicillatus	Australian Pelican					2010	2001	2009	2009
Phalacrocorax carbo	Great Cormorant				2004	2010		2009	2008
Phalacrocorax sulcirostris	Little Black Cormorant		1999			2010	2001	2012	2008
Phalacrocorax varius	Pied Cormorant	nt			2004	2008		1999	2008
Phaps chalcoptera	Common Bronzewing		2011	2004	2009	2013		2012	2013
Phaps elegans	Brush Bronzewing				2014			2002	2007
Platalea flavipes	Yellow-billed Spoonbill					2003	2001	2008	2006
Platalea regia	Royal Spoonbill	nt				2010		2007	2006
Platycercus elegans	Crimson Rosella		2011	2005	2010	2010	1999	2014	2013
Platycercus eximius	Eastern Rosella		2006	2002	2009	2010	2001	2010	2011
Platycercus sp.	Rosella species							2011	
Plegadis falcinellus	Glossy Ibis	nt						2007	2008
Podargus strigoides	Tawny Frogmouth		2011	2004		2014		2010	2014
Podiceps cristatus	Great Crested Grebe				2010			2002	2008
Poliocephalus poliocephalus	Hoary-headed Grebe		1999		2010	2010		2012	2006
Porphyrio porphyrio	Purple Swamphen		1999	2000	2010	2013		2012	2013
Porzana fluminea	Australian Spotted Crake					2003		2007	
Porzana pusilla palustris	Baillon's Crake	vu L						2007	1999
Porzana tabuensis	Spotless Crake							2007	2001
Psephotus haematonotus	Red-rumped Parrot					2010		2005	2006
Rostratula australis	Australian Painted Snipe	VU cr L						2007	
Stictonetta naevosa	Freckled Duck	en L							2003
Tachybaptus novaehollandiae	Australasian Grebe			2004	2010	2010		2012	2008
Tadorna tadornoides	Australian Shelduck					2010		2010	

Threskiornis molucca	Australian White Ibis		2002	2002	2009	2010	2001	2010	2010
Threskiornis spinicollis	Straw-necked Ibis		2002	2002	2009	2010		2010	2010
Todiramphus sanctus	Sacred Kingfisher				2004	2004	2001	2009	2013
Tribonyx ventralis	Black-tailed Native-hen								1998
Trichoglossus chlorolepidotus	Scaly-breasted Lorikeet							2001	2004
Trichoglossus haematodus	Rainbow Lorikeet		2011	2004	2010	2010	2001	2014	2011
Tyto javanica	Pacific Barn Owl								2003
Tyto tenebricosa tenebricosa	Sooty Owl	vu L	1999					2004	2003
Introduced									
Phasianus colchicus	Common Pheasant	dbt					1999		
Anas platyrhynchos	Northern Mallard	*	1999	2000		2008		2010	2009
Anas superciliosa X Anas platyrhynchos	Pacific Black Duck/Mallard Hybrid	*				2008		2011	2010
Columba livia	Rock Dove	*				2008		2009	2013
Streptopelia chinensis	Spotted Turtle-Dove	*	2002	2002	2009	2014	2001	2014	2014
Birds- Passerine									
Native									
Acanthagenys rufogularis	Spiny-cheeked Honeyeater					2010			
Acanthiza chrysorrhoa	Yellow-rumped Thornbill				1999		1999	2006	2006
Acanthiza lineata	Striated Thornbill		2011	2004	2010	2004	2001	2012	2011
Acanthiza nana	Yellow Thornbill					2008	1999	2004	2001
Acanthiza pusilla	Brown Thornbill		2011	2005	2010	2013	2001	2014	2011
Acanthiza reguloides	Buff-rumped Thornbill				1999	2008			1999
Acanthorhynchus tenuirostris	Eastern Spinebill		2002	2005	2009	2013	1999	2010	2010
Acrocephalus stentoreus	Clamorous Reed Warbler		1999		2009	2010	2001	2011	2009
Anthochaera carunculata	Red Wattlebird		2011	2004	2010	2013	2001	2014	2014
Anthochaera chrysoptera	Little Wattlebird					2000		2014	2013
Anthochaera phrygia	Regent Honeyeater	CR cr L						2001	
Anthus novaeseelandiae	Australasian Pipit					2003		2006	
Artamus cyanopterus	Dusky Woodswallow				2009	2003	2001	2009	2008
Artamus personatus	Masked Woodswallow					1998			

Calamanthus fuliginosus	Striated Fieldwren							2001	
Cheramoeca leucosternus	White-backed Swallow				2009				
Chthonicola sagittatus	Speckled Warbler	vu L		2004	1998				
Cincloramphus cruralis	Brown Songlark							2010	
Cincloramphus mathewsi	Rufous Songlark								1999
Cisticola exilis	Golden-headed Cisticola					2010	2001	2012	2009
Climacteris erythrops	Red-browed Treecreeper		2011					1999	2000
Climacteris picumnus victoriae	Brown Treecreeper (south-eastern ssp.)	nt							2010
Colluricincla harmonica	Grey Shrike-thrush		2002	2005	2014	2013	2001	2012	2013
Coracina novaehollandiae	Black-faced Cuckoo-shrike		2000	2004	2009	2008	1999	2010	2010
Cormobates leucophaeus	White-throated Treecreeper		2011	2005	2010	2013		2010	2013
Corvus coronoides	Australian Raven		2002		2004	2007		2002	2007
Corvus mellori	Little Raven		2011	2005	2010	2013	2001	2014	2013
Cracticus nigrogularis	Pied Butcherbird	Native				2008			2010
Cracticus tibicen	Australian Magpie		2011	2005	2010	2013	2001	2014	2013
Cracticus torquatus	Grey Butcherbird		2011	2005	2009	2010	2001	2014	2013
Daphoenositta chrysoptera	Varied Sittella		1999		2001	2007		2010	2011
Dicaeum hirundinaceum	Mistletoebird			2004	2009	2003	1999	2009	2011
Dicrurus bracteatus	Spangled Drongo					2001			
Eopsaltria australis	Eastern Yellow Robin		2011	2005	2014	2014	2001	2010	2013
Falcunculus frontatus	Crested Shrike-tit		1999		2005	2008		2009	2011
Gerygone fusca	Western Gerygone					2010		1999	
Gerygone mouki	Brown Gerygone	Native							2011
Grallina cyanoleuca	Magpie-lark		2011	2004	2010	2014	2001	2014	2013
Hirundo neoxena	Welcome Swallow			2004	2010	2010	2001	2012	2011
Lalage sueurii	White-winged Triller					2003			2009
Lichenostomus chrysops	Yellow-faced Honeyeater			2005	2010	2010		2012	2013
Lichenostomus leucotis	White-eared Honeyeater		2002	2005	2010	2008		2009	2013
Lichenostomus ornatus	Yellow-plumed Honeyeater	Native						2010	

