

14. Appendices

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Appendix A. Biolink study scope and methods

Eco Logical Australia, in collaboration with Alex Lechner and Darrel Tiang Chin Fung from University of Nottingham, was engaged to undertake a connectivity study using the GAP-CLoSR framework and prepare the associated biolink plan. In addition, Eco Logical Australia was tasked with:

- developing a list of faunal 'indicator species' for informing broader conservation planning for each of the highlands southern fall bioregion, Gippsland plain bioregion and the urban growth area regions in the shire
- preparing a set of standards for the indicator species (refer to Appendix D), containing connectivity and habitat specifications and recommendations for conservation planning
- undertaking an assessment of the environmental values of Cardinia Shire's unconstructed roads (refer to Appendix G)
- developing a prioritisation matrix to allow the prioritisation of conservation management actions within the shire over the short, medium and long-term.

While separate tasks, each of the above have been incorporated into this biolink plan and underpin the connectivity study and future conservation planning.

Consultation

Consultation was undertaken with government and community stakeholders during the initial stages of the project to develop a shared vision for the biolink plan. This involved the distribution of a questionnaire and facilitation of 2 workshops in October 2019; one aimed at government stakeholders and the other at community stakeholders.

The purpose of the consultation was to gather specific information to inform development of the biolink plan and connectivity study. The main topics included:

- current stakeholder objectives and goals – understanding the existing land management and biodiversity conservation initiatives within and adjacent to the shire
- connectivity - identification of high value landscape features such as existing core habitat nodes and biolink corridors to inform and prioritise modelling objectives
- indicator species - identification of key fauna indicator species to inform future conservation management.

A summary of the workshop findings and questionnaire results are provided in Appendix C.

Indicator species

The selection of the indicator species involved a desktop inventory of all fauna species in the shire and the compilation of a preliminary list of 30 potential candidates based on the selection criteria. A review of the candidate species during stakeholder consultation workshops in November 2019 was undertaken to reduce the list to a maximum of 15 indicator species.

GAP-CLoSR decision framework

Spatially explicit models which incorporate ecological traits of species and fine-scale landscape elements can help to provide insights and predictions into ecological connectivity at multiple spatial scales. The most common approach to model connectivity internationally and in Australia is based on least-cost path analysis (Adriaensen et al 2003; Foltête et al 2012). Least-cost path analysis characterises non-habitat areas based on the cost of dispersal to or through these landcover types. These dispersal costs represent the difficulty, energetic costs or mortality risk of movement (Adriaensen et al 2003; Sawyer et al 2011). The costs of dispersal through each landcover type are combined with species-specific dispersal probabilities over a range of distances. The importance of a patch or linkage within a network can be quantified using the graph theoretic approach (Urban and Keitt 2001, Minor and Urban 2008, Rayfield et al. 2011). Modelling tools such as Circuitscape, Linkage Mapper, and Graphab can be used to calculate these least-cost paths and provide the graph-metric analysis to assign the relative importance.

The GAP CLoSR decision-support tool provides both a processing framework to develop key spatial layers and parameters for these models, and a conceptual framework for incorporating specific ecological thresholds for species such as minimum viable patch size and movement capabilities. The tool is based on concepts of fine-scale animal movement and ecological connectivity developed in a previous Australian study on dispersal ecology and habitat connectivity (Doerr et. al. 2010). The tool can be used by conservation planners in managing habitat connectivity at the regional scale while taking account of implications for fine-scale landscape features. Comparisons of connectivity implications can also be made at different spatial scales (regional or local) and under different scenarios. Spatially explicit models of ecological connectivity using the GAP CLoSR framework were developed and applied to the study area.

Conceptualising the landscape

Patches and linkages

The ecological connectivity network concept, which the GAP CLoSR framework models, is built on two key real-world features: habitat patches and linkages (or least-cost pathways). Patches are areas of core habitat of sufficient size and structure to support populations of the focal species (or the dispersal guilds they represent). Linkages are the pathways within the landscape that the focal species can use to disperse between habitat patches, effectively connecting them in a fragmented landscape. The least-cost pathway represents the shortest linkage between 2 patches utilising stepping-stones (areas of refuge) that a species may use to facilitate movement. Referred to as 'structural connectivity elements', these stepping-stones may be patches of vegetation which are too small to be considered a habitat patch (e.g. a single paddock tree) or other non-habitat features which could be used as short-term refuge (e.g. a shelter belt).

Resistance and barriers

In order to accurately represent the difficulty, or 'cost', of travelling across different land cover types, 'resistance' is incorporated into the model. For many species, open grassland or pasture is considered to have no resistance; however, as it does not act as a stepping-stone, a species will only move so far across this land type before it decides to 'turn back'. As the land cover changes so too does the risk or cost of the movement, which in turn reduces the distance a species will travel to reach another patch. Urban landscapes, for example, may not prevent dispersal completely, however they may make movement more difficult, resulting in lower dispersal distances. Where the resistance is so great the species cannot move through the landscape, such as across a busy highway or watercourse, the resistance is considered to be impenetrable and is referred to as a 'barrier'.

Networks and components

To assist in the interpretation and weighing of connectivity features and allow the development of a landscape scale 'connectivity network', the modelling assigns 'nodes' and 'edges' to each patch and linkage respectively. These terms can be used interchangeably when interpreting the modelling, however only patches, linkages and connectivity elements represent real-life features present within the study area.

In the graph theoretic approach applied using the Graphab software (Foltête et al 2012), isolation and fragmentation are represented by component boundaries. These represent a group of nodes (patches) that are linked to each other but isolated from other components. They thereby show where habitat is isolated and where it is connected. The size, shape, and number of patches they contain characterise levels of fragmentation in the landscape and barriers to connectivity.

The significance of patches and linkages in the connectivity network is estimated using graph theoretic approach and metrics calculated in Graphab. The metrics considered in this study are 'delta integral index of connectivity' (IIC). The IIC is defined as the probability that 2 points randomly placed within a landscape fall into habitat areas that can be reached (Pascual-Hortal and Saura, 2006). Values for this metric increase with greater connectivity from zero to one and attempt to identify the most critical patches and linkages contributing to the maintenance of overall landscape connectivity.

Conceptualising dispersal behaviour

To allow parameterisation of the model and therefore represent the dynamics of a particular dispersal guild, a 'focal species' is selected and defined by its habitat and dispersal traits.

Key parameters identified for each focal species includes:

- landcover types that represent habitat and the minimum patch size
- landcover types that could act as stepping-stones a facilitate dispersal (i.e. structural connectivity elements)
- the relative resistance value of all other landcover types within the landscape (often defined as a percentage or multiplier)
- the maximum distance an individual is willing to travel between patches along a linkage, referred to as the 'inter-patch distance'
- the maximum 'gap-crossing distance' an individual is willing to travel between structural connectivity elements.

These parameters represent the maximum distance an animal can move along linkages between stepping-stones and ultimately habitat patches. For example, recent studies have found that several Australian woodland birds rarely cross gaps greater than 100 m and distances of greater than 1 km between patches (Doerr et al. 2011, Smith, Forbes & Betts 2013). The model considers these thresholds and calculates whether animals can move between habitat patches based on these movement traits and the arrangement of structural connectivity elements between them.

Connectivity analysis

Connectivity can be thought of as the extent to which a landscape facilitates the movements of organisms and their genes (Rudnick et al. 2012). The maintenance and restoration of connections between habitat patches is designed to maximise 'functional connectivity', which is the degree to which organisms move through the landscape between patches, successfully breed and contribute to gene flow and ultimately persist (Belisle 2005; Doerr et al. 2010). Underlying this is the concept of 'structural connectivity' composed of natural features (such as trees, patches, or corridors of vegetation) which facilitate wildlife movements and are critical to achieving functional connectivity among populations (Fischer and Lindenmayer 2007; Van Der Ree et al 2004).

While the importance of connectivity is recognised as being critical for conservation, identifying which species have suitable connectivity, or what landscape elements contribute to connectivity remains a challenge for regional planning. Most connectivity modelling examples are either very general, whereby connectivity is applied to landscape features, or very specific, whereby connectivity is applied to a single species or multiple species modelled separately. The recently-developed 'General Approach to Planning Connectivity from Local to Regional Scales' (GAP CLoSR) method combines both a species approach with a general landscape features analysis, characterising connectivity for groups of species ('dispersal guilds') based on shared dispersal and habitat characteristics (Lechner et al. 2016, 2017). For this report, we have adapted the same dispersal guild concept and modelling approach.

Study area

The connectivity study area encompasses the Cardinia Shire Council municipal boundary. For the purpose of the connectivity analysis, the shire has been broken into three regions roughly aligning with the southern highlands falls bioregion in the north, the Gippsland plain bioregion in the south, and the urban growth area around Pakenham. The Nar Goon – Longwarry Road has been used as the boundary between the north and south regions due to the change in physical landscape at this point and the resistance associated with this barrier.

Approach

Several processes are involved in habitat connectivity modelling using the GAP CLoSR method, which can be summarised into the following key steps:

- focal species selection and parameterisation (literature review and expert opinion)

- landcover classification to identify habitat and gap-crossing layers (remote sensing)
- characterise landcover resistance (remote sensing and expert opinion)
- modelling using GAP CLoSR decision framework.

Further detail on each step is provided in the sections below.

Focal species selection

A dispersal guild approach was taken which characterises connectivity for groups of species based on shared dispersal behaviour and ecological requirements (Lechner et al. 2015b, Lechner et al. 2017). The intent is to select dispersal guilds representative of the biodiversity present within the study area and which may be limited by connectivity. Given the scope of this study provided for the modelling of three focal species, only low and moderate mobility species have been selected as these represent guilds most effected by fragmentation, which is a key limiting factor for Australian native species and also in the shire. A variety of potential patch size and habitat requirements provided further variables to consider when selecting the focal species

See Table 8 (mobility and habitat size use for biolink connectivity study) in main document

Within these guilds a representative focal species was selected from the 15 indicator species identified for the biolink plan. Focal species were selected to ensure they covered a range of habitat types and localities throughout the shire and had dispersal thresholds and habitat parameters that could be reasonably determined based on information contained in the scientific literature and expert opinion. The three focal species selected, and their associated connectivity parameters are provided in Table 9 (in the main document).

The selection of species was limited to those with a strong association to woody-vegetation, including forests, woodlands and tall scrubs (e.g. swamp scrub). Grassland specific guilds were not considered due to the inability of the remote sensing analysis to differentiate between different types of non-woody vegetation (e.g. native grasslands from pastures from lawns).

Landcover classification

The fine-scale classification of land cover is an essential step for developing appropriately detailed input maps of habitat, structural connectivity elements and landcover that is consistent across the entire Shire and at a resolution suitable to support the GAP CLoSR modelling framework. A secondary objective was to separate vegetation cover into both native and non-native datasets.

Existing native vegetation and tree canopy cover datasets for the shire (i.e. DELWP's native vegetation regulation extent mapping) is too coarse and would result in an over-representation of habitat and connectivity if used as the basis for the connectivity study. To achieve the fine-scale resolution required, a landcover map was produced using high-resolution aerial imagery. This involved the combination of analysis methods, including object-based image analysis (OBIA), texture and vegetation indices, along with complimentary datasets to produce a final land classification map for the entire shire.

Input datasets

Land cover was mapped using 10 cm² aerial imagery datasets which included blue, red, green and near infrared bands. Due to the large size of the dataset and related computational limitations the data required processing in raw format. To address this, the study area was divided into north and south regions and the pixel size reduced to 100 cm². Despite these modifications, the resolution is still considered to be high compared to other connectivity models which commonly use pixel sizes ranging between 25 and 50 m (e.g. Lechner et al., 2017, 2015a), and is considered fine enough to model the interpatch and gap crossing distances of the focal species.

Spectral analysis

The first step was to determine if vegetation could accurately be mapped based on the spectral output with a focus on separating native vegetation from introduced species.

A series of testing points were identified via aerial interpretation across the shire based on known records and local knowledge (Table A1). These points were analysed to determine whether the associated spectral signatures were significantly different enough to discriminate them from each other. The spectral values of raster pixels were extracted for three weed species and two introduced land covers and compared to native and broad anthropogenic land cover classes. Values for red, green, blue, near infrared (NIR), normalized difference vegetation index (NDVI) and texture were extracted for each of the pixels. This included a total of 180 points for each land cover class using a cluster sampling approach based on 20 locations and the surrounding pixels using a 3m² window.

The points were manually identified for 12 classes and the pixel value extraction done using python (an SQL script language). Differences in the spectral values were plotted and a principle component analysis applied to look at differences and similarity between the land cover classes.

Table A1. Landcover classes tested

Non-vegetation	Native	Introduced
<ul style="list-style-type: none"> • Bare soil • Road • Built-up • Open water 	<ul style="list-style-type: none"> • Native trees • Native shrubs • Native groundwater 	<ul style="list-style-type: none"> • Intensive horticulture • Introduced pasture • Pinus radiata • <i>Rubus anglocandicans</i> • <i>Ulex europaeus</i>

General landcover mapping

Following completion of the spectral analysis, general land cover mapping was undertaken in three stages:

1. pre-processing
2. segmentation and supervised classification
3. manual editing and incorporation of auxiliary datasets.