Lichenostomus penicillatus	White-plumed Honeyeater	1999	2001	1999	2013	2001	2014	2011
Malurus cyaneus	Superb Fairy-wren	2011	2005	2014	2014	2001	2012	2014
Manorina melanocephala	Noisy Miner	2000	2002	2010	2010	2001	2012	2011
Manorina melanophrys	Bell Miner	2000	2004	2010	2008	2001	2009	2009
Megalurus gramineus	Little Grassbird			2009	2008		2012	2003
Meliphaga lewinii	Lewin's Honeyeater							1998
Melithreptus brevirostris	Brown-headed Honeyeater			2010			2000	2001
Melithreptus lunatus	White-naped Honeyeater		2005	2010	2010		2010	2011
Menura novaehollandiae	Superb Lyrebird				1999		2011	2007
Microeca fascinans	Jacky Winter						2000	2005
Myiagra cyanoleuca	Satin Flycatcher	2011	2005	2004			2010	2013
Myiagra inquieta	Restless Flycatcher	2006						2010
Myiagra rubecula	Leaden Flycatcher							2005
Myzomela sanguinolenta	Scarlet Honeyeater						2010	
Neochmia temporalis	Red-browed Finch	2002	2005	2014	2014	2001	2012	2014
Oriolus sagittatus	Olive-backed Oriole	2011	2004	2009	2010		2001	2009
Pachycephala olivacea	Olive Whistler							2000
Pachycephala pectoralis	Golden Whistler	2008	2005	2009	2010	1999	2011	2013
Pachycephala rufiventris	Rufous Whistler	2011	2005	2009	2010		2010	2013
Pardalotus punctatus punctatus	Spotted Pardalote	2011	2005	2010	2010	2001	2014	2011
Pardalotus striatus	Striated Pardalote		2004	2008	2006		1999	2011
Petrochelidon ariel	Fairy Martin				2010		2006	2001
Petrochelidon nigricans	Tree Martin			2004	2000		2009	2000
Petroica boodang	Scarlet Robin	1999		2009	1999		2001	2000
Petroica goodenovii	Red-capped Robin						2000	
Petroica phoenicea	Flame Robin			1999	2010		2009	2004
Petroica rodinogaster	Pink Robin			2001				2001
Petroica rosea	Rose Robin			2004			2004	2000
Philemon corniculatus	Noisy Friarbird							2009
Phylidonyris novaehollandiae	New Holland Honeyeater		2005	2010	2008	2001	2012	2009

Phylidonyris pyrrhoptera	Crescent Honeyeater		1998		2009			2008	2005
Psophodes olivaceus	Eastern Whipbird			2005	2004			2008	2011
Ptilonorhynchus violaceus	Satin Bowerbird								2008
Pycnoptilus floccosus	Pilotbird								2000
Rhipidura albiscapa	Grey Fantail		2011	2004	2014	2013	2001	2010	2013
Rhipidura leucophrys	Willie Wagtail			2002	2009	2010	2001	2012	2013
Rhipidura rufifrons	Rufous Fantail		2011		2004			2009	2013
Sericornis frontalis	White-browed Scrubwren		2011	2005	2014	2014	2001	2011	2013
Sericornis magnirostris	Large-billed Scrubwren				2005				2005
Smicrornis brevirostris	Weebill								2006
Stagonopleura bella	Beautiful Firetail								2011
Strepera graculina	Pied Currawong		2011	2005	2009	2010	1999	2011	2014
Strepera versicolor	Grey Currawong			2004	2013	2013		2009	2013
Zoothera lunulata	Bassian Thrush			1999		2014		1999	2013
Zosterops lateralis	Silvereye		2011	2005	2010	2010	2001	2010	2013
Introduced									
Acridotheres tristis	Common Myna	*	2011	2004	2010	2013	2001	2014	2013
Alauda arvensis	European Skylark	*			1999	2010		2012	1999
Carduelis carduelis	European Goldfinch	*			2005	2014	2001	2009	2008
Chloris chloris	European Greenfinch	*			2004	2014		2010	2009
Lonchura castaneothorax	Chestnut-breasted Mannikin	*						2005	
Passer domesticus	House Sparrow	*	2002	2001	2009	2014	1999	2014	2010
Passer montanus	Eurasian Tree Sparrow	*			2009			2001	2001
Pycnonotus jocosus	Red-whiskered Bulbul	*						2006	2003
Sturnus vulgaris	Common Starling	*	2002	2001	2009	2013	2001	2014	2013
Turdus merula	Common Blackbird	*	2011	2005	2014	2014	2001	2014	2014
Turdus philomelos	Song Thrush	*			1999	2013		2004	2009
Birds- Waders									
Native									
Calidris acuminata	Sharp-tailed Sandpiper							2003	

Chlidonias hybridus javanicus	Whiskered Tern	nt						2006	1998
Chroicocephalus novaehollandiae	Silver Gull				2005	2010	2001	2011	2009
Elseyornis melanops	Black-fronted Dotterel					2010		2012	2009
Erythrogonys cinctus	Red-kneed Dotterel							2011	2003
Himantopus himantopus	Black-winged Stilt				2008	2005		2006	2003
Hydroprogne caspia	Caspian Tern	nt L							1998
Larus pacificus pacificus	Pacific Gull	nt				2000			
Porzana sp.	Unidentified Crake							2000	
Tringa nebularia	Common Greenshank	vu						2003	
Vanellus miles	Masked Lapwing		2000	2001	2009	2013	2001	2012	2010
Mammals									
Native									
Acrobates pygmaeus	Feathertail Glider								2012
Antechinus agilis	Agile Antechinus				2014	2013		2011	2013
Antechinus swainsonii	Dusky Antechinus								1997
Hydromys chrysogaster	Water Rat							1997	
Macropus giganteus	Eastern Grey Kangaroo			2005	2009				2007
Misc Target taxa not found	Target taxa not found		2011		2011	2009		2009	2012
Ornithorhynchus anatinus	Platypus		2002	1998		1997		1998	2003
Petauroides volans	Greater Glider	VU vu L							2016
Petaurus australis	Yellow-bellied Glider		2007						2004
Petaurus breviceps	Sugar Glider				2014	2014		2011	2014
Phascogale tapoatafa	Brush-tailed Phascogale	vu L							1998
Phascolarctos cinereus	Koala								2015
Pseudocheirus peregrinus	Common Ringtail Possum		2014	2004	2014	2014	1999	2014	2014
Rattus fuscipes	Bush Rat					2013		2011	2013
Rattus lutreolus	Swamp Rat					2014			2013
Tachyglossus aculeatus	Short-beaked Echidna		2000	2005	2005			2002	
Trichosurus vulpecula	Common Brushtail Possum		2000	2004	2001			2011	2001
Vombatus ursinus	Common Wombat			2005	2005			2000	2006

Wallabia bicolor	Black Wallaby			2002	2009				2007
Introduced									
Felis catus	Cat	*			2014	2013			2014
Lepus europeaus	European Hare	*				2013		2012	2013
Mus musculus	House Mouse	*	2000		2001	2014		2014	2013
Oryctolagus cuniculus	European Rabbit	*	2006	2005	2013			2012	2013
Rattus norvegicus	Brown Rat	*						1997	
Rattus rattus	Black Rat	*	2000			2014		2014	2014
Vulpes vulpes	Red Fox	*	2002		2009			2006	2012
Reptiles									
Native									
Anepischtos maccoyi	McCoy's Skink		1999	2005	2005				
Austrelaps superbus	Lowland Copperhead							2014	2014
Chelodina longicollis	Eastern Snake-necked Turtle	dd	2011	2011				2012	2006
Lampropholis delicata	Delicate Skink		2000						
Lampropholis guichenoti	Garden Skink		2000	2005		2014			2014
Lissolepis coventryi	Swamp Skink	vu L	2000						
Niveoscincus coventryi	Coventry's Skink			2005					
Pseudemoia rawlinsoni	Glossy Grass Skink	vu							2013
Saproscincus mustelinus	Weasel Skink			2005	1998				2014
Tiliqua nigrolutea	Blotched Blue-tongued Lizard			2002					
Tiliqua scincoides	Common Blue-tongued Lizard								2010
Varanus varius	Lace Monitor	en							2015
Fish									
Native									
Anguilla australis	Southern Shortfin Eel		2006			2009	2006	2009	2009
Galaxias brevipinnis	Climbing Galaxias		2006					1997	2006
Galaxias maculatus	Common Galaxias						2006	1997	2009
Galaxias truttaceus	Spotted Galaxias								2004
Galaxiella pusilla	Dwarf Galaxis	VU en L				2009		1999	1997

Misc Dry	Dry waterbody				2009		2009	2009
Nannoperca australis	Southern Pygmy Perch				2009		2009	2009
Philypnodon grandiceps	Flathead Gudgeon				1997		2009	2009
Introduced								
Carassius auratus	Goldfish	*	2006		2007		2009	2009
Cyprinus carpio	European Carp	*			2009		2009	2007
Gambusia holbrooki	Eastern Gambusia	*		1999	2009	2006	2009	2009
Misgurnus anguillicaudatus	Oriental Weatherloach	*			2007		2009	2006
Perca fluviatilis	Redfin	*				2006	2009	1998
Rutilus rutilus	Roach	*					1997	2007
Salmo trutta	Brown Trout	*					1997	1997
Crustacean								
Native								
Cherax destructor destructor	Common Yabby						2009	
Engaeus tuberculatus	Tubercle Burrowing Crayfish	en						2016
Engaeus urostrictus	Dandenong Burrowing Crayfish	cr L						2016
Euastacus woiwuru	Central Highlands Spiny Crayfish		2006				2006	2006
Decapod								
Native								
Paratya australiensis	Common Freshwater Shrimp		2006		2000		2009	2009

Species	Reference
General concepts	
Patches of at least 10 ha (i.e. large enough to sustain a population of a species) need to be less than 1.1 km apart for them to be 'connected'. There also needs to be stepping stones <105 m apart between them to facilitate movement.	(Doerr et al. 2010)
For birds in the Australian Capital Territory, the '150 m/1.0 ha to 1.3 km/10 ha rule' should be followed for birds. That is, that connections between patches of native vegetation will generally support most species' movements if the connection does not have any gaps in it >150 m, if the inter-patch distance (the distance between patches being connected) is no longer than 1.3 km, and if the patches at either end are at least 10 ha in size.	(Doerr et al. 2014)
Black Wallaby *Wallabia bicolor*	
Was recorded in both forest patches (between 20 and 80 ha in size) and corridors directly connected to forest patches, but not recorded in corridors 1500 m away from forest (i.e. suitable habitat). Also recorded in pasture 300 m from forest (i.e. suitable habitat).	(Downes et al. 1997)
Dispersal does occur, albeit infrequently, over 10 – 17 km shown by genetic analysis of separated populations.	(Paplinska et al. 2009)
Has a reduced dispersal ability over pastures than through pine plantations.	(Mortelliti et al. 2015)
There is a significant potential impact of roads, as black wallabies had a high relative mortality rate on roads.	(Ramp & Ben-Ami 2006)
Roadside habitat home ranges were 15.6 ± 0.9 ha (95% harmonic mean, range 42.6 ± 5.5 ha). These were smaller than those in reserves (large-scale suitable habitat). No radio-tracked individual crossed the highway, also this study recorded some roadkills - so crossings were attempted. One radio-tracked individual did frequently use an underpass to move from one side of the highway to the other.	(Ben-Ami & Ramp 2013)
Echidna *Tachyglossus aculeatus*	
Only two instances of echidnas using underpasses were detected in 18 months of monitoring of a four lane highway near Brisbane.	(Bond & Jones 2008)

Species	Reference
Home ranges vary widely in different areas, but a consistent minimum seems to be ~20 ha.	(Nicol et al. 2011)
Dogs can be a significant predator of echidnas, and there is significant disturbance effect from dogs on echidna movement.	(Holderness-Roddam & McQuillan 2014)
This species is a habitat generalist – found throughout Australia from alpine areas to semi-desert.	(Strahan 2008)
Sugar Glider *Petaurus breviceps*	
Occurred in isolated habitat patches as small as 16 ha, and in a connected network of patches as small as 1.5 ha. Has a minimum recorded home range of 3-5 ha, depending on habitat quality.	(Suckling 1984; Quin et al. 1992; Caryl et al. 2013)
Do not occur in medium-density residential areas, but could live in very low density residential, provided high tree cover. Sugar gliders also travelled almost four times farther into less urbanized matrix than into highly urbanized matrix.	(Caryl et al. 2013)
Maximum dispersal of 1.9 km has been recorded in farmland, but this is typically 600 – 700 m. However, the typical distance individuals are prepared to leave a bushland reserve and travel into adjacent/connected urban areas was 30 - 40 m, with a maximum of 180 m recorded.	(Suckling 1984; Caryl et al. 2013)
Sugar gliders have a maximum glide lengths of 30 m, while a typical gap-crossing threshold for Squirrel Glider *P. norfolcensis* is ~50 m for Squirrel Glider.	(Suckling 1984; Jackson 1999; van der Ree et al. 2003; Asari et al. 2010; van der Ree et al. 2010)
Australian Reed-warbler *Acrocephalus australis*	
European Reed-warblers *A. scirpaceus* were reluctant to cross gaps wider than 50 m.	(Bosschieter & Goedhart 2005)
This species occurs in thick vegetation in wetlands, dams and lake edges, along the vegetated edges of creeks and drains, and in flooded crops. It chiefly breeds in stands of *Phragmites* and *Typha*, and forages in dense vegetation as described above plus adjacent areas of thick shrubs and crops.	(Higgins, PJ *et al.* 2006)
For *A. paludicola*, they have a minimum home range of 2 ha on both breeding and wintering grounds.	(Schaefer *et al.* 2000; Arbeiter & Tegetmeyer 2011)