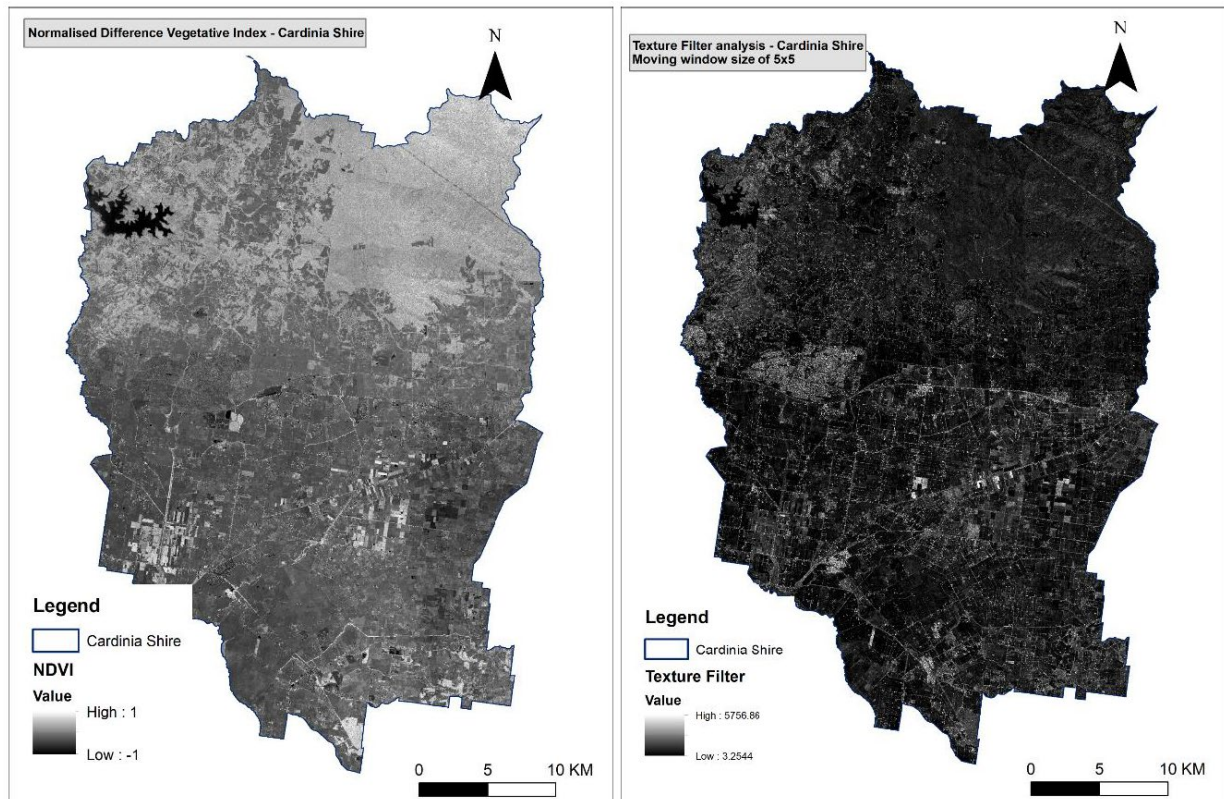
1. Pre-processing

In preparation for classification, the north and south image products underwent two methods of pre-processing. Firstly, the density in the images was generated through use of the infrared and red values of pixels to determine the NDVI using the formula:

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

The texture analysis was then done on the green band using a 5m² moving window size to determine the heterogeneity of land cover features. The outputs from this pre-processing can be seen in Figure A1.

Figure A1. (a) Normalised difference vegetative index where value range from 1 (dense vegetation) to 0 (soil) – 1 (water). (b) Texture layer derived using a 5x5 moving window analysis. High values indicate the land covers are highly heterogenous



2. Segmentation and supervised classification

For the northern region of the study area, the NDVI and texture layer were used alongside the blue band to create a composite raster layer, which was then segmented into image-objects. These image-objects were then classified under supervision using a support vector machine classifier. Supervision involved comparing the classifications to training locations where points with known land cover classes could be used to determine the accuracy of classifications.

For the southern portion of the study area, the same method was used; however, the texture layer was excluded from the composite raster layer due to unknown faults in the texture band resulting in reduced accuracy of the object-based classification compared to object-based classification done with exclusion of the texture layer.

3. Manual edition and incorporation of auxiliary datasets

Several manual edits were made to the land cover layer after the application of supervised classification. Many areas that had non-woody vegetative groundcover were amended as they had been classified as woody vegetation.

The NDVI layer was used to erase shadows and correct pastures wrongly classified as woody vegetation. A threshold was used to remove all vegetation types, resulting in mostly non-vegetation landcover.

Intensive agricultural areas were digitized manually as the OBIA, segmentation and texture combinations did not result in an accurate classification of this varied landcover class. This was done by using a combination of land use datasets (Table A2) and aerial interpretation.

Table A2. Layers used after manual adjustments and processing methods

Landcover	Layer	Processing steps
Roads	tr_roads	<p>Roads were separated into main and minor roads, highways and freeways. Low traffic roads were removed from the original dataset by removing routes identified as 'PATH', 'TRACK', and 'TRAIL'. Further manual filtering was conducted by visually removing roads that were not identified as a roads on Google Earth. Major and minor roads were identified based on the Google Earth classification of roads. While Freeways and Highways are specific to the Princes Freeway and South Gippsland Highway respectively.</p> <p>Each road type was sampled at random locations to measure their average width which was then used to buffer the original polyline dataset.</p> <p>The following are the final buffer width for all road classes:</p> <ul style="list-style-type: none"> • Minor roads: 5.8m • Major roads: 7.3m • Highway: 8.4m • Freeway: 11.4m
Railways	tr_rail	<p>Railways were separated into major and minor rail. Single track rail were categorised as minor rail and dual track rail as major rail. The disused South Gippsland rail line was removed for the purpose of this study.</p> <p>Random points were sampled along rail lines to obtain the average width of each rail type with buffers applied as follows:</p> <ul style="list-style-type: none"> • Minor rail: 2.3m • Major rail: 7m
Waterbodies	hy_waterarea_farm_dams	<p>Hy_waterarea_polygon and farm_dams were merged and used as the water body layer. Waterways and streams were obtained from hy_watercourse, DR_Channel_Centerline and DR_Natural_Waterway_Centerline.</p> <p>Waterway layers were overlaid onto the 10cm2 aerial imagery and lines that did not correspond to any obvious river/stream/drain/channel in the aerial map were removed. Waterways were sampled at random locations to obtain an average width of 7 m used to buffer the original polyline dataset</p>

Finally, a range of auxiliary layers were used to refine the landcover layer with a focus on identifying spatially discrete features such as roads and waterways, as well as defining unusual landcover types.

Roads and rivers were used to update the classified and corrected woody vegetation layer to break up the large patches to better reflect the reality of the current vegetation cover. Roads were derived from the dataset provided and were divided into six different categories to allow for differing resistance values. The same applied for rail lines which were split into two categories.

For urban areas, a size threshold was applied to the parcel and property dataset and high-density urban complexes in towns were categorised as urban. While large distinct structures in rural areas or isolated small to medium houses in rural areas were classified based on building footprints.

Habitat category

In order to differentiate by vegetation divisions and their associated habitat values, the woody vegetation layer was further sub-divided using the modelled pre-1750 Ecological Vegetation Class dataset. This was done based on either vegetation group or class values as defined in Table A3.

Table A3. Classification of vegetation into habitat groups

Habitat	Data-layers	Fields	Value
Forest	nv1750evcbcs	X_EVCGROUP	'rainforests', 'riparian forest', 'wet or damp forests', 'lowland forests'
		X_EVCNAME	'riparian forest', 'riparian forest/warm temperate rainforest mosaic', 'herb-rich foothill forest', 'shrubby foothill forest', 'valley grassy forest', 'valley grassy forest/herb-rich foothill forest complex', 'valley heathy forest'
Woodlands	nv1750evcbcs	X_EVCGROUP	'heathy woodlands', 'herb-rich woodlands', 'lower slopes or hills woodlands', 'plains woodlands or forests', 'riverine grassy woodlands or forests'
		X_EVCNAME	'grassy dry forest', 'grassy forest', 'heathy dry forest', 'swampy riparian woodland', 'swampy woodland'
Heathlands	nv1750evcbcs	X_EVCGROUP	heathlands'
Scrubs	nv1750evcbcs	X_EVCNAME	'berm grassy shrubland', 'coastal headland scrub', 'riparian scrub', 'riparian scrub/swampy riparian woodland complex', 'riparian thicket', 'swamp scrub', 'swamp scrub/plains grassy forest mosaic', 'swampy riparian complex', 'swampy riparian woodland/swamp scrub mosaic', 'aquatic herbland/swamp scrub mosaic', 'estuarine wetland/estuarine swamp scrub mosaic', 'plains grassland/plains grassy woodland mosaic', 'blackthorn scrub'
Mangroves	nv1750evcbcs	X_EVCNAME	'mangrove shrubland', 'coastal saltmarsh', 'coastal saltmarsh/coastal dune grassland/coastal dune scrub/coastal headland scrub mosaic', 'coastal saltmarsh/mangrove shrubland mosaic', 'estuarine flats grassland'
Saltmarsh	nv1750evcbcs	X_EVCNAME	All non-woody vegetation in coastal areas covered by: 'coastal saltmarsh', 'mangrove shrubland', 'coastal saltmarsh', 'coastal saltmarsh/coastal dune grassland/coastal dune scrub/coastal headland scrub mosaic', 'coastal saltmarsh/mangrove shrubland mosaic', 'estuarine flats grassland'

Final land classification

Based on the classification approach, a total of 15 landcover classifications were identified for the study area as outlined in Table A4.

Table A4. Final landcover classifications

Landcover category	Description and impact on connectivity
Forest	<ul style="list-style-type: none"> • Native woody vegetation likely to support forest structural characteristics. • May provide core habitat where patches exceed min area requirements. • Small and linear patches considered to be connectivity elements.
Woodland	<ul style="list-style-type: none"> • Native woody vegetation likely to support woodland structural characteristics. • May provide core habitat where patches exceed min area requirements. • Small and linear patches considered to be connectivity elements.
Scrub	<ul style="list-style-type: none"> • Native woody vegetation likely to support scrub structural characteristics. • May provide core habitat where patches exceed min area requirements. • Small and linear patches considered to be connectivity elements.
Heathlands	<ul style="list-style-type: none"> • Native woody vegetation likely to support heathland structural characteristics. • May provide core habitat where patches exceed min area requirements. • Small and linear patches considered to be connectivity elements.
Mangrove	<ul style="list-style-type: none"> • Woody coastal vegetation. • Non-habitat for any of the focal species. • Do not support connectivity for any of the target conservation species.
Coastal saltmarsh	<ul style="list-style-type: none"> • Non-woody coastal vegetation. • Non-habitat for any of the focal species. • Do not support connectivity for any of the target conservation species.
Pasture and open areas	<ul style="list-style-type: none"> • Pasture or grasslands without woody trees. Bare soil. • Do not provide connectivity. • Do not increase resistance.
Agriculture	<ul style="list-style-type: none"> • Any land that shows signs of tiling visually present in the true colour aerial imagery, regardless of any sign of crop growth. • Intensive horticulture or broadacre. • May increase resistance for some species.
Waterway – rivers, streams and channels	<ul style="list-style-type: none"> • May increase resistance for some species.
Water – ponds and lakes	<ul style="list-style-type: none"> • May increase resistance for some species.
North highway - Old Princes Highway	<ul style="list-style-type: none"> • Large multi-lane road with high traffic that increases resistance for all species.
South highway - South Gippsland highway	<ul style="list-style-type: none"> • Large multi-lane road with high traffic that increases resistance for all species.
Princes Freeway	<ul style="list-style-type: none"> • Large multi-lane road with high traffic that divides the study area into two. • This is where the borders of south and north meets.

Landcover category	Description and impact on connectivity
	<ul style="list-style-type: none"> This freeway will not provide resistance if the north and south is modelled separately, but will increase resistance manyfold for all species if study area is modelled as a whole
Roads – major	<ul style="list-style-type: none"> These major roads lead in and out of the study area. Likely to include moderate to high volumes of traffic. They will increase resistance and, in some case, may be barriers.
Roads – minor	<ul style="list-style-type: none"> These include all other kinds of roads and will increase resistance.
Rail- major	<ul style="list-style-type: none"> Increase resistance for all species.
Rail- minor	<ul style="list-style-type: none"> Increase resistance for all species
Built-up	<ul style="list-style-type: none"> Urban areas and large structures in rural areas are mapped. Higher and lower density land cover mapping areas are represented by having larger areas and no vegetation; thus, will be a barrier due to gap-crossing distance.

Resistance classification

The parameterisation of resistance for each of the focal species was based on previous modelling studies and expert opinion gathered from the workshops and subsequent consultation. The results are presented in Table A5

Table A5. Focal species' resistance value (as a percentage) for different landcover types

	Eastern yellow robin	Southern greater glider	Southern brown bandicoot
Waterways and waterbodies	150	300	1000
Open area	100	100	100
Agriculture	200	150	150
Built-up	200	Infinite	150
Major and minor rail	150	150	200
Multi-lane roads (highways and freeways)	300	300	1000
Major roads	200	200	300
Minor roads	150	150	150

Connectivity modelling

Graphab

Modelling was conducted using the Graphab software. Graphab is used to identify the optimal paths among all patches, where a least-cost path can be generated. A least-cost path between two patches will exist if the cumulative cost distance is below the interpatch dispersal distance threshold. A least-cost path will not be generated if the cumulative cost to traverse the distance between the two patches exceeds the interpatch dispersal distance threshold. The cumulative cost distance describes the accumulated travel cost from one location to another based on the resistance surface rather than actual distance.

Review and testing

Preliminary modelling of connectivity was undertaken using the habitat landcover classifications (i.e. forests, woodlands, scrub and heathlands) and dispersal and resistance parameters for each of the three focal species.

Multiple test scenarios were completed based on varying minimum habitat patch sizes, with outputs reviewed against existing datasets to verify the accuracy of the inputs. Key datasets used in the review included:

- Species records contained in the Victorian Biodiversity Atlas (all species).
- Remote camera survey records provided by the SBB Recovery Group (Southern Brown Bandicoot and Eastern Yellow Robin).
- Local survey data provided by Cardinia Shire Council.
- DELWPs habitat importance mapping.