Species	Reference
Eastern Yellow Robin *Petroica eopsaltria*	
This species used only a vegetated fauna overpass to cross an 80 m road, and there were no observed crossings of the road away from this overpass.	(Jones & Pickvance 2013)
Pairs maintain territories of 5 – 6 ha.	(Higgins & Peter 2002)
The species is dependent on a shrubby understorey or sub-canopy layer to provide perching and nesting sites.	(Debus 2006)
The mean gap-crossing distance (± s.d.) was 75.4 ± 31.7 m with a maximum of 189 m and 88% of gap-crossing distances were of <100 m.	(Doerr et al. 2011)
Five ha is the minimum area required for successful breeding by a pair.	(Debus 2006)
The density of roads had a very strong, negative relationship with the occurrence of the eastern yellow robin, while there was a strong positive correlation with the density of rivers in the landscape and the extent of dense tree cover in the landscape.	(Trollope et al. 2009)
Superb Fairy-wren *Malurus cyaneus*	
Other species of Fairy-wren (Red-backed *M. melanocephalus* and Variegated *M. lamberti*) only used a vegetated fauna overpass to cross an 80 m road, and there were no observed crossings of the road away from this overpass.	(Jones & Pickvance 2013)
In suburban areas, territories of superb fairy-wrens were in less disturbed areas than unused areas.	(Crates et al. 2011)
This species is largely restricted to areas that have a dense layer of native shrubs surrounding grassy areas. They were absent from suburban sites where there were either only few shrubs or sites with exotic shrubs, regardless of the abundance of those shrubs.	(Parsons et al. 2008)
Dispersal has been recorded over 3.1 km, with dispersal much greater in females than in males (male maximum dispersal recorded was around 500 m).	(Mulder 1995)
White-throated Treecreeper *Cormobates leucophaea*	
Pairs maintains 2–6 ha all-purpose territories throughout the year.	(Higgins *et al.* 2001)

Species	Reference
The minimum threshold for occupancy of a remnant patch by a pair is 6 ha, and the maximum distance between an occupied site and next suitable habitat patch was 400 m.	(Watson et al. 2001)
Juveniles displayed a mean maximum travel distance of 1.7 km from their natal territories during dispersal forays (individuals ranged from 0.17 – 4.80 km).	(Doerr & Doerr 2005)
The species used only a vegetated fauna overpass to cross an 80 m road, and there were no observed crossings of the road away from this vegetated overpass.	(Jones & Pickvance 2013)
This species did not cross gaps of >65 m in response to playback.	(Robertson & Radford 2009)
Density of roads proved to have a very strong, negative relationship with the occurrence of the white-throated treecreeper, while there was also a strong positive correlation with the density of rivers in the landscape and the extent of dense tree cover in the landscape. The smallest patch occupied by white throated treecreepers was 32 ha.	(Trollope et al. 2009)
Blue-tongue Lizards *Tiliqua* spp.	
There was no obvious effect of fragmentation – blue-tongue lizards occurred in patches <10 ha which were also isolated by at least 300 m from suitable continuous habitat.	(Jellinek et al. 2004)
Blue-tongue lizards were found to be generally ubiquitous, even in suburban habitats, but they did specifically avoid road habitats. Adults had home ranges of <1 ha.	(Koenig et al. 2001)
Pets (especially cats) are thought to be the primary concern for blue-tongue lizards in outlying suburbs, whereas habitat loss resulting from construction activity is a more significant threat to Blue-tongue populations in inner-city areas.	(Koenig et al. 2002)
Southern Bullfrog *Limnodynastes dumerilii*	
In analyses, 3 km was considered the upper dispersal distance for amphibians. Stream networks were considered to be major dispersal corridors, while urban areas and roads and rail lines were considered to be a total barrier unless there were appropriate fauna crossing points incorporated.	(Morris et al. 2012)
Aquatic vegetation was the most influential predictor of species' presence (D=62.8%) and showed a strong threshold effect: the probability of occupancy increased from 0.1 to 0.87 when increasing the proportion of aquatic vegetation cover from 0.25 to 0.3. Subcatchment imperviousness (D= 20.9%) had a negative influence on occupancy, which decreased from 0.6 to 0.1 as soon as imperviousness departed from zero.	(Canessa & Parris 2013)

Species	Reference
There was a negative effect of road cover in a 500 m radius around the pond on species presence, corresponding to a prediction that the pond with the highest surrounding road cover would have between 12 and 19% of the species richness observed at the pond with the lowest road cover in the surrounding area.	(Parris 2006)
Eastern Snake-necked Turtle - *Chelodina longicollis*	
Only moves over terrestrial habitats during the day, but this might be due to benign environmental conditions (a study in hotter condition had more movements at night).	(Graham et al. 1996)
Anthropogenic impact was measured by calculating road density (km of road/km2) within 700 m of each pond, based on typical movements of the species in the area. This analysis found no apparent effects of urbanisation.	(Ferronato et al. 2016)
Measured structural connectivity using wetland size and two indices of wetland density. Wetland density was measured as the number of wetlands within a 2-km buffer of each wetland, and as the mean distance from the focal wetland to all others within the buffer. The probability of inter-wetland movement decreased with increasing distance between wetlands. Neither network nor relative connectivity was related to any physical landscape attribute commonly used as a surrogate for actual connectivity (e.g., patch density, inter-patch distance, and patch size). Movements were highest between temporary and permanent wetlands, and the maximum recorded movement was 5.2kms (but that occurred over 22 years).	(Roe et al. 2009)
In a radio-tracking study, 95% of terrestrial turtle locations were within 375 m of the nearest wetland.	(Roe & Georges 2007)
The number of encounters were positively correlated with total wetland area and negatively correlated with urban development area, and these factors explained 51% of the variation in the data Both factors were measured within a 700 m radius circle from each encounter location.	(Ferronato et al. 2014)
Urban turtles in Canberra moved more between wetlands than forest turtles, but those moves were all along drainage lines. Roadkills were only observed where there were no underpasses, or where such underpasses were not in the natural channel. Urban turtles also didn't use terrestrial sites at all, but stayed within wetlands.	(Rees et al. 2009)

Appendix 6: Focal species fact sheets

See attached pdfs

Appendix 7: Detailed description of waterway barriers and recommendations to enhance wildlife connectivity. The ID number corresponds with locations shown on Figure 28.