Based on this review, Table A6 outlines the adjustments made to the model inputs and/or approach

Table A6. Issues addressed through test scenarios

Issue	Description	Solution
SBB habitat	Some areas of low, dense vegetation (e.g. blackberry or tall grasses) that may provide habitat for SBB were not mapped as habitat through the landcover classification. This was largely a result of the small area and varied nature of this vegetation.	The final dispersal guild model for SBB used an aggregated habitat map in which features within 25 m of one another were considered part of a single patch. Scenarios for 1, 2, 3, 4- and 5-hectare patch size were run and compared with recent records and known habitat nodes with the Shire, based data obtained from the Victorian Biodiversity Atlas (DELWP 2019) and from David Nicholls (SBB recovery group).

Modelling outputs

Existing linkages

A connectivity model output was produced for each of the three focal species based on the final land classification layer and species dispersal and resistance parameters. For each species the model identifies habitat patches, least-cost dispersal pathways (linkages) and connectivity components. This information has been collated into a single interpretive map which incorporates the IIC weightings to provide an overview of landscape connectivity for a variety of dispersal guilds, allowing the identification of core habitat nodes and biolink corridors.

Potential linkages

To identify potential linkages in the landscape and inform management priorities, the final connectivity models for each species were re-run with:

- no resistance; and
- no resistance and x2 interpatch-crossing distance.

In addition, a scenario was run across the entire shire using high mobility parameters (i.e. 1500 metre inter-patch distance) and small patch size parameters (i.e. 1 ha aggregated).

By comparing differences in the model outputs for each species, and the change in component boundaries and IIC, potential connectivity improvements can be elicited. This approach is useful for understanding the level of fragmentation in a landscape and where small actions may provide significant benefits.

Potential linkages identified for the three focal species have been deducted and classified by their relative index of connectivity to provide an indication of priorities for future connectivity investment.

Prioritisation framework

Decision criteria

A suite of decision criteria has been developed based on previous studies and feedback from the stakeholder consultation in 2019 (Table A7). The criteria represent the factors a conservation planner or manager may need to consider when determining which biodiversity assets (including biolink corridors) to protect, enhance or create through future investment. Indicator datasets for each decision criteria were selected based on the best available data with regards to resolution, accuracy and reliability.

Table A7. Summary of rank and weighting values

Rank	Assigned weight	Rationale
5	x 3	Values that are recognised as most important across the study area. These are associated with state or national significance for biodiversity conservation value, including those with legislative status or that are associated with state recognised key processes
4		
3	x 2	Values that generally contribute to landscape connectivity significance at the local and regional level
2		
1	x 1	Values that support local connectivity through consolidation of important habitat

Preliminary ranking and weightings for each of the criteria datasets has been assigned by ELA. The criteria were ranked from 1 to 5 in order of ecological sensitivity to fragmentation and landscape connectivity (5 being the highest) (Table A8). Following the ranking process each criterion was collectively assigned a multiplier for the resultant criteria score, reflecting the relative importance of the criteria towards landscape connectivity within the context of the study area and major values for biodiversity and conservation.

Table A8. Decision criteria for the biolink prioritisation framework

Category	Decision Criteria	Rationale
Statutory / Conservation Value	Threatened ecological communities	Six listed threatened vegetation communities identified under the <i>Flora and Fauna Guarantee Act</i> occur within the study area. In addition to FFG Act listed communities, the berm grassy shrubland, estuarine flats grassland and cool temperate rainforest evcs were also included within this category due to their rare geographic occurrence and Endangered Bioregional Conservation Status within the region.
	Threatened flora and fauna	Threatened flora and fauna all have a state legislative status under the FFG Act; including 6 species with national legislative status under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).
	Proximity to drainage lines and waterbodies	Drainage lines and associated riparian vegetation form the basis for habitat health and connectivity across a landscape. The importance of riparian buffer areas is consistent with state legislative guidelines.
	Conservation areas	State recognised conservation areas that are associated with key biological values and/or identified within government approved plans/strategies
Landscape Biodiversity Value	Consolidated vegetation cover	This value identifies local consolidation of biodiversity across the study area.
	Vegetation/habitat quality	This criterion identifies the overall contribution to values for flora/fauna habitat specific to the regional context
	Regional connectivity	This criterion identifies the overall contribution to habitat connectivity across the landscape and identifies fragmentation and barriers to connectivity in a regional context.
	Local connectivity	This criterion identifies areas contributing to current and potential local habitat connectivity.

An Analytical Hierarchy Process (AHP) is recommended to further refine these rankings. The AHP is suitable for complex decisions which involve the comparison of decision elements which can be difficult to quantify (Saaty 1980; Crossman et al. 2009; Mendoza and Macoun 1999). A Delphi based process (Linstone and Turoff 1975) in a workshop/group environment could be used to facilitate the AHP.

A summary of the steps involved in data preparation requirements for the analysis and associated criteria, rationale, data layers, rank and weightings proposed are outlined in Table A10.

Prioritisation framework

The conservation index score is the sum of the rank and weighing for each of the statutory and landscape decision criteria. The final scores were normalised to provide an index ranging from 0 to 100 using the following formula:


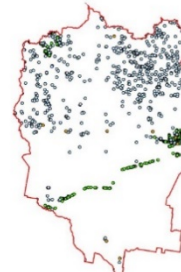
$$X \text{ normalized} = ((X - X \text{ min}) / (X \text{ max} - X \text{ min})) * 100$$



The resultant normalised values were then categorised into five conservation priority categories as displayed in Table A9.

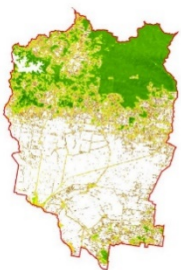
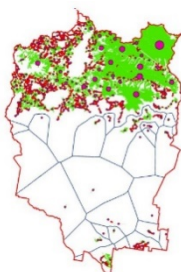
Table A9. Conservation priority categories


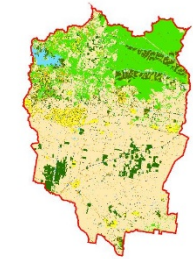
Priority	Description
Very High	Areas of high connectivity, usually including values listed State or Federal legislation that are under a high degree of threat from human impacts and/or risk from pests and disease. All management efforts should be focused on maintaining connectivity and eliminating impacts on these areas.
High	Areas of high connectivity, that generally contribute to landscape connectivity in a regional context, that are subjected to a degree of risk. Impacts on these areas should be avoided whenever it is possible with focus on enhancing connectivity;
Moderate	Areas that exhibit indirect effects of connectivity loss which are important at a local and regional level. Management should be focused on minimising impacts on these areas wherever possible with focus on enhancing and restoring connectivity;
Low	Areas that include a degree of ecological disturbance which may impact on long term connectivity and/or habitat values that are of low to moderate value within the region. Impacts on these areas should be minimised by management wherever possible with focus on restoring connectivity;
Very low	Areas that comprise of very little connectivity value or areas that have moderate connectivity value coupled with very low risk of threats. Management of these areas produces negligible enhancement for connectivity

Table A10. Data preparation and weighting for the conservation index

Layer	Decision criteria	Rational and description	Data layer	Values	Rank	Weight
	Threatened ecological communities	Six listed threatened vegetation communities identified under the <i>Flora and Fauna Guarantee Act</i> occur within the study area. In addition to FFG Act listed communities, the Berm Grassy Shrubland, Estuarine Flats Grassland and Cool Temperate Rainforest EVCs were also included within this category due to their rare geographic occurrence and Endangered Bioregional Conservation Status within the region.	NV2005_FFG_COMM; NV2005_EVCBCS	0, 50 or 100. 100 = all FFG communities 50 = selected EVCs 0 = all other areas	5	x3
	Threatened flora and fauna	Threatened flora and fauna all have a State legislative status under the FFG Act; including 6 species with national legislative status under the <i>Environment Protection and Biodiversity Conservation Act 1999</i> (EPBC Act).	Records from: Victorian Biodiversity Atlas; Southern Brown Bandicoot Recovery Team; Council's internal datasets. Location of threatened flora and fauna records to have a maximum accuracy of <=1000m.	0 or 100. 100 = within 20m of a known threatened flora record or within 100m of a known threatened fauna record. 0 = all other areas.	5	x3

Layer	Decision criteria	Rational and description	Data layer	Values	Rank	Weight
	Proximity to drainage lines and waterbodies	Drainage lines and associated riparian vegetation form the basis for habitat health and connectivity across a landscape. The importance of riparian buffer areas is consistent with state legislative guidelines.	Vicmap Hydro watercourse and water area; WETLANDDIR Area within 50m of natural drainage line and waterbodies	0 or 100. 100 = within 50m of a drainage line or a waterbody. 0 = further than 50m from a drainage line or a waterbody.	4	x3
	Conservation areas	Conservation areas and Biological significant sites identified under the <i>National Parks Act 1975</i> and Council's <i>Biodiversity Conservation Strategy</i> . As well as covenanted properties listed under the Cardinia Shire Council project Trust for Nature and state layers such as Biosite, Coastal Bird Habitats and Environmental planning overlays.	Parkres layer and Council's RESERVE (DIR MGT); Trust for Nature properties; msa_bcs_cons_area; BIOSITE_Merged_08082017; COASTAL_BIRD_HABITAT; VIC_Map: environmental planning_overlays - Environmental Significance Overlays / Significant Landscape Overlay.	0, 25, 50 or 100 100 = legally recognised areas (Reserves, trust properties and conservation areas) 50 = Important areas (Biosites; Coastal bird habitat; Environmental and Landscape overlays) 25 = within 150m from any legally recognised and important areas 0 = all other areas.	4	x3

Layer	Decision criteria	Rational and description	Data layer	Values	Rank	Weight
	Vegetation/ habitat quality	<p>High quality habitat for terrestrial and aquatic species based on statewide recognized layers measuring habitat composition, structure and function.</p> <p>This criterion identifies the overall contribution to values for flora/fauna habitat specific to the regional context</p>	<p>Native Vegetation Regulation Condition (2017) analysis ranking clipped to ConVegCover (2020). Divided into biodiversity classes.</p> <p>Healthy waterways Fish habitat suitability categories buffered by 50m.</p> <p>Priority was assigned to Terrestrial habitat categories were overlap occurred between the two layers.</p>	<p>0,20,40,60,80 or 100</p> <p>Terrestrial habitat categories: 100 = Very high (80 to 100) 80 = High (60 to 80) 60 = Moderate (40 to 60) 40 = Low (20 to 40) 20 = Very Low (1 to 20) 0 = No habitat</p> <p>Fish habitat categories: 100 = Very high 80 = High 60 = Moderate 40 = Low 20 = Very Low 0 = No habitat</p>	2	x2
	Regional connectivity	This criterion identifies the overall contribution to habitat connectivity across the landscape and identifies fragmentation and barriers to connectivity in a regional context.	Biolink_corridors (2020)	<p>0, 50 or 100</p> <p>Connectivity Classes 100 = Priority Corridors 50 = Potential Corridors 0 = all other areas</p>	3	x2

Layer	Decision criteria	Rational and description	Data layer	Values	Rank	Weight
	Local connectivity	Current and potential linkages that connect localised habitats through least cost paths	<p>Biolink_Linkages (2020); Biolink_CoreHabitat (2020);</p> <p>All core habitat types were merged and treated with equal weighting.</p> <p>Linkages were combined based on prioritised mobility class (with 'low' having the highest priority and 'high' having the lowest)</p> <p>Both layers were weighted by Integral Index Connectivity and combined</p>	<p>0, 20, 40, 60, 80 or 100</p> <p>Within 150m of a linkage of: 100 = very high importance 80 = high importance 60 = moderate importance 40 = low importance 20 = very low importance 0 = all other areas</p>	4	x3
	Consolidated vegetation cover	The size of a patch of vegetation. A patch is defined as an area of consolidated vegetation that is separated from other patches by a mapped road or track.	ConVegCover (2020) and Biolink Lancover waterbody class (2020)	<p>0, 25, 50, 75 or 100</p> <p>Patch Size classes 100 = Regional (>200 ha) 75 = Local (10 – 200 ha) 50 = Small (1 – 10 ha) 25 = Clump (<1 ha) 0 = Non vegetation</p>	1	x1

Biodiversity assets in Cardinia Shire

Table A11. Biodiversity assets in Cardinia Shire

Area	Corridor
<ul style="list-style-type: none"> • Bayles Recreation Reserve • Beaconsfield Nature Conservation Reserve • Beenak State Forest • Bunyip River • Bunyip Sanctuary • Bunyip State Park • Cannibal Creek Catchment • Beaconsfield Flora and Fauna Reserve • Cardinia Creek parklands • Deep creek • Emerald Lake Park • Emerald quarry (Emerald Starbush) • Gumbuya World • Harbury reserve (Trust for Nature) • John's Hill • Kurth Kiln Regional Park • Lang Lang Conservation Reserve and bushlands • Menzies Creek Bushland Reserve • Mount Cannibal Flora and Fauna Reserve • Pepi's Land • RJ Chambers Flora and Fauna Reserve • Sassafras Creek Nature Conservation Reserve • The Inlets (Cardinia Creek and Deep Creek outlets at Tooradin) • Toomuc Creek • Beaconsfield Nature Conservation Reserve • Western Port Bay and coastal reserves • Wright Forest 	<ul style="list-style-type: none"> • Bessie Creek to Ararat Creek • Bunyip River to Western Port Bay • Bunyip State Park to Cardinia Reservoir • Cardinia Creek to Western Port Bay • Cockatoo Creek to Macclesfield Creek to Yellingbo Nature Conservation Reserve • Emerald lake Park and Wattle Creek to Wright Forest and Cockatoo Creek • High voltage - East West Link lines (within the urban growth corridor) • Princess Highway to Bypass • Puffing Billy Rail Line • Shepherds Creek to Yellingbo C.R • Sherbrook Forest connection to Bunyip State Park and through extension to Yarra Valley • Toomuc Creek beginning at RJ Chambers reserve down to the Princess Highway • Wright Forest to Cockatoo Creek to Yellingbo Nature Conservation Reserve

Key threats to biodiversity conservation in Cardinia Shire

Table A12. Key threats to biodiversity conservation in Cardinia Shire

Environmental	Land use
<ul style="list-style-type: none"> • Climate change • Domestic animals (i.e. cats and dogs) • High intensity or frequent fires • Loss of insects/pollinators • Pests, including deer, foxes and rabbits • Phytophthora • Soil degradation and loss • Vegetation removal • Weeds 	<ul style="list-style-type: none"> • Agricultural development/practices • Channelisation of waterways • Fire and flood protection • Inappropriate land management activities • Management of new and existing utilities • Rezoning • Urban expansion

Appendix B. Existing strategies, plans and connectivity studies

Stakeholders

As recognised in Council's *Biodiversity Conservation Strategy 2019-29*, the management of the shire's natural environment rests with a broad range of public and private stakeholders, as outlined in Table B1. In developing the biolink plan, many of these organisations and groups were consulted during and after the stakeholder workshops in 2019 and will continue to be engaged in the finalisation of the plan and implementation.

Table B1. Key stakeholders of the biolink plan

Sector	Organisation or group
Victorian Government	<ul style="list-style-type: none"> The Department of Environment, Land, Water and Planning (DELWP) Parks Victoria
Local government	<ul style="list-style-type: none"> Cardinia Shire Council Baw Baw Shire Council Yarra Ranges Shire Council Casey City Council Bass Coast Shire Council South Gippsland Shire Council
Public authorities	<ul style="list-style-type: none"> Port Phillip and Western Port CMA Melbourne Water VicTrack VicRoads
Environmental groups	<ul style="list-style-type: none"> Western Port Biosphere Phillip Island Nature Links SBB Regional Recovery Group Cardinia Environment Coalition (CEC) Western Port Catchment Landcare Network Southern Ranges Environment Alliance Cannibal Creek Catchment Biodiversity group Port Phillip to Healesville Nature Links 'Friends' groups Indigenous plant nurseries Landcare groups Wildlife shelters Individual volunteers
Private interests	<ul style="list-style-type: none"> Shire residents Private businesses Rural landholders, including TFN properties Community organisations Research and educational organisations Our future generations

Existing strategies, plans and connectivity studies

The plans, strategies and studies listed in Table B2 and Table B3 were used as references in the preparation of this biolink plan, to ensure consistency with existing strategies and regional plans.

Table B2. Plans and strategies

Document title	Description
<i>Biodiversity Conservation Strategy 2019-29</i> (Cardinia Shire Council 2019)	<p>Aim Strategic and planned approach to sustainably manage the shire's natural environment, so it is resilient, healthy and valued by the community</p> <p>Objectives:</p> <ul style="list-style-type: none"> • Protect native flora, fauna and habitats (i.e. waterways); • Enhance the quantity and quality of indigenous flora and fauna on private and public land; • Connect native flora and fauna across landscape through Biolink corridors and steppingstones; and • Engage and educate the local communities.
<i>Cardinia Shire's Liveability Plan 2017-29</i> (Cardinia Shire Council 2017)	<p>Aim Strategically planning and maintaining opens spaces and places – ensure safety, accessibility, appealing and connected;</p> <p>Objectives:</p> <ul style="list-style-type: none"> • Enriching local identity and place making through public art and cultural expression; • Increasing access to leisure, sport and recreation opportunities; and • Protecting and enhancing the environmental quality of open spaces and places.
<i>Healesville to Phillip Island Nature Link: Cardinia Waterways Catchments Section</i> (Macwhirter 2018)	<p>Aim Create a nature link of national significance connecting three of Victoria's iconic ecotourist attractions (Healesville Sanctuary, Puffing Billy Steam Train and Phillip Island Nature Parks) through the use of natural corridors on public and private land.</p> <p>Objectives:</p> <ul style="list-style-type: none"> • Form continuous links from the Western Port Biosphere to the Ash forests of the Yarra Ranges to provide refuge and migration pathways; • Improve ecological connectivity to improve the future for species conservation; • Habitat improvement through nurturing biodiversity; and • Educate public regarding human-nature relationships.
<i>Integrated Water Management Plan 2015-25</i> (CSC 2015)	<p>Aim Deliver a framework to guide Council towards a more sustainable approach to water management to decrease the reliance on potable water and enhance ecological health of receiving waterways.</p> <p>Objectives:</p> <ul style="list-style-type: none"> • Quantify and minimise stormwater flows, and pollutant loads to waterways; • Ensure efficient use of potable water within Council facilities and encourage community to reduce usage; • Reduce Councils reliability on potable water by identifying and using alternative water sources; • Contribute to sustainable groundwater management (including exploring the option of alternative sources for agriculture); • Reduce the impact on the environment; and

Document title	Description
	<ul style="list-style-type: none"> Protect the shires waterway values and open these assets up to the community.
<i>The Regional Catchment Strategy for the Port Phillip & Western Port region</i>	<p>Aim Sets targets for environmental assets that are the cornerstones of ecological health and resilience in the Port Phillip and Western Port region – native vegetation, native animals, waterways and wetlands, hinterland, coasts and the bays.</p> <p>Objectives:</p> <ul style="list-style-type: none"> Permanently maintain the extent of numerous large and/or important patches of native vegetation and ensure they are managed primarily for conservation purposes Retain the collective quantity/quality of the other native vegetation across the landscape.
<i>Biolink Project Action Plan (CEC 2008)</i>	<p>Aim Protect and enhance biodiversity through the development of biolink within Western Port Catchment Central Region</p> <p>Objectives:</p> <ul style="list-style-type: none"> Protect and enhance native biodiversity through the development of biolink; and Support fundamental natural ecological processes
<i>Latrobe Catchment Biolink Strategy (Maclagan 2011)</i>	<p>Aim Prevent land degradation and improve ecological resilience across the region – restore the environment and provide benefits to landholders and the broader community.</p> <p>Objectives:</p> <ul style="list-style-type: none"> Encourage landholders to improve the quantity, quality and connectivity of natural habitats; and Create biolink between local areas and private property
Officer and Pakenham East Native Vegetation Precinct Plans, Cardinia Road Employment Precinct Structure Plan (various)	<p>Aim Protection of significant native vegetation and biodiversity in the context of urban development</p>
<i>Southern Brown Bandicoot Habitat Protection Strategy and Environmental Significance Overlay (EA 2016)</i>	<p>Aim Development of statutory planning mechanisms to protect habitat for the nationally endangered Southern Brown Bandicoot, within the townships of Bunyip, Garfield and Tynong.</p> <p>Objectives:</p> <ul style="list-style-type: none"> Integration of conservation requirements into the planning scheme (provides a statutory mechanism that accounts for both large- and small-scale developments); Limit the loss of native vegetation; Zoning and overlays to protect areas of significant native vegetation and natural values;

Document title	Description
	<ul style="list-style-type: none"> • Maintain a mosaic of habitats (dense sheltering and nesting habitats, foraging habitats etc); and • Maintain functional connectivity between different habitats.
<i>Sub-regional species strategy for the Southern Brown Bandicoot</i> (DEPI 2014)	<p>Aim Key mechanisms to deliver the conservation outcomes for the Southern Brown Bandicoot</p> <p>Objectives:</p> <ul style="list-style-type: none"> • Prevention of any further local extinctions; • Achievement of a net increase in distribution of occupied habitat; • Achievement of a net increase of overall population size; • Prevent loss of genetic diversity from the metapopulation • Increase public awareness of Southern Brown Bandicoot (biology, conservation, importance etc); and • Local community support for management actions.
<i>Predator control strategy for the Western Port Biosphere Reserve</i> (EA 2014)	<p>Aim Strategic framework for the establishment and implementation of a broad-scale predator control program</p> <p>Objectives:</p> <ul style="list-style-type: none"> • Pest management with a primary focus on foxes; • Identify control techniques that are effective and economic; • Prioritisation of areas to target for future control works; • Technical recommendations and protocols for on ground works; and • Monitoring requirements, with recommendations for biodiversity monitoring, and protocols to undertake operational monitoring to assess the efficiency of control works
<i>Yarra 4 Life – Strategic Plan 2017-22</i> (PPWPCMA 2012)	<p>Objectives:</p> <ul style="list-style-type: none"> • Connect ecosystems in the Yarra Valley area; and • Connect people with the natural environment.

Table B3. Connectivity studies

Study title	Description
<i>Southern Brown Bandicoot Strategic Management Plan</i> (EA 2009)	Identifies population clusters and associated core habitat and linkages, population structure, land use and key threats and constraints
<i>Bass Coast Biodiversity Biolink Plan</i> (Bass Coast Shire Council 2018)	Identifies ecological assets, threatening processes, opportunities and existing or potential biolink
<i>Western Port Biosphere Reserve Biodiversity Plan</i> (Chambers and Jacka 2015)	Identifies biodiversity values, current initiatives and projects, including Growing Connections project and associated biolink, and key objectives and actions.
<i>Biolink Project Action Plan mapping</i> (CEC 2009)	Shows project sites, public land under various authorities and potential or existing biolink.
<i>Assessment of riparian setback widths required to support biodiversity values</i> (EA 2009)	Determines recommendations or 'best practice' protocols for riparian setback widths for key species across the Port Phillip and Western Port Catchment.
<i>Nature Print – Strategic Management Prospects</i> (DELWP 2019)	Prioritisation mapping of management actions.

Appendix C. Stakeholder workshop – summary of outcomes

Date: Wednesday 30 October 2019
 Morning session: government stakeholders
 Afternoon session: community stakeholders

Introduction

The purpose of the workshop was to gather specific information from key stakeholders involved with conservation management in the region to inform development of the biolink plan and connectivity modelling.

The workshop focused on three areas:

- **Biodiversity objectives and goals** – development of the biolink plan must sit within the context of all land management and biodiversity conservation initiatives within and adjacent to the shire. Understanding the objectives of these initiatives and the organisations behind them is critical to ensuring the plan is relevant and effective.
- **Connectivity** - connectivity between patches of vegetation within the landscape plays an important role in the movement of fauna and the viability of populations. To guide long-term conservation management works for fauna, identification of conservation landscape infrastructure such as core areas, nodes, stepping-stones and corridors of highest value for protection within Cardinia Shire is needed. Input will be used to inform and validate the connectivity analysis.
- **Indicator species** - native fauna species have varying habitat requirements and levels of tolerance to land use change, with increased pressure on peri-urban and rural environments across the Shire of Cardinia expected in future years. To ensure future conservation efforts are effective we are seeking input for the selection of fauna 'indicator' species suitable for informing future conservation and connectivity planning and monitoring.

Participant responses as well as preliminary information provided in the workshop is presented below.

Biodiversity objectives and goals

At the workshop participants were provided with existing government and community organisation plans. Participants also supplied organisational and community-based plans and initiatives that were used to development of the Biolink plan objectives and goals. These are summarised in Table C1.

Table C1. Current plans, initiatives and actions

Conservation focus	Other considerations
<ul style="list-style-type: none"> • DEWLP's Protecting Victoria's Environment - Biodiversity 2037 • Melbourne strategic assessment (particularly SBB) • Precinct Strategic Plans • Planning scheme and environmental overlays • Lang Lang flood plan • Waterway sites of biodiversity significance plan 2013 • CSC Weed management strategy 2019-29 • Yarra Shire biodiversity priorities (Kym Sanders) 	<ul style="list-style-type: none"> • Bushfire regulations, planning and management • Other planning objectives • VicRoads major roads projects • State govt planning policies • Cardinia Shire equestrian strategy (strategic recreation trails) • Roadside management • Road network upgrades including sight lines • Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation – current initiatives re community engagement of waterways.

Conservation focus	Other considerations
<ul style="list-style-type: none"> • Johns Hill Landcare strategic plan • Macclesfield and Monbulk Landcare plan (existence unknown) • Yellingbo - Butterfield (Y2B) [Helmeted honeyeater] plan • PPWCMA biodiversity conservation plan • Toomuc Landcare fox control program • Johns Hill Landcare planting projects • Swamp Landcare Projection of Ramsar Wetlands mangrove plantings • Melbourne Water integrated water management strategy • Peri-urban weed strategy/partnership project • Green wedge plans • Growling Grass Frog sub-regional strategy • City of Casey revegetation strategy • Gardens for wildlife • Melbourne waterways streamside frontage grants (e.g. private landowners) • Melbourne Water Healthy Waterways Strategy • Yellingbo conservation area - DELWP strategy currently in development • Indigenous land management activities (WLC) • PPWCMA regional catchment strategy • Future urban forest strategy • Climate adaptation strategy • BCS conservation areas • Future CSC roadside management strategy • CMA Ramsar protection program • Integrated water management forums • Offsets 	<ul style="list-style-type: none"> • Cultural significance (particularly waterways) • Cardinia's health and wellbeing initiatives • Urban development • Flood mitigation works and vegetation removal (MW) • Maintenance of levees and waterways (revegetation not always possible due to integrity issues) • Weed management where leads to habitat removal • Rail links and rail trail • Recreational use of landscape • Drainage on swamp plain • DELWP focus on green infrastructure for mental wellbeing • Ecosystem services • Urban farming / food circles •

Other stakeholders

Table C2. Other stakeholders

Private	Community	Public/not for profit
<ul style="list-style-type: none"> • Farming community • Other land managers e.g. farmers • Indigenous nurseries • Business groups • Developers • Cat owners • Golf clubs • Quarries • Gumbuya World • Trust for nature property owners • Real estate agents • Wurundjeri land council • Puffing Billy • Rural residents • Utility authorities/providers 	<ul style="list-style-type: none"> • Landcare groups • Friends groups • Traditional owner groups • Migrant communities • Youth groups • Community recreational network groups (walking, mountain bike group) • Wildlife carers 	<ul style="list-style-type: none"> • Cardinia Shire Council • Vic Track • Vic Roads • Recreation Reserves Coms • Schools • DEWLP • Trust for Nature • Internal council departments • Melbourne Water • PPWP CMA • South East Water • Yarra Valley Water • MRPV • CFA

Vision

Suggestions for potential vision:

- Retain and enhance biodiversity through the creation and protection of effective biolink across the landscape and waterways
- No extinction in CSC; and
- Protect and re-establish landscape biolink across CSC and beyond.