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Dandenong Creek and Liverpool Rd ID #1	• 1 concrete box culvert • 3m x 3m x 16m • For creek flow • Natural substrate(?) • Tree gap ~30m	• Likely barrier to some focal bird species due to traffic volume • Replace culvert with open span bridge • No dry passage – add shelf • Plant trees between Dobson Ln and Liverpool Rd or install rope bridge over Liverpool Rd	 
Dandenong Creek and Dobson Ln ID #2	• 1 concrete box culvert • 3m x 3m x 5m • For creek flow • Natural substrate • Tree gap ~20m	• Low traffic volume service road adjacent to Liverpool Rd • Unlikely a barrier to wildlife movement due to narrow road and low traffic volume • Plant trees between Dobson Ln and Liverpool Rd or install rope bridge over Dobson Ln • Replace culvert with open span bridge • No dry passage – add shelf	 

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Dandenong Creek and Colchester Rd ID #3	• 1 concrete box culvert • 3m x 2m x 18m • For pedestrians and possibly very high-flow flood events • Creek piped at this location • 1 culvert with steel grate for flood events • Tree gap 0m	• Likely barrier to most focal species due to traffic volume and pedestrian traffic in underpass • Culvert with steel grille definite barrier for all species • Tree canopies connected nearby so unlikely a barrier to glider movement • Daylight creek and install open span bridge • Plant trees and shrubs close to Colchester Rd behind existing guard rail to reduce gap size • Separate pedestrian and wildlife zones	  
Dandenong Creek and Dorset Rd ID #4	• 1 concrete pipe culvert, 1m x 40 m • 1 concrete pipe culvert, 2.5m x 40m • 1 concrete pipe culvert, 2 m x 40 m • 1 concrete box culvert, 2.5m x 2.5m x 40 m • Pipe culverts for flood events, box culvert for pedestrians • Creek is piped • Tree gap ~5m • Separate pedestrian and wildlife zones	• Barrier to most focal bird species due to traffic volume • Tree canopy gap ~5m, so not barrier to gliders • Daylight creek and install open span bridge • Plant trees on west side of Dorset Rd • Plant extra trees in centre median	   

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Dandenong Creek and Bayswater Rd ID #5	• Open span bridge with concrete base • 2.5m x 5m x 30m • For flood events and pedestrian • Creek is piped • Tree gap >100m	• Would allow turtle movement during flood events but compromised by sharing with pedestrians and cyclists • Definitely a barrier to all other focal species due to gap size and traffic volume • Plant extra trees and shrubs on edge of Bayswater Rd, especially east side of Bayswater Rd and in median • Daylight creek • Separate pedestrian and wildlife zones • Replace concrete section of underpass with natural substrate • Too many powerlines in vicinity to achieve rope bridge	 
Dandenong Creek and Belgrave Railway ID #6	• Open span bridge, 4.5m x 15 m x 9 m, for flood events • Steel pipe culvert, 2.5m x 15 m, for pedestrians • Good separation of wildlife and pedestrians • Good tree cover along train line north and south of creek crossing	• Possible filter to focal birds due to open approaches to bridge • Undertake revegetation on both approaches to underpass • Daylight creek • Replace concrete floor of bridge with natural substrate • Undertake revegetation to connect creekline vegetation with vegetation along train line	 

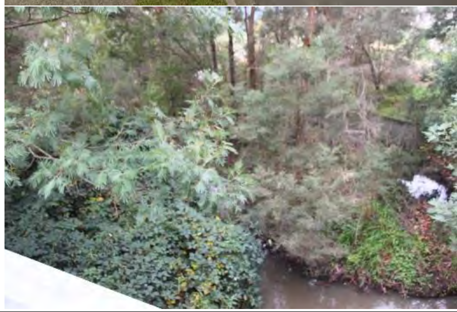
Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Dandenong Creek and Wantirna Rd ID #7	• Open span bridge • 4m x 20m x 13m • For pedestrians and creek flow • Pedestrian path fenced from creek-flow section • Tree canopy gap ~30m, with powerlines on west side	• Minor barrier to most species • Undertake revegetation on both sides to improve approaches • Replace concrete base with natural substrate • Plant trees on west side of Wantirna Rd	  
Dandenong Creek and Eastlink (North), Wantirna ID #8	• Two open span bridges, separated by ~10m • 3m x 60 m x 18m • Natural substrate under bridges • For creek flow and pedestrians • Pedestrian path is not fenced from creek-flow section • Tree gap size > 100m	• Complete barrier to gliders • No issues for turtles • Minor barrier to other focal species due to lack of vegetation on approaches to underpass • Protect small tree growing between the two structures • Plant trees and shrubs on both sides of Eastlink and between both structures • When trees sufficiently tall, install rope bridge under or over Eastlink • Place 'furniture' (i.e. logs, tree stumps, rock etc) under bridges to provide cover for small animals	   

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Dandenong Creek and Boronia Rd ID #9	• Two open span bridges, separated by 2m • Each structure 12m wide • For creek flow and pedestrians • Pedestrian section 4m x 2.5m x 12m • Creek flow section 4m x 13m x 12m • Tree gap size ~ 60m • Pedestrian section with concrete base • Creek flow section with large rocks in creek and concrete abutment. • Pedestrian path fenced from creek-flow section	• Barrier to gliders • No issues for turtles or birds • Lack of natural stream bank a limitation for terrestrial species • Reduce weed cover and revegetate • Plant trees in median of Boronia Rd and on verges of both bridges • Install rope bridge above Boronia Rd	   
Dandenong Creek and Burwood Hwy ID #10	• Two open span bridges, separated by 12m • Each bridge 2.5m x 40m x 15m • For creek flow and pedestrians • Pedestrian path fenced from creek-flow section • Centre channel for creek has concrete base • Flood zones either side of creek channel with natural substrate • Dense reeds and shrubs on both approaches • Tree gap size ~ 60m	• Unlikely a barrier to most focal species, except gliders • Plant trees between bridge structures and within median of Burwood Hwy • Lots of cat, dog and fox prints in mud under bridges, including rat footprints (possibly water rat?) • Install rope bridge above bridges over Burwood Hwy	   

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Dandenong Creek and High Street Rd ID #11	• 2 open span bridges, separated by 2m • Each bridge 2.5m x 30 m x 15 m • For creek flow and pedestrians • Natural substrate for section with creek flow • Pedestrian path with concrete substrate • Pedestrian path fenced from creek-flow section • Tree gap ~40m • For pedestrians and creek flow	• Unlikely a barrier to birds given dense reeds and understorey • Possibly a barrier for gliders, given gap size and relative height of trees and bridge structure • Not an issue for turtles • Replace weed cover with native shrubs and grasses • Plant trees between within median and possibly between bridge structures if sufficient space • Consider installing rope bridge above High Street Rd • Install furniture (logs, rocks etc) under bridge structures to provide shelter for small vertebrates	   
Dandenong Creek and Ferntree Gully Rd ID #12	• 2 open span bridges, separated by 4m • Each bridge 2.5m x 40m x 15m • For creek flow and pedestrians • Pedestrian path has concrete substrate • Pedestrian path fenced from creek-flow section • Natural substrate for section with creek flow • Tree gap ~50m	• Likely a barrier for glider movement due to gap size and low relative height of trees above bridge height • Unlikely a barrier for other species – lots of fox and cat prints in mud under bridge • Plant trees within median of Ferntree Gully Rd • Plant trees between bridge structures • Install rope bridge above creek • Install furniture (logs, rocks etc) under bridge structures to provide shelter for small vertebrates	   

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Dandenong Creek and Wellington Rd ID #13	• 2 open span bridges, separated by 3m • Each bridge 3.5m x 45m x 15m • 1 concrete pipe culvert, 2m diameter x 50m • Substrate under bridge is concrete, but with soil and grass growth covering much of it • Bridge for high-flow events and pedestrians • Pedestrian path fenced from creek-flow section • Culvert takes regular creek flow • Tree gap ~70m • Powerlines on south side of Wellington Rd	• Barrier to gliders • Unlikely an issue for other species, but approaches to bridge structure quite open and will limit use by small birds • Replace concrete base with natural substrate • Plant trees in median of Wellington Rd • Plant trees and shrubs on both approaches to bridge structure • Install rope bridge over Wellington Rd • Install furniture (logs, rocks etc) under bridge structures to provide shelter for small vertebrates	   
Dandenong Creek and Stud Rd ID #14	• 2 open span bridges separated by 4 m • Each bridge 4m x 25m x 8m • For creek flow and pedestrians • Creek flow substrate natural and bitumen path for pedestrians • Pedestrian path fenced from creek-flow section • Tree gap ~40m • Powerlines on both sides of Stud Rd • Moderately dense plantings of trees and shrubs on both sides of Stud Rd	• Likely a barrier to gliders • Other focal species not an issue • Difficult to install rope bridges due to powerlines on both sides of Stud Rd – consider rope bridge under Stud Rd? • Plant trees and shrubs on both approaches to bridge	 

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Corhanwarrabul Creek and Stud Rd1 ID #15	• 1 open span bridge on Stud Rd south bound carriageway • 5 concrete box culverts on Stud Rd north bound carriageway • Open span bridge is 3.5m x 10m x 15m • Culverts each 2m x 3m x 13m • Concrete substrate to culverts • Natural substrate under bridge • Central culvert takes normal flow, outer culverts raised slightly • 10 m wide gap between carriageways • Tree gap > 100m • No flat embankment under bridge • For creek flow	• Barrier to gliders • Likely barrier to focal birds species • Unlikely an issue for turtles • Barrier to wallaby due to pooling of water under bridges and steep, muddy embankments • Replace culverts with open span bridge • Widen bridge structures to allow flat embankment adjacent to creek • Plant trees in median and on both sides of Stud Rd • Plant trees and shrubs on both approaches to underpasses • Fox and cat prints under bridge • Difficult to install rope bridge due to powerlines on both sides of Stud Rd	   
Corhanwarrabul Creek and Stud Rd2 ID #16	• 5 box culverts • Each culvert 2m x 3m x 40m • Concrete base to culverts • Flooded at time of inspection • For creek flow • Tree gap >100m	• Barrier to all species except turtles • Replace with open span bridge • Plant trees and shrubs on both approaches • Difficult to install rope bridge due to powerlines on both sides of Stud Rd	  

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Waterford Valley Golf Club Lake and Karoo Rd ID #17	• Probably culvert(s) • Unable to inspect due to private land and tall cyclone mesh fencing • Filled with water – part of lake system	• Unlikely a barrier to turtles • Unlikely a barrier to focal bird species or gliders due to shrub and tree growth on either side of narrow road and relatively low traffic volume	No photos due to site innaccessibility
Monbulk Creek and Bunjil Way ID #18	• Open span bridge • 2m x 3m x 10m • Natural substrate under bridge • Narrow road (8m) with relatively low traffic volumes • Tree gap ~10m • Dense tree and shrub growth on both approaches to bridge • Large rip-rap lining creek channel under bridge as erosion control	• Not a barrier for gliders or turtles • Unlikely a barrier to focal bird species • Likely a barrier for wallabies due to low clearance and lack of flat, dry embankment adjacent to creek • Create flat path adjacent to creek under bridge	  

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Monbulk Creek and Blackwood Park Dr ID #19	• 1 open span bridge for pedestrians • 1 open span bridge for traffic • Pedestrian bridge 2m x 5m x 3m • Traffic bridge 2m x 5m x 5m • Both bridges for creek flow • Natural substrate • Tree gap ~10m	• Road bridge is currently single lane only, likely to be widened in near future • If widening occurs, ensure open span bridge with maximum height and allow for flat embankment on both sides of creek channel • Not a barrier for gliders or turtles • Possibly a barrier for focal bird species due to traffic volume, but gap size small so less of a concern • Likely a barrier for wallabies due to narrow channel, lack of flat embankment and road bridge filled with water	   
Monbulk Creek and Napoleon Rd ID #20	• Open span bridge • 4m x 12m x 15m • Natural substrate • For creek flow • Tree gap ~40m • No flat embankment on either side of creek	• Unlikely a barrier to focal birds due to narrow road and dense shrub growth in river channel • Possible barrier to gliders • Install rope bridge, but powerlines on one side of Napoleon Rd is a complication • Re-contour embankments under bridge to create some flat space on one or both sides of creek	   

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Monbulk Creek and Lysterfield Rd ID #21	• Open span bridge • 2m x 6m x 16m • For creek flow • Natural substrate • Tree gap ~4m	• Not a complete barrier to any focal species • Might hinder movement of focal bird species due to relatively high traffic volume	 
Ferny Creek and Brennock Park Dv ID #22	• Open span bridge • 2m x 6m x 16m • For pedestrians and creek flow • Ferny Creek piped immediately upstream of this location • Concrete substrate • Tree gap 30m • Pedestrian path fenced from creek section • Creek and creek channel constricted under this structure – presumably to allow sufficient space for pedestrian path	• Likely a barrier to all focal species except turtles • Increase bridge length and recontour creek to include flat embankment on one or both sides of creek channel • Plant trees on both sides of bridge, especially upstream • Daylight creek upstream of bridge • Install rope bridge, but complicated by powerlines	   

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Ferny Creek and Glenfern Rd ID #23	• 6 pipe culverts and 1 box culvert • Box culvert 2.5m x 2.2m x 22m • Pipe culverts each 1.8m x 25m • Pipe culverts for high flow events • Box culvert for pedestrians • Tree gap ~50m • Creek is piped at this location	• Likely a barrier to most species, except turtles when creek in flood • Daylight creek and replace culverts with open span bridge • Plant trees on both sides of Glenfern Rd • Install rope bridge • Plant extensive shrubs and trees along creek bed to improve approaches to culverts, but performance will always be limited by small size and length of culverts	   
Ferny Creek and Hancock Rd ID #24	• 12 box culverts for high flow events • 1 box culvert for pedestrians • Drainage culverts 1.4m x 2.5m x 12m • Pedestrian culvert 2m x 2.7m x 22m • Concrete substrate • Tree gap ~30m • Creek is piped at this location	• Likely barrier to all species except turtles during flood event • Sugar gliders can glide downstream but not upstream due to different heights of trees on opposite sides of road • Focal birds may cross when traffic volume is light • Daylight creek and replace culverts with open span bridge • Plant trees on both approaches • When trees tall enough, install rope bridge •	   