Goals

Suggestions for potential goals:

- Increase community awareness
- Improve condition of existing remnant vegetation for key target species
- Connect core habitats (waterways, significant vegetation etc)
- Create economic incentives to protect vegetation e.g. rates, carbon credits;
- Diverse biolink that provide for all organisms
- Biodiversity enhancement
- Maintain/improve genetic connectivity
- Effective pest control
- Stop habitat loss
- Protect and promote the movement / dispersal of native fauna across landscape
- Protect and enhance existing flora for habitat linkages
- Provide refugia for fauna to mitigate changing climate / climate adaptation
- Empower community to get involved
- Connect people with nature
- Increase community understanding of importance of connectivity assets
- No net loss of vegetation cover
- Strategic weed management
- Improve vegetation condition
- Farmland to have 10% vegetation
- Inform effective ESOs
- Limit the impact of the urban environment + urban growth on habitat
- Connect public land assets with vegetation on private land
- Improve terrestrial links as well as waterways
- Long-term and achievable.
- Protect n% of C.S.C area for biolink habitat

Objectives

Suggestions for potential objectives:

- Prioritise existing high value habitats
- Incorporate stepping-stones into management decisions
- Promote awareness and engagement of landowners/community
- Foster people/schools/community/networks
- Prioritise bush blocks and large reserves not linked by waterways
- Recognise and reward landowners who are undertaking biodiversity conservation works (e.g. trust for nature rates rebate)
- Identify priority areas of remnant vegetation
- Identify priority key linkages
- Celebrate achievement/progress (acknowledge)
- Engender broad community support and education
- Develop strong collaboration of key stakeholders e.g., VicRoads
- Support development of skills and knowledge to improve biodiversity and connectivity

- Coordination of effort and communications
- Ensure consistent terminology for habitat improvement and environmental works (effective communication tools)
- Effective engagement with diverse cross-section community (families, youth) - combating common misconceptions/fears of nature
- Establish effective baseline monitoring
- Establish knowledge base for connectivity that can be built on beyond this project.
- Work with adjacent councils to improve connectivity – coordinated strategy.
- Integrate connectivity priorities into planning scheme
- Effective compliance
- Manage roadsides to create and protect significant habitat linkages
- Increase environmental allowance from rates
- Manage water quality to enhance biodiversity in Western Port

Timeframes

- Improve / establish 10km of linkages per year
- In 5 years, every school to have a waterway to look after
- Long-term
- Actions sooner rather than later
- Factor in current growth rates of community

Connectivity

Connectivity between patches of vegetation within the landscape plays an important role in the movement of flora and fauna and the viability of populations. To guide long-term conservation works for fauna, land managers can identify conservation landscape infrastructure such as high-value core areas, nodes, stepping-stones and corridors. The following questions seek to identify areas of significant habitat within Cardinia Shire and current conservation efforts that may improve connectivity.

Where are the priority areas and linkages in Cardinia Shire?

Table C3. Priority areas and linkages

Location	Linkages
<ul style="list-style-type: none"> • Cardinia Creek Corridor • Bunyip State Park • Cannibal Creek Catchment incl. Mt Cannibal • Bayles Recreation Reserve • RJ Chambers Reserve • Cardinia Reserve • Kurth Kiln • Bunyip Sanctuary • Beaconsfield Reserve • Beaconsfield Nature Conservation Reserve • Pepi's Land (headwaters for lots of creeks) • Emerald quarry (Emerald Starbush) • Critchley Parker Junior Reserve • Emerald Lake Park • Wright Forest • John's Hill • Gumuya World (Tooradin + CC outlet) • Western Port Bay • Toomuc Creek • Deep creek • Bunyip River 	<ul style="list-style-type: none"> • Cockatoo Creek > Macclesfield Creek > Yellingbo • Shepherds Creek to Yellingbo C.R (big properties in here, good return for investment) • Bunyip S.P to Cardinia reservoir (link) • Wright Forest > Cockatoo Creek > Yellingbo C.R • Emerald Lake Park and Wattle Creek to Wright Forest and Cockatoo Creek • Bessie Creek - Ararat Creek including Harbury (Trust for Nature) • Sherbrook Forest connection to Bunyip State Park and through extension to Yarra Valley • Cardinia Creek • Main drain corridor to coast (Bunyip River) • High voltage - East West Link lines • Puffing Billy Rail Line • Toomuc Creek beginning at RJ Chambers reserve down to the Princess highway stage 1 • Stage 2 - Princess Highway to Bypass

Location	Linkages
<ul style="list-style-type: none"> Sassafras Nature Conservation Reserve (Menzies Creek) - Ridge Rd Menzies Creek Yallock Creek marked on map including large old trees 	

What are Cardinia Shire's most threatened biodiversity assets and where are they found?

Table C4. Cardinia Shire's important biodiversity assets and location

Habitat type	Land type
<ul style="list-style-type: none"> SBB Habitat type (including sand soils) Growling Grass Frog habitat Helmeted honey eater habitat Coastal Saltmarsh Mud flats Marshlands Woodlands 	<ul style="list-style-type: none"> All waterways and riparian habitat Drains along roads Koo Wee Rup drains All existing bushland Melbourne water drainage lines Private land adjacent to key corridors and ecosystem services that wildlife corridors provide Foothills north of growth area (unique ecosystems) Significant roadsides – high priority roadsides Crownland/paper roads Crown allotments Roadsides Sympathetic landowners Council reserves Other public land reserves

What are the opportunities, barriers and knowledge gap this plan could cover?

Table C5. Opportunities, barriers and knowledge gap

Opportunities	Barriers	Knowledge gaps
<ul style="list-style-type: none"> Connecting to private landowners Multi-agency work Stakeholders collaboration - Council, MW, private landholders Protection in planning scheme Provide criteria for allocation of budget Focus for collaborative work/action (around biolink priorities) Community engagement Revegetation on private land Increase number of private landholders Newer developments provide corridors Build on Landcare works 	<ul style="list-style-type: none"> Competing priorities for fire and flood protection Impact on agriculture production Impact on private land Money Phytophthora Defendable space clearing in BMO Pests - Deer Encourage predator and pest movement through improved connectivity Urban growth area New utility easements Community apathy (barrier) Fire vegetation restrictions Council roadside slashing Agricultural development/practices 	<ul style="list-style-type: none"> Conservation value of roadside vegetation (data decade old) What's on private land? Lidar data for Cardinia Shire Data existing within other organisations Data on quality on bush blocks as habitat (survey of private property) Benefits of ecosystem services to local landholder Unconstructed government roads (paper roads)

Opportunities	Barriers	Knowledge gaps
<ul style="list-style-type: none"> Enhance what we have existing Opportunity to work with existing pest control networks Collaborate with community groups at a tangent to existing networks and existing council conservation initiatives (e.g. Council weed grant) Secure federal funding for threatened sp. Influence VicRoads major roads projects and biodiversity designs and outcomes Better fire management outcomes Rethink shelter-belt design Multi-storey farming on private land Multi-directional links to reduce S/E wind impact Narrow corridor through established urban areas Mixed + mono planting to reduce fire risk 	<ul style="list-style-type: none"> Woody weeds/pest Domestic animals Soil damage/soil loss Loss of insects/pollinators Channelising of waterways Rapid change in landscape and vegetation Conflict between corridors and roads Climate change and effect on flora and fauna CFA concerns about 'wicks' where vegetation corridors provide fire connectivity 	

What are your suggested priority actions for the biolink plan?

Table C6. Priority actions

Action	Action
<ul style="list-style-type: none"> Support volunteers – areas shouldn't be looked after by volunteers alone. Engage with young people, potentially through schools More on-ground resources e.g. rangers, Council officers, bushland crews Targeted /coordinated pest control – deer (priority), cats, foxes, pigs Mechanisms to introduce initiatives for landowners to take up investment biolink priorities Engage all landholders to garner buy-in including business, industry and rural Allocate responsible party/officer for biolink actions – could split by waterways, coastal and terrestrial Establish networks with neighbouring Councils, Melbourne Water, Private Landholders, Friends Groups, etc Establish one natural reserves team for each ward in the shire Focus offset or carbon credits at priority areas for connectivity improvement or creation. 	<ul style="list-style-type: none"> Improve compliance Improve planning laws Weed removal Provide guidance on fire resistant plants, appropriate management of fire risks etc. Plan for climate change Coordinate and fostering community events Protection of council land allotments Roadside weed removal Baseline and ongoing monitoring to inform adaptive management Cat curfew/sterilisation/enforcement and eradication (responsible pet ownership) Targeted revegetation on priority biolink Protect existing remnant vegetation - create incentives Protection of mature habitat trees Connect people with nature Promote Trust for Nature program Plant giveaway Creek management plans

Action	Action
<ul style="list-style-type: none"> • Non-productive farms as focus for conservation actions • Increase planning controls – establish new overlays and adapt municipal strategic statement • Encourage complimentary production systems • Promote value of nature to tourism • Invest in revegetation • Invest in local and Landcare groups • Adapt weed control approach to protect habitat associated with these species (e.g. bandicoots using blackberry) • Promote local champions (advertise/educate/knowledge sharing) • Establish knowledge network for connectivity centred on relevant individuals • Undertake surveys focused on understanding home ranges, key links for dispersal etc for Cardinia’s species • Develop guidelines for appropriate fauna friendly fence designs • Prioritise areas for engagement with landowners • Look at rural land program in Yarra Valley for guidance. • Reduce chemical use through native plant companion plantings • Focus on life form revegetation for habitat rather than species specific i.e. overstorey, mid, low, groundcover. • Fence all key waterway corridors 	<ul style="list-style-type: none"> • Farm productivity workshops - horse health, fencing • Promote regenerative agriculture • Engage with school groups • Incorporate biolink into planning scheme • Leverage MW corridors and stream frontage grants for private landowners for connectivity improvements • Undertake environmental audit of Cardinia Reservoir • Provide guidance on multi-purpose linkage designs that provide commercial and conservation opportunities • Support private land initiatives • Engage fire management planning committee to determine evidence-based risk or lack of associated with corridors (Dianne from Bass Coast) • Improve active/passive reserves to provide biolink • Incentivise conservation investment through rate reduction • Pet registration - extra \$10 for habitat preservation/species protection • Roadsides - bottom panel needs redesigning for wombats and echidnas • Communicate the economic value of ecosystem services and iconic species/flagship species • Actively foster friends and Landcare groups as medium to engage with the broader community • Develop multi-faceted models

Indicator species

Native fauna species have varying habitat requirements and levels of tolerance to land use change, with increased pressure on peri-urban and rural environments across the Shire of Cardinia expected in future years. To ensure future conservation efforts are effective we are seeking input for the selection of fauna 'indicator' species suitable for informing future conservation and connectivity planning and monitoring.

Criteria

Workshop participants ranked species from high (3) to low (1) for their suitability as indicator species based on the criteria in Table C7.

Table C7. Indicator species criteria

Criteria	Description
Fauna group	Select a range of species representative of different faunal groups, habitat types, functional roles etc.
Conservation significance	Select species with a variety of conservation status based on listing at a local/shire, regional, state or national level.
Abundance	Select a range of species that are both rare and common within the shire.
Tolerance to disturbance / urban environments	Select a range of species so as to have both high and low tolerance to disturbance and urban settings.
Structural habitat requirements	Select species that utilise different habitat features or structures.
Range and patch size requirements	Select a range of species that represent both large and small patch size / home range requirements.
Connectivity requirements	Select a range of species with different dispersal abilities (e.g. inter-patch movement and gap crossing thresholds).
Ease and efficacy of survey	Identify some species that are easy to survey and monitor.
Opportunities for future collaboration	Select species which can be used as a focus of future engagement, education or collaboration.

Species selection

The results of this exercise are presented in Table C8, with an overall rank assigned based on an average across the eight workshop groups. Species in Table C9 are those added by participants and therefore will not have been ranked by all groups.