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Ferny Creek and Bunjil Way ID #25	• 6 pipe culverts and 1 open span bridge • Pipe culverts 2m x 17m • Open span bridge 2.4m x 34m x 17m • Pipe culverts for flood events • Open span bridge for creek flow and pedestrian use • Tree gap 35m • No fence between pedestrian path and creek section	• Unlikely a barrier to turtles or focal bird species • Replace or fill in the gaps in the large rock rip-rap under bridge • A barrier to gliders until young trees grow taller – assess again 5 years and possibly install rope bridge • Re-contour creek bed to provide dry passage through 1 or 2 pipe culverts • Plant extra trees on approaches to culverts and bridge • Install nest boxes for gliders in young regrowth in golf course	   
Blind Creek and Eastlink ID #26	• 2 multi-span bridges for Eastlink separated by 7m • 3 pipe culverts for bike path adjacent to Eastlink • Bridges 2.4m x 40m x 28 m • Culverts 1.5m x 6m • Bridges for creek flow and pedestrians • Culvert for creek flow • Tree gap > 100m • Natural substrate for creek under Eastlink and concrete for pedestrian path • Culvert has metal substrate • Pedestrian path is fenced from creek section • Wire mesh fence along bike path will limit wildlife movement	• Multi-span bridges have large open spaces underneath • Definitely a barrier to gliders • May limit movement from focal birds due to large open spaces under bridges, but not a complete barrier • Install rope bridge underneath Eastlink • Install furniture (e.g. logs, rocks etc) to provide cover for wildlife • Plant trees and shrubs on both approaches and between multi-span bridges and between Eastlink bridges and bike path • Replace wire mesh fence with more open-style barrier to allow wallaby movement, if occurring in area	   

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Blind Creek and High Street Rd ID #27	• 6 box culverts • 2.2m x 2.4m x 20m • 5 culverts for creek flow, 1 culvert for pedestrian use • Concrete substrate • Tree gap ~80m • Pedestrian path is fenced from creek section	• Definitely a barrier to gliders and wallabies • Possible barrier to focal birds • Fox paw prints in mud of outer cells of culvert, saw 2 pacific black ducks fly through culvert • Pour concrete false floor in outer two cells to provide dry passage in normal flow conditions • Install rope bridge	 
Blind Creek and Timmothy Dv ID #28	• 3 box culverts • 2 culverts for creek flow and 1 culvert for pedestrian use • Concrete substrate • Tree gap ~40m	• Unlikely a complete barrier to any focal species due to narrow road, relatively low traffic volume and reasonably large culvert • Replace culverts with open span bridge • Add one shelf in one culvert to provide dry passage • Plant trees and shrubs on both approaches to culvert • Plant trees on edge of Timmothy Rd	 
Blind Creek and Stud Rd ID # 29	• 2 pipe culvert • 2m diameter, length unknown • Concrete substrate • Blind Creek is piped upstream of Stud Rd past Knox City Shopping Centre (to Lewis Park?)	• Barrier to all focal species	

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Blind Creek and Burwood Hwy ID #30	• 2 multi-span bridges, separated by 3m • 3m x 4m x 16m • Tree gap >100m • Western side of open span bridge has section behind brick wall as pedestrian path • Creek is piped just downstream of Burwood Hwy behind concrete retarding basin wall • No flat area beside creek channel	• Definitely barrier to gliders and probably most other focal species as well • If area upstream of Stud Rd is improved, consider improving this structure • Daylight creek downstream • Increase width of space under bridge • Install rope bridge • Plant trees on approaches and on median of Burwood Highway	
Blind Creek and Lewis Rd ID #31	• 4 box culverts • 2m x 3m x 17m • 1 culvert for pedestrians and 3 culverts for high flow events • Creek is piped at this location • Concrete substrate • Tree gap ~16m	• Likely barrier to most focal species except turtles • Daylight creek and replace culverts with open span bridge • Extra tree and shrub planting on both approaches • Install rope bridge, but complicated by powerlines	

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Blind Creek and Scoresby Rd ID #32	• 3 box culverts • 2m x 3m x 15m • 2 culverts for high flow events and 1 for pedestrians • Tree gap ~20m • Lots of kikuyu grass around both approaches • Creek is piped at this location, becoming unpiped just west of Scoresby Rd	• Likely barrier to most focal species except turtles • Daylight creek and replace culverts with open span bridge • Extra tree and shrub planting on both approaches • Install rope bridge, but complicated by powerlines	   
Blind Creek and Manuka Rd ID #33	• 6 pipe culverts • 1.8m x 15m • Concrete substrate • For high flow events • Creek piped at this location • Tree gap ~40m	• Likely barrier to most focal species except turtles during high flow event • Daylight creek and replace culverts with open span bridge or box culverts • Extra tree and shrub planting on both approaches • Install rope bridge	 
Blind Creek and Rankin Rd ID #34	• 7 pipe culverts • 1.5m x 17m • Concrete substrate • For high flow events • Creek piped at this location • Tree gap ~25m	• Unlikely a barrier to gliders • Likely barrier to most focal species except turtles during high flow event • Daylight creek and replace culverts with open span bridge or box culverts • Extra tree and shrub planting on both approaches	 

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Blind Creek and Wattletree Rd ID #35	• 1 box concrete • 1.2m x 3m x 25m • Concrete substrate • For high flow events • Creek piped at this location • Tree gap ~20m • Relatively intact bushland on west side of road	• Unlikely a barrier to gliders • Unlikely barrier to focal bird species when traffic volume low • Likely barrier to wallabies due to low height of culverts • Daylight creek and replace culvert with open span bridge	 
Blind Creek and Dorset Rd ID #36	• 2 pipe culverts • 1 box culvert • Pipe culverts 2m diameter x length unknown • Box culvert 2m x 3m x 25m • Pipe culverts for high flow events and flows into piped creek • Box culvert for pedestrians • Tree gap ~40m • Pipe culvert has steel grille in front to prevent human access	• Box culvert likely barrier to most focal species due to pedestrian traffic • Pipe culvert definite barrier to all species • Daylight creek and replace culverts with open span bridge • Plant trees on both sides of Dorset Rd • Install rope bridge but complicated by powerlines	   

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Dandenong Creek and Eastlink (South), North Dandenong ID #37	• 2 open span bridges, separated by 11 m • Each bridge 7m x 140m x 19m • For creek flow and pedestrians • Tree gap 70m • Natural substrate under bridges, pedestrian path concrete • Pedestrian path fenced from creek-flow section • Large pool of water between bridges • Large flat area of bank on either side of creek channel • Possible rip rap on south side of creek, and grass on north side of creek • Tall trees and tall shrubs retained quite close to both sides of Eastlink	• Barrier to gliders • Unlikely a barrier to other species • Install rope bridge above or below Eastlink • Add furniture under bridges to provide shelter to small terrestrial vertebrates and small birds • Plant trees and shrubs between bridges	
Corhanwarrabul Creek and Henderson Rd ID#38	• A bridge across Corhanwarrabul Creek is currently being designed. • Corhanwarrabul Creek is an important east-west link across the municipality, and a poorly designed bridge at Henderson Rd will affect both the movement of wildlife along the creek as well as lower habitat quality along the waterway	• Ensure the bridge has sufficient clearance for wildlife to pass underneath. • Ensure noise and light spill from the road into adjacent vegetation is minimised. • Include rope bridges for possums and gliders to cross above the bridge	

Site Name and Map ID	Structure type, purpose and dimensions (H x W x L)	Assessment and recommendations	Site Images
Ferny Creek and Dorset Rd extension ID#39	• An easement exists for an extension of Dorset Rd to the south of Burwood Hwy, currently used as informal open space • The Dorset Rd extension will traverse Ferny Creek near Glenfern Park, potentially dissecting important areas of habitat and open space	• Ensure that the crossing of Ferny Creek takes into account the natural values of the adjacent area and enhances both the quality of habitat and the landscape connectivity for wildlife • The easement for the Dorset Rd extension should also encompass recreational and conservation uses (see Appendix 8)	 
Monbulk Creek and Dorset Rd extension ID#40	• An easement exists for an extension of Dorset Rd to the south of Burwood Hwy, currently used as informal open space • The Dorset Rd extension will traverse Monbulk Creek near Napoleon Rd, potentially disrupting movement along the creek	• Ensure that the crossing of Monbulk Creek takes into account the natural values of the adjacent area and enhances both the quality of habitat and the landscape connectivity for wildlife. Special consideration should be given for platypus as there are recent records in this area • The easement for the Dorset Rd extension should also encompass recreational and conservation uses (see Appendix 8)	 
Dorset Rd extension and drainage channel ID#41 and Lysterfield Rd ID#42	• An easement exists for an extension of Dorset Rd to the south of Burwood Hwy. • The easement for Dorset Rd runs through private property to the south-east of Blackwood Park Drive • The drainage channel is a small drain to the south east of Napoleon Rd, within private property, and the Dorset Rd extension encompasses this drainage channel	• Enhance the function, flow and quality of the channel by returning it to a natural stream, with bends and floodplains • The easement for the Dorset Rd extension should also encompass recreational and conservation uses (see Appendix 8)	 

Appendix 8: Dorset Road Extension- A case study

The proposed Dorset Rd Extension runs between Ferny Creek and Napoleon Rd, then continues on to Lysterfield Rd. Currently the area set aside for the extension is used for passive recreation such as dog walking and as informal open space. There are a number of mature native trees and shrubs in the section between Ferny Creek and Napoleon Rd, while the section between Napoleon Rd and Lysterfield Rd runs through agricultural land along Monbulk Creek.

In the event the road extension goes ahead, there is an opportunity to explore a multimodal transport corridor that would offer movement opportunities for vehicular traffic, pedestrians and biodiversity. Figure 39 shows a concept of a multi-modal road/pedestrian and nature conservation corridor that could be applied. Conversely, the reservation for the road extension could also be used as a dedicated biodiversity corridor and public open space, and existing roads be widened instead, thereby improving traffic flow in the area and negating the need to extend Dorset Rd to Lysterfield Rd. Using this easement for passive recreation and biodiversity would achieve multiple benefits, including increasing the liveability of Knox, encouraging recreation and physical activity and increasing connection to nature, with multiple positive mental, social and physical health outcomes.

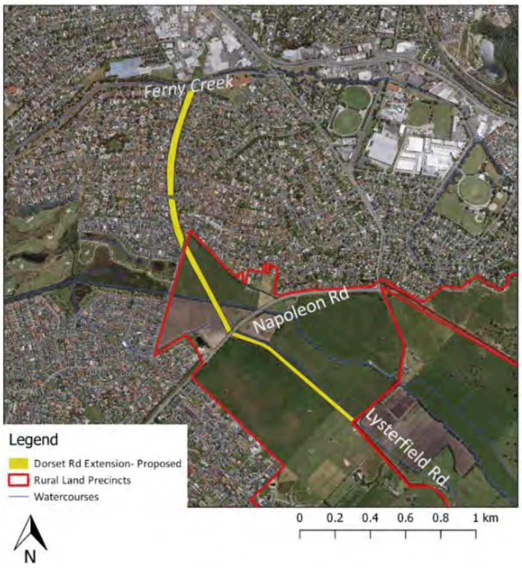


Figure 39. General location of the proposed Dorset Rd Extension (left) and an example of a Biolink connector street and shared path crossing prepared by Ecology Australia for the Botanic Ridge PSP- Southern Brown Bandicoot Conservation Management Plan (right).

Knox Wildlife Atlas 2017

One of the deliverables from this program was a compilation of all Wildlife records for Knox, collated from multiple data sources (See Appendix 3). The shapefiles resulting from this collation exercise are provided here.

Knox2km_BiodiversityRecords_CompiledSources_15June2017.shp

Records of wildlife species compiled from multiple sources. Each record has been assigned a Unique ID which can be used to locate it in the original source dataset. GDA94

VBA_13km_Merged-xinverts_inclTaxaGroup.shp

Records of wildlife extracted from the Victorian Biodiversity Atlas © State of Victoria at 31 May 2017. GDA94 https://vba.dse.vic.gov.au/vba/#/

Knox Wildlife Atlas 2017 – Source Files

These are the original files which were used to compile the Knox Wildlife Atlas 2017. They contain the Unique IID fields which can be used to link records in the Knox Wildlife Atlas with their original source record. These should be retained with the Knox Wildlife Atlas 2017 as they form important reference material to supplement the atlas.

Focal Species

The Knox Wildlife Conservation and Connectivity Analysis used ten Focal Species to investigate important areas for wildlife in Knox. The shapefiles containing the site level information for each focal species used for our analysis are provided here.

FocalSpp1995_500mSITESwospp_16June2017_mga55.shp

500 m buffers around locations which are considered to be the site of the record. GDA94/ UTM Zone 55

FocalSpp1995_SITESwospp_16June2017_mga55.shp

Locations where the focal species were recorded. GDA94/ UTM Zone 55

FocalSpp1995_SITESwospp_16June2017_siteinfo.shp

Locations where the focal species were recorded, which includes information produced during the Site Analysis for each focal species. GDA94/ UTM Zone 55.

FocalSpp1995_SITESwspecies_16June2017.shp

Data base of focal species observed at each Location. GDA94

FocalSpp1995_SITESwspecies_16June2017_siteinfo.shp

Data base of focal species observed at each Location, which includes information produced during the Site Analysis for each focal species. GDA94

Barriers to Wildlife Movement

Shapefile containing location of the barriers identified in Section 4.4.

Sensitive Areas Buffers

These are the shapefiles containing the buffers used to perform the analysis of Important areas for the conservation and connectivity of wildlife in Knox (section 4.5 in the accompanying report).

Appendix 10: Executive Summary

See attached pdf

Appendix 11: Overview of locations for maps in Section 4.5.2. The importance of each Rural Land Precinct for habitat and connectivity of wildlife4.5.2. The importance of each Rural Land Precinct for habitat and connectivity of wildlife (Figs. 30-37).