Table C8. Species Selection

Species	G1	G2	G3	G4	G5	G6	G7	G8	Ranking
Growling grass frog (<i>litoria raniformis</i>)	3	3	3	3	3	3	1	3	2.75
Powerful owl (<i>ninox strenua</i>)	3	2	3	3	3	3	2	3	2.75
Southern brown bandicoot (<i>isoodon obesulus obesulus</i>)	3	3	3	3	3	3	1	3	2.75
Platypus (<i>ornithorhynchus anatinus</i>)	2	3	3	3	3	3	3	1	2.625
Southern greater glider (<i>petauroides volans</i>)	2	3	3	3	1	3	3	1	2.375
Superb lyrebird (<i>menura novaehollandiae</i>)	2	2	2	3	1	3	3	3	2.375
Blue-tongued lizard (<i>tiliqua scincoides</i>)	3	3	1	3	1	2	2	3	2.25
Eastern yellow robin (<i>eopsaltria australis</i>)	3	3	1	3	1	3	3	1	2.25
Lace monitor (<i>varanus varius</i>)	2	3	3	2	2	3	2	1	2.25
Chocolate wattled bat (<i>chalinolobus morio</i>)	2	2	3	3	1	3	2	1	2.125
Superb fairy wren (<i>malurus cyaneus</i>)	3	2	3	2	3	2	1	1	2.125
Swamp skink (<i>lissolepis coventryi</i>)	2	2	2	3	3	3	1	1	2.125
Agile antechinus (<i>antechinus agilis</i>)	3	3	1	1	2	2	3	1	2
Swamp wallaby (<i>wallabia bicolor</i>)	3	2	2	2	2	3	1	1	2
Eastern pygmy possum (<i>cercartetus nanus</i>)	1	3	1	1	3	3	2	1	1.875
Gould's wattled bat (<i>chalinolobus gouldii</i>)	2	3	1	1	2	3	2	1	1.875
Grey shrike-thrush (<i>colluricincla harmonica</i>)	3	3	1	1	1	2	3	1	1.875
Short-beaked echidna (<i>tachyglossus aculeatus</i>)	3	1	3	1	1	2	1	3	1.875
Eastern spinebill (<i>acanthorhynchus tenuirostris</i>)	3	2	2	1	1	2	2	1	1.75
Gang-gang cockatoo (<i>callocephalon fimbriatum</i>)	2	1	2	2	2	3	1	1	1.75
Golden whistler (<i>pachycephala pectoralis</i>)	2	2	1	1	1	3	2	1	1.625
Metallic skink (<i>niveoscincus metallicus</i>)	2	2	1	1	2	3	1	1	1.625
New holland honeyeater (<i>phylidonyris novaehollandiae</i>)	2	1	1	1	2	3	2	1	1.625
Scarlet robin (<i>petroica boodang</i>)	2	2	2	1	1	3	1	1	1.625

Species	G1	G2	G3	G4	G5	G6	G7	G8	Ranking
Blue-winged parrot (<i>neophema chrysostoma</i>)	1	1	1	1	3	3	1	1	1.5
Rufous whistler (<i>pachycephala rufiventris</i>)	2	1	2	1	1	3	1	1	1.5
Southern toadlet (<i>pseudophryne semimarmorata</i>)	1	2	1	2	1	2	1	1	1.375
Common eastern froglet (<i>crinia signifera</i>)	1	1	1	1	1	3	1	1	1.25

Table C9. Other candidates

<ul style="list-style-type: none"> • Azyre Kingfisher • Black Fish • Common Wombat • Dwarf Galaxias • Eastern Curlew • Helmeted Honey-eater • King Parrot • Kookaburra 	<ul style="list-style-type: none"> • Lathams Snipe • Lowland Lead-beater Possum • Spiny Crayfish • Spotted Marsh Frog • Sugar Glider • Tiger Snake • Whip Bird • White-throated Tree Creeper
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Questionnaire responses

Organisational objectives or goals

Please briefly outline your organisations objectives or goals with respect to biodiversity conservation?

- Weed control
- Protection, revegetation and management of Indigenous plants
- Educating local communities and raising awareness
- Working with local authorities and landowners
- Waterways management and protection
- Protection of remnant bush on private land
- Enhance and protect biodiversity.

Does your organisation currently have any objectives or goals to improve habitat connectivity within the Shire of Cardinia or the south-east region?

- Weed control on council and private land;
- Revegetation along creeks and roads;
- Waterways and wetland protection and management;
- Inter-organizational cooperation; and
- Education of local communities.

With regards to habitat connectivity, what do you believe should be the priority within the Shire of Cardinia?

- Conservation and protection of existing habitats;
- Protect and enhance waterways, farming fences should no longer be able to be built directly up to creek edge;
- More corridor links, within and outside of Shire;
- Roadside protection (decrease road speeds, animal signs etc.);
- Community education; and
- Weed control on all roads.

Connectivity

Do you manage any significant corridors or areas of native vegetation or waterways that are important for fauna movement?

Table C10. Significant corridors or areas of native vegetation

Location	Description of values
Trust for Nature Reserve (Harbury)	Bush corridor continuing south along Bessie Creek, coming from the Bunyip State Park and bushland from the north.
Bayles Reserves	Forms stepping-stones and habitat patches connected to the Yallock Drain and Barrow Pit Drain.
Cannibal Creek catchment	Retains areas of connected high value habitat patches.
Cardinia Creek catchment	North of Princes Highway, this catchment retains extensive corridors of riparian vegetation linking a series of conservation reserves. Potential for lateral connectivity across jurisdictions and to different habitat features.
Emerald Lake Park	Large section of significant native vegetation (relatively free of weeds) and is also a western forest section that is being returned slowly to native forest. Large tree ferns in a gully, Powerful Owl feeding and roosting area, links to Wright Forest where they nest.

How and why could habitat connectivity be improved across Cardinia Shire?

Table C11. Connectivity improvements

How	Benefits	Example location (if possible)
Revegetation of indigenous/native trees and shrubs	Improves corridors	
Enforcement of current laws (i.e. clearing of vegetation laws)	Prevent the clearing of native vegetation when it is not related to bushfire management	Private land
Cooperation with local community and authorities	Encourage and incentivize community to improve on habitat as either corridor, stepping stone or sources/sink patches	Private land
Retention of scattered trees and native vegetation	Scattered trees create stepping stones for fauna. Native vegetation and scattered trees form connectivity.	Private land
Responsible pet ownership	Promote within communities to raise awareness of the impacts on native habitats/species.	
Removal of old fences with bushes/shrubs	Allows the movement of native animals more freely	
Weed removal/control on all properties	To allow for indigenous species to spread	Creek edges & roadsides, private and public land, Emerald Beaconsfield road (particularly for Sweet Pittosporum)

Which areas in the Cardinia Shire, other than Bunyip State Park and Western Port, do you think are important biodiversity assets?

- All waterways;
- All public land and remnant vegetation;
- Reserves and Corridors;
- Cardinia Reservoir; and
- Mt Cannibal and Cannibal Creek Reserve.

Q: What actions are you, or a group that you know of, undertaking to improve connectivity for fauna?

- Revegetation along creeks and rivers;
- Weed control;
- Community education; and
- Pest surveys and control.

Q: How does the current knowledge of connectivity in the Cardinia Shire assist or restrict your ability to manage species for conservation?

- Assisting:
 - Council cooperation
 - Cooperation with Indigenous groups within the shire
- Restricting:
 - Regular meetings (bi-annual) are needed to keep everyone up to date;
 - No overall plan;
 - Not enough available land for retaining, restoring, regenerating;
 - Community awareness and knowledge;
 - Limited connectivity;
 - Knowledge gaps; and
 - Irresponsible pet ownership.

Indicator species

Which fauna species have you noticed decline over the last 10 years within Cardinia Shire? Which have become more abundant?

- Declined:
 - southern brown bandicoot, southern toadlet, waderbirds, brush-tailed possums, golden whistlers, rufous whistlers, platypus, woodland bird species
- Increase:
 - common myna, noisy minor, kangaroos, rainbow lorikeet, bell miner, little wattlebird, sulphur-crested cockatoos
 - anecdotal evidence suggests lace monitor, greater glider

Which common species might be impacted by increased urbanization within the Cardinia Shire?

- | | |
|-------------------------|--|
| • Wombats | • Platypus |
| • Echidnas | • Antechinus |
| • Swamp Wallaby | • Ring-tailed Possum |
| • Eastern Grey Kangaroo | • Eastern Yellow Robin |
| • Native Rats | • Hollow dependant species – owls, parrots, bats |
| • Bandicoots | • Lace Monitors |
| • Black Wallabies | |

Please list areas within Cardinia Shire that support a good diversity of fauna groups, excluding Bunyip State Park and Western Port?

Table C12. Biodiversity hotspots

Location	Associated features
Mt Cannibal	Large diversity of small native plants and easy access to permanent water
Cannibal Creek Reserve	Diverse vegetation and permanent flow (even through drought)
Chambers Reserve	Large amount of vegetation diversity
Toomuc Creek Reserve	Large amount of vegetation diversity (upper story to groundcover)
Emerald Lake Park	Large amount of vegetation diversity, two lakes and associated tributaries, large diversity of fauna (diverse bird population, frogs, mammals etc.)
Wright Forest	Large amount of vegetation diversity, large eucalypts, some old with hollows present.

Q: The following criteria have been proposed to develop a list of 15 indicator species for Cardinia Shire. Please advise other potential criteria or changes to those listed.

The list will contain a variety of different species based on:

- faunal grouping
- conservation significance
- abundance (e.g. widespread, localised, not recently recorded)
- tolerance to disturbance and/or urban environments
- structural habitat requirements (e.g. trees, shrubs, grasslands etc)
- range and patch size requirements
- connectivity requirements (e.g. dispersal distance, gap crossing thresholds, stepping-stones)
- efficacy of survey (e.g. repeatable, cost-effective)
- opportunities for future Council/community collaboration

No changes required.

Q: Council and Eco Logical Australia have prepared a preliminary list of indicator species based on the criteria listed above. Please rank the species you believe would benefit from efforts to improve connectivity.

Table C13. Preliminary indicator species ranking

Species	Great benefit	Somewhat benefit	Very little benefit
Agile antechinus (antechinus agilis)	✓		
Blue-tongued lizard (tiliqua scincoides)		✓	
Blue-winged parrot (neophema chrysostoma)	✓		
Chocolate wattled bat (chalinolobus morio)	✓		
Common eastern froglet (crinia signifera)		✓	

Species	Great benefit	Somewhat benefit	Very little benefit
Eastern pygmy possum (<i>Cercartetus nanus</i>)	✓		
Eastern spinebill (<i>Acanthorhynchus tenuirostris</i>)	✓		
Eastern yellow robin (<i>Eopsaltria australis</i>)	✓		
Gang-gang cockatoo (<i>Callocephalon fimbriatum</i>)		✓	
Golden whistler (<i>Pachycephala pectoralis</i>)	✓		
Gould's wattled bat (<i>Chalinolobus gouldii</i>)	✓		
Grey shrike-thrush (<i>Colluricincla harmonica</i>)	✓		
Growling grass frog (<i>Litoria raniformis</i>)	✓		
King parrot (<i>Alisterus scapularis</i>)		✓	
Lace monitor (<i>Varanus varius</i>)	✓		
Metallic skink (<i>Niveoscincus metallicus</i>)	✓		
New holland honeyeater (<i>Phylidonyris novaehollandiae</i>)	✓		
Platypus (<i>Ornithorhynchus anatinus</i>)	✓		
Powerful owl (<i>Ninox strenua</i>)	✓		
Rufous whistler (<i>Pachycephala rufiventris</i>)	✓		
Scarlet robin (<i>Petroica boodang</i>)	✓		
Short-beaked echidna (<i>Tachyglossus aculeatus</i>)	✓		
Southern brown bandicoot (<i>Isodon obesulus obesulus</i>)	✓		
Southern greater glider (<i>Petauroides volans</i>)	✓		
Southern toadlet (<i>Pseudophryne semimarmorata</i>)	✓		
Superb fairy wren (<i>Malurus cyaneus</i>)	✓		
Superb lyrebird (<i>Menura novaehollandiae</i>)	✓		
Swamp skink (<i>Lissolepis coventryi</i>)	✓		
Swamp wallaby (<i>Wallabia bicolor</i>)	✓		
Please list any additional species you believe would be a suitable candidate based on the criteria listed.	kookaburra, wombat, koala, long-nosed bandicoot, emu wren, helmeted honeyeater, wader birds, brush-tailed possum, eastern curlew, latham's snipe, azure kingfisher, bronzewing, painted button-quail, white's thrush		

Appendix D. Indicator species standards

Growling grass frog (*Litoria raniformis*)

Habitat

The EPBC Act listed growling grass frog depends on a mix of aquatic and terrestrial habitat for breeding, foraging, shelter and dispersal, and are typically found in areas with both permanent and semi-permanent waterbodies with still or slow-moving water (Department of Environment and Energy 2009). Optimal habitat includes emergent vegetation around the edges of waterbodies, mats of floating and submerged plants, salinity less than 10 mS/cm, minimal shading from trees and terrestrial vegetation such as grasses, rocks, logs and debris surrounding the waterbodies to provide essential over-wintering habitat (Department of Environment and Energy 2009, SWIFFT 2020). However, they are also known to occur at less favourable sites such as in ditches, dams, irrigation channels and disused quarries (SWIFFT 2020).

Habitat and structural connectivity requirements

Key habitat requirements include permanent and ephemeral wetlands or waterways, adjacent areas for basking (rocks and bare ground), floating/submerged vegetation, sunny and good water quality. Support for known meta-populations by establishing connected habitat dispersal routes is critical to for species survival. Clustered wetlands around known populations provides key connectivity between sites. Wetland requirements for suitable habitat include (DELWP, 2017);

- design of wetland clusters to best practise standards which will facilitate species breeding and movement
- wetland area of approximately 3,000 m² to provide at least 0.1 hectares of deep (greater than 1.5 metres) water over the long term. where possible at least one wetland a cluster should be large.
- water supply to meet breeding requirements, ideally water levels should draw down over late summer and autumn to support healthy ecological processes in the littoral zones.
- predator control
- provision of deep water to provide for a diversity of terrestrial, riparian, semi-aquatic and aquatic vegetation (Ecology Partners, 2010). Dense submergent vegetation is critical (DELWP, 2017).
- provision of drainage infrastructure to manage wetland hydrology
- management of predatory fish
- anti-chytrid attributes: wherever feasible, rock piles should be place around the perimeter to warm the shallow waters to assist Growling Grass Frogs combat chytrid fungus infection.
- terrestrial habitat: shading of GGF wetland should be avoided especially in the areas designed for warm anti-chytrid properties. Short vegetation with an open structure is preferred; any shrub and tree planting should be sparse and mulch should not be used within 50 metres of the wetlands.

Breeding

During breeding season male frogs call between November and March, with the peak calling period between November and December. Breeding sites usually contain a mix of emergent vegetation such as *Typha sp.*, *Phragmites sp.*, *Scheonoplectus sp.*, *Eleocharis sp.*, *Rumex sp.*; submergent vegetation *Potamogeton sp* and *Chara sp.*; floating species *Triglochin sp*, *Azolla sp.*, *Lemna sp.* and filamentous algae (Heard, Robertson and Scroggie 2004; Heard, Robertson and Scroggie 2008 and Hamer and Organ 2008). Aquatic vegetation, particularly submergent provides a platform for male frogs to call from, for females to deposit eggs where they can develop with access to abundant food, shelter and provide protection for tadpoles from predators (Heard, Robertson and Scroggie 2004).

Connectivity between clusters of suitable waterbodies is essential to promote movement between breeding sites to maintain genetic diversity and promote recolonisation following local extinction (Department of Environment and Energy 2009). Although Growling Grass Frog are a highly mobile

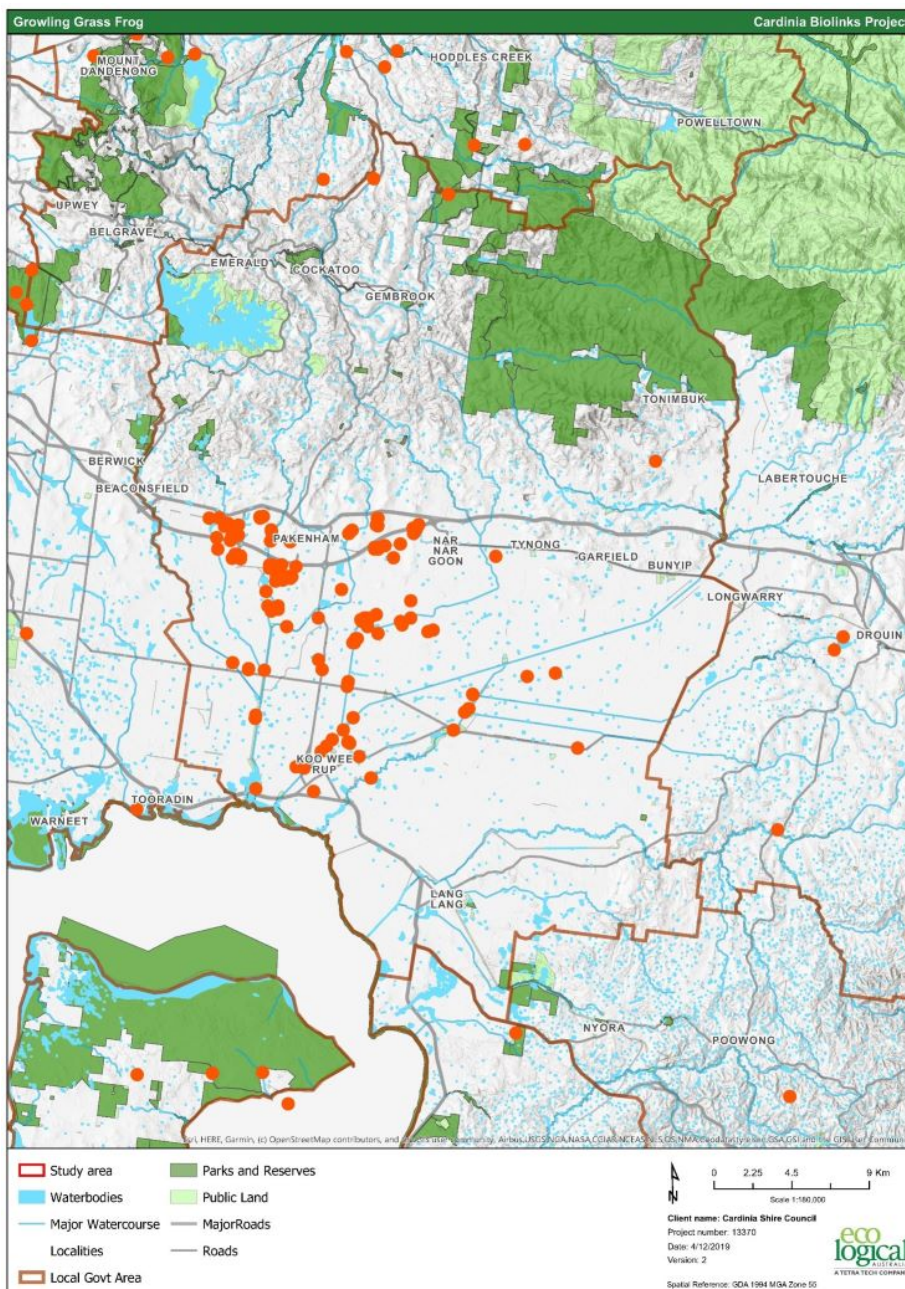
species, moving up to 1 km per night usually after periods of rainfall, occupancy of suitable waterbodies is greater when located < 200 m apart (Hamer and Organ 2008; SWIFFT 2020).

Distribution and key populations in Cardinia Shire

Growling grass frog distribution within Cardinia Shire is primarily clustered around the townships of Pakenham, Nar Nar Goon and Koo Weep Rup within the Gippsland Plain Bioregion. Scattered populations are present within the surrounding areas and as shown in Figure D1.

The *Biodiversity Conservation Strategy for Melbourne’s Growth Corridors* sets out the conservation measures required for Victoria under the *Melbourne Strategic Assessment (MSA) Program*. Actions identified within the *Growling Grass Frog Masterplan* identify investment areas of strategic importance for the species along reaches of creek line south of Pakenham Bypass along the Cardinia Creek, Gum Scrub Creek, Toomuc Creek and the creek waterway east of Toomuc Creek. This includes the creation of new habitat and protection of existing habitat.

Figure D1. Growling grass frog population distribution across Cardinia Shire



Threats to population

Principal threats to growling grass frogs are habitat loss and degradation such as changes in hydrological regime, displacement by development, infection with Chytrid fungus, removal of aquatic and terrestrial vegetation, barriers to dispersal such as sealed roads, fallen logs and debris which provide over-wintering habitat, damage to banks by trampling caused by stock and predation of eggs and larvae by introduced fish such as mosquito fish (*Gambusia affinis*) (Department of Environment and Energy 2009).

Recommended conservation management

- Protect and maintain wetlands with extant populations.
- Identify breeding sites across Cardinia Shire and create a list of priority sites where connectivity needs improvement.
- Improve connectivity between extant populations by adding wetlands < 200m apart from breeding sites. This will increase population size and reduced local extinction. Focus on areas at low elevations where climatic conditions are less conducive to the effects of chytrid fungus compared to higher elevations (Heard, Robertson and Scroggie 2004). If the creation of new wetlands is not cost effective, rehabilitation of degraded wetlands near breeding sites may improve connectivity for this species and decrease the extinction risk.
- Increase cover of emergent, submergent and floating aquatic vegetation at wetlands and dams.
- Control invasive aquatic vegetation such as common reed (*Phragmites australis*) and spiny rush (*Juncus acuta*).
- Ensure overwintering habitat such as rocks and logs are available in the adjacent terrestrial habitat.
- Consider impacts caused by urban development in the planning stage on hydrology and movement corridors such as drainage and creek lines.
- Enhance wetland function by increasing inflow and reducing outflow of water. This could be achieved by; creating new drainage lines, capture of stormwater and enhancing wetland depth (Heard, Scroggie and Clemann 2010).
- Monitor water quality and flow rate.
- Undertake control actions of introduced predatory fish such as gambusia at wetlands which may have otherwise provided suitable habitat for growling grass frog.
- Encourage landowners with extant populations to limit access to the dams or wetlands by stock through exclusion fencing to limit trampling and overgrazing.
- Liaise with landowners to improve habitat for growling grass frog on their land by encouraging planting of emergent, submergent and floating vegetation in dams within their property.

Key references

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Powerful owl (*Ninox stenua*)

Habitat

The FFG Act listed powerful owl is a forest dwelling bird that favours the drier forests in Victoria which contain a high number of mature, live hollow bearing eucalypts with a diverse understory containing species such as blackwood wattle (*Acacia melanoxydon*) (Loyn et al 2002). Powerful owl prefer foothill forests containing a mix of canopy species but can also be found in wet forests with sheltered dense gullies, along well vegetated watercourses and open areas adjacent to forests including farmland, parks and remnant bushland (Emison et al. 1987, Loyn et al. 2001, 2002, 2004).

Habitat and structural connectivity requirements

Woodland and forest habitat with large hollow bearing trees, and adequate canopy vegetation to prevent exposure of nesting sites are key habitat and structural requirements. Well vegetated waterways provide key connectivity between habitat areas.

Breeding

Breeding occurs between monogamous pairs during Autumn and Winter, with peak breeding in June (SWIFFT 2020). Nest sites are located high up in live eucalypts in hollows large enough to support the female and two offspring (Newton et al. 2002). Nearby roost trees (< 50 m) are commonly native *Eucalyptus*, *Acacia* and *Leptospermum* (Newton et al. 2002). The home range of powerful owl varies considerably, between 300 Ha and 4770 Ha, and is dependent on habitat quality and prey abundance, primarily Ringtail Possum (McNabb 1996 and Sonderquist et al. 2002).

Distribution and key populations in Cardinia Shire

Figure D2 shows that within Cardinia Shire, the powerful owl is found primarily in the north, where there are more areas of remnant bushland including, Beaconsfield Flora and Fauna Reserve, Mount Cannibal, Weatherhead Reserve and a private Trust for Nature property, however they may utilise more open farmland for foraging.

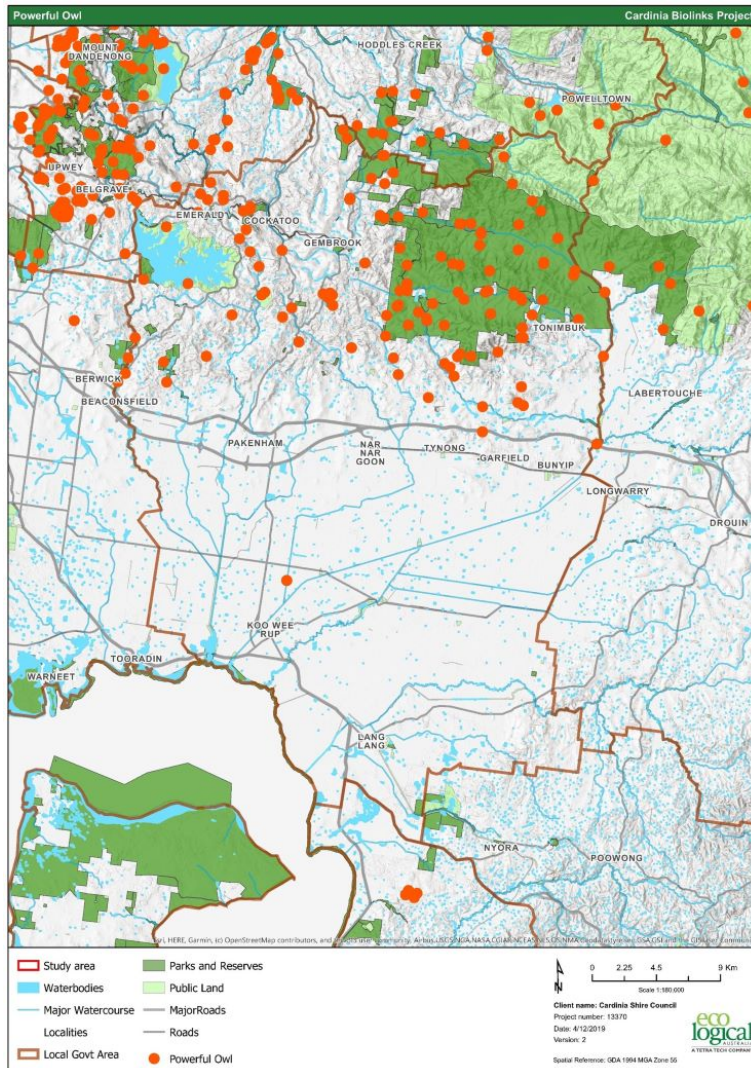
Threats to population

Principal threats to powerful owl are predation of juveniles by European red fox and feral cats and land clearance which reduces the availability of tree hollows for nesting, abundance of prey and habitat quality through the loss of protective canopy vegetation.

Recommended conservation management

- Maintain riparian corridors and foraging habitat
- Encourage private landholders to maintain habitat for powerful owl on their property such as large old trees and dense understory.
- Identify key areas of powerful owl habitat for preservation.
- Consider impacts to powerful owl habitat during the planning stage.

Figure D2. Powerful owl population distribution across Cardinia Shire



Key references

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Loyn, R., McNabb, E., Volodina, I. and Willig, R. 2002. Modelling distributions of large forest owls as a conservation tool in forest management: a case study from Victoria, southeastern Australia. *Ecology and Conservation of Owls Eds.*

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Soderquist, T.R., Lowe, K.W., Loyn, R.H. and Price, R. 2002. Habitat quality in Powerful Owl (*Ninox strenua*) territories in the Box-Ironbark forests of Victoria. *Ecology and Conservation of Owls Eds.* CSIRO Publishing.

Southern brown bandicoot (*Isoodon obesulus obesulus*)

Habitat

The EPBC Act listed southern brown bandicoot inhabits a variety of habitats including heathland, shrubland, sedgeland, heathy open forest and woodland primarily on sandy soils (Menkhorst and Seebeck 1990; Paull 1995; Van Dyck and Strahan 2008). Vegetation structure is an important factor for Southern Brown Bandicoot, with ideal habitat comprising dense cover of native or exotic vegetation approximately 50 - 80 percent foliage density, up to 1 m tall (Paull 1995; Sanderson and Kraehenbuehl 2006; DoEE 2020). In areas where land clearance is high, exotic plant species such as blackberry (*Rubus fruticosus*) become an important habitat resource, particularly around waterways, drainage lines and roadsides by providing refuge from predators (Quin 1985; Paull 1995; Sanderson and Kraehenbuehl 2006). Due to the fire prone habitat that Southern Brown Bandicoot occupies, habitat with a mosaic of Eucalypt age classes is recommended to maintain stable populations (DoEE 2020).

Habitat and structural connectivity requirements

Key habitat and structural connectivity requirements include continuous dense ground cover (can be native or exotic such as blackberry (*Rubus fruticosus*), with adjacent open areas for foraging and a mosaic of eucalypt age classes (habitat).

Breeding

In Victoria, southern brown bandicoot breeding predictable and seasonal, usually between late winter and early summer, coinciding with peak food abundance (Cockburn 1990; Lobert and Lee 1990). Home range varies between sexes with males requiring 5-20 Ha, and females 2-3 Ha.

Distribution and key populations in Cardinia Shire

Distribution of southern brown bandicoot in Cardinia Shire, as shown in Figure D3, is primarily in the south and urban growth areas. Known populations in the area include Koo Wee Rup Swamp, Pakenham railway line corridor, townships of Garfield – Longwarry and Melbourne Water drains.

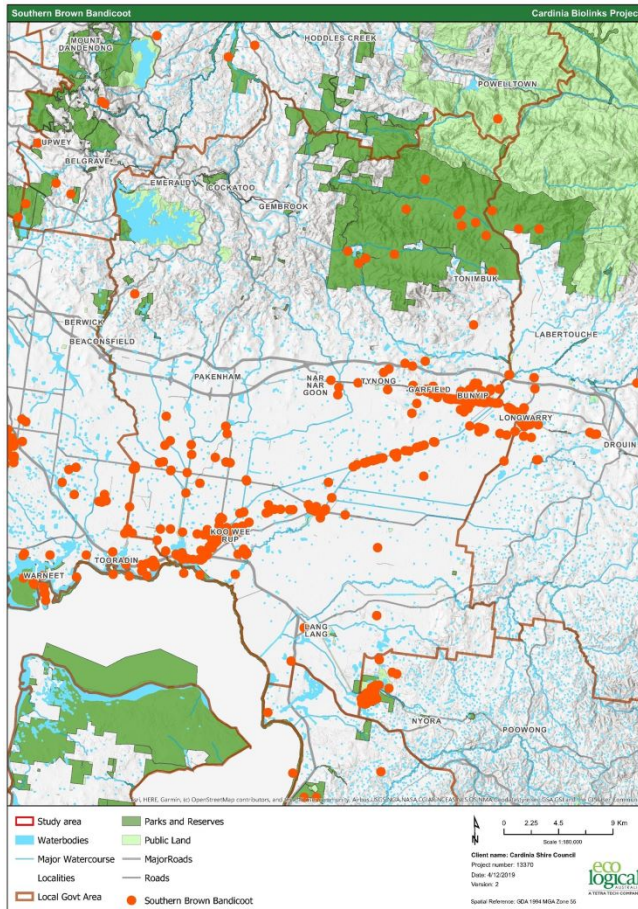
Threats to population

Principal threats to southern brown bandicoot landscape clearing, particularly the loss of continuous dense ground cover, predation by feral cats and European red fox.

Recommended conservation management

- Maintain habitat and improve connectivity for known populations.
- Consider fire regime and conservation of mature eucalypts.
- Monitor weed control in the shire to ensure retention of key habitat (blackberry).

Figure D3. Southern brown bandicoot population distribution across Cardinia Shire



Key references

- Cockburn, A. 1990. Life history of the bandicoots: developmental rigidity and phenotypic plasticity. 'Bandicoots and Bilbies'. Ed by J.H. Seebeck, P.R. Brown, R.L. Wallis and C.M. Kemper. (Surrey Beatty and Sons: Sydney).
- DoEE 2020. Species Profile and Threats Database. *Isodon obesulus obesulus* – Southern Brown Bandicoot. Department of the Environment and Energy. Available: http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=68050 [20 January 2020].
- Lobert, B. and Lee A.K. 1990. Reproduction and Life History of *Isodon obesulus* in Victorian heathland. 'Bandicoots and Bilbies' (Eds. JH Seebeck, PR Brown, RL Wallis, CM Kemper) (Surrey Beatty and Sons, Sydney).
- Menkhorst, P.W. and Seebeck, J.H. 1995. In: Mammals of Victoria, Distribution, ecology and conservation, Ed. Peter Menkhorst, Southern Brown Bandicoot. Oxford University Press.
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- Sanderson, K. J. and Kraehenbuehl, J. 2006. Southern Brown Bandicoots *Isodon obesulus obesulus* in Belair National Park. *Australian Mammalogy* 28:2, 147-152.
- Quin, D.G. 1985. Aspects of the feeding ecology of the bandicoots, *Perameles gunii* (Gray 1838) and *Isodon obesulus* (Shaw and Nodder 1797) (Marsupialia: Peramelidae) in southern Tasmania. BSc. Honours Thesis. (University of Tasmania).
- Van Dyck, S. and R. Strahan. 2008. *The Mammals of Australia, Third Edition*. Reed New Holland. pp 880.

Platypus (*Ornithorhynchus anatinus*)

Habitat

Platypus are a semi-aquatic monotreme that inhabits freshwater systems across eastern Australia ranging between Queensland's Anna River to the north and the far south of Victoria and Tasmania (Divljan 2019). Throughout this extent of occupancy, the platypus is found at all altitudes - associated with a range of temperatures - including the lowlands and plateaus of tropical rainforests and the cold, high altitudes of the Australian Alps and Tasmania (Divljan 2019). Waterbodies with coarse bottom substrates such as cobbles and gravel are a preferred habitat feature for the Platypus, which uses this feature for foraging (Divljan 2019). Additionally, earth banks covered by native vegetation also is ideal habitat for the species that facilitates construction of burrows in the banks that are protected and stable (Divljan 2019).

Habitat and structural connectivity requirements

Waterways and lakes lined with high quality riparian vegetation are a key structural habitat requirement for allowing connectivity of platypus populations.

Breeding

Platypus reaches reproductive maturity in their second year of life; although females will often be found not to reproduce until the fourth year of the 20-year platypus lifespan. With a variable breeding season across its extent of occupancy, platypus in Victoria typically breed between August to October, when males initiate breeding through courting females for varying durations repeated over several days. Following copulation, females undergo a 21-day gestation period prior to laying 1 - 3 eggs which they incubated for 10 days in pre-constructed nests within their burrows. After hatching, young are reliant on the mother for a 3 - 4-month lactation period before emerging from the burrow.

Distribution and key populations in Cardinia Shire

Figure D4 shows the distribution of the platypus in the Cardinia Shire predominantly occurs in the north west along major watercourses. Within Cardinia Shire, platypus have been recorded primarily in the north near Cardinia Reservoir, Cockatoo and Gembrook.

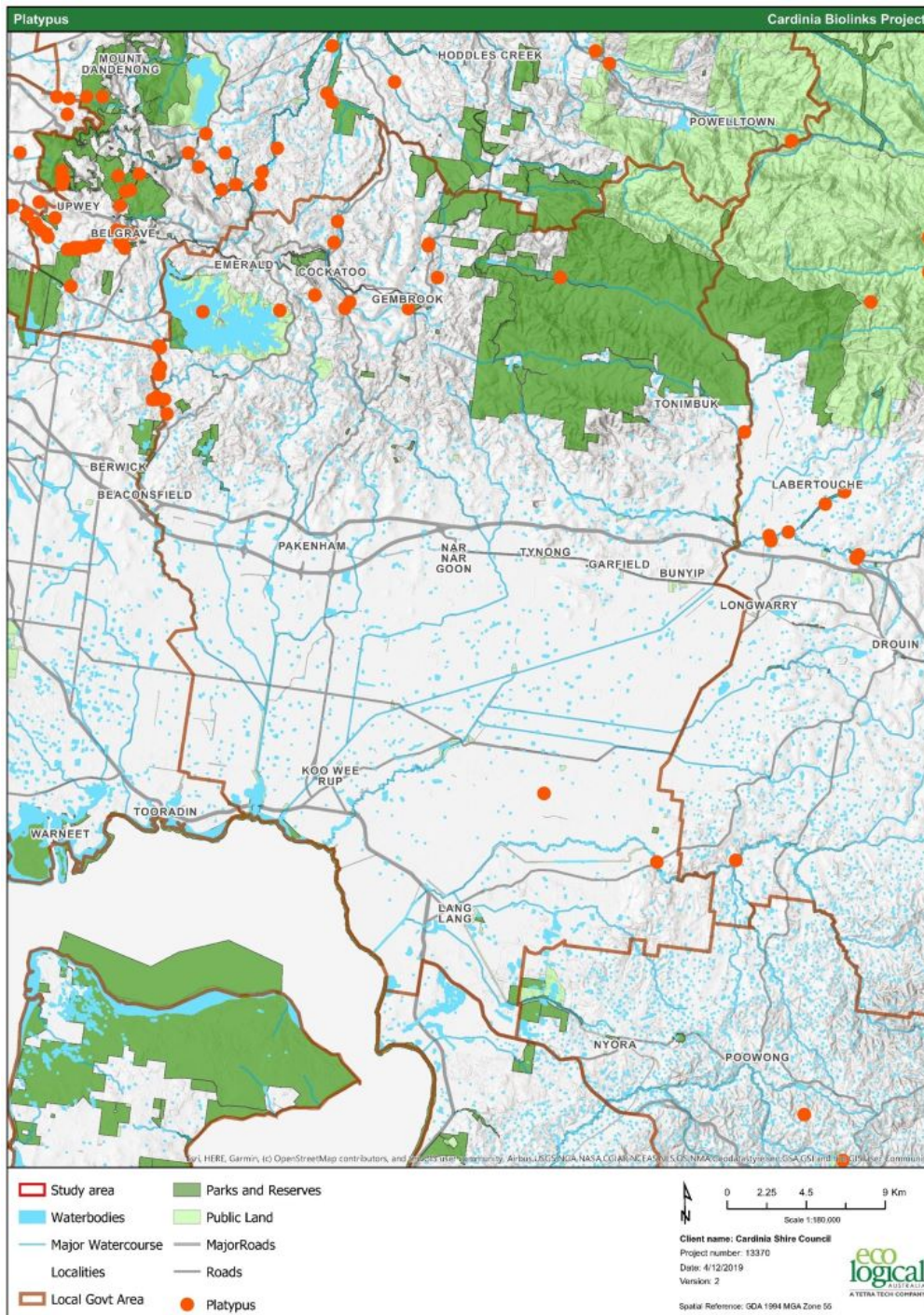
Threats to population

With very low tolerance to disturbance and ability to survive in urban environments, threats to populations of platypus include land clearance, predation by native and invasive species, reduced water quality, bank erosion, in-stream turbidity, barriers in streams, modification and straightening of waterways, off-target damage from fishing activities, and loss of stream biodiversity (APC n.d.; Divljan 2019).

Recommended conservation management

- Maintenance and restoration of bank and channel stability.
- Stormwater drainage management.
- Provision of woody habitat within streams.
- Maintenance of flow in water bodies that provide habitat.
- Refuge area provision during drought.
- Design of platypus-friendly habitat.
- Weed control and restoration of native riparian vegetation.
- Consideration of platypus and breeding season when planning works in areas adjacent to platypus habitat.
- Promotion of platypus conservation to the community.
- Conservation of threatened habitats.

Figure D4. Platypus population distribution across Cardinia Shire



Key references

Australian Platypus Conservancy (APC) (n.d.) *Ecology and Behaviour*, Australian Platypus Conservancy, Campbells Creek, Victoria. Available: <https://platypus.asn.au/ecology-behaviour/>. [5 February 2020].

Australian Platypus Conservancy (APC) (n.d.) *Platypus Management Guidelines*, Australian Platypus Conservancy, Campbells Creek, Victoria. Available: <https://platypus.asn.au/management-guidelines/>. [5 February 2020].

Divljan, A. 2019. *Platypus*. Australian Museum, Sydney. Available: <https://australianmuseum.net.au/learn/animals/mammals/platypus/>. [4 February 2020].

Southern greater glider (*Petauroides volans*)

Habitat

The EPBC Act listed southern greater glider is an arboreal marsupial with an extent of occupation spanning the Australian coast from Wombat State Forest in central Victoria through New South Wales to the Windsor Tableland in north Queensland. Across this extent it is largely restricted to eucalypt forests and woodlands. Preferring to reside in areas with taller, montane, moist eucalypt forests, with relatively old trees and abundant hollows. They reside in tree hollows during the day. Relatively small home ranges of 1 – 4 ha are typical but tend to be larger – reaching as large as 16 ha - in more productive low forests and more open woodlands (TSSC 2016; WPSQ n.d.).

Habitat and structural connectivity requirements

Structural habitat requirements of the southern greater glider to ensure connectivity between populations are contiguous corridors comprised of old, large hollow-bearing trees.

Breeding

Southern greater glider breeding season occurs between March and June with birth of a single young occurring between April and June. Young are only produced once per year, with offspring leaving the pouch after 3 – 4 months after which they spend 3 months between the nest or on the mother's back when the mother is not gliding. It is after 8 – 10 months that young become entirely independent, reaching sexual maturity in their second year and living for up to 15 years (WPSQ n.d.).

Distribution and key populations in Cardinia Shire

The southern greater glider is predominantly found distributed across the northern parts of the Cardinia Shire as shown in Figure D5. Known key populations in the area include Harbury TFN Property, Black Snake Range/Burgess Road Bunyip State Park, Weatherhead Range/Dingo Ridge Track Bunyip State Park, Black Snake Creek/Dyre Bunyip State Park, and Shepherds Creek Kurth Kiln.

Threats to population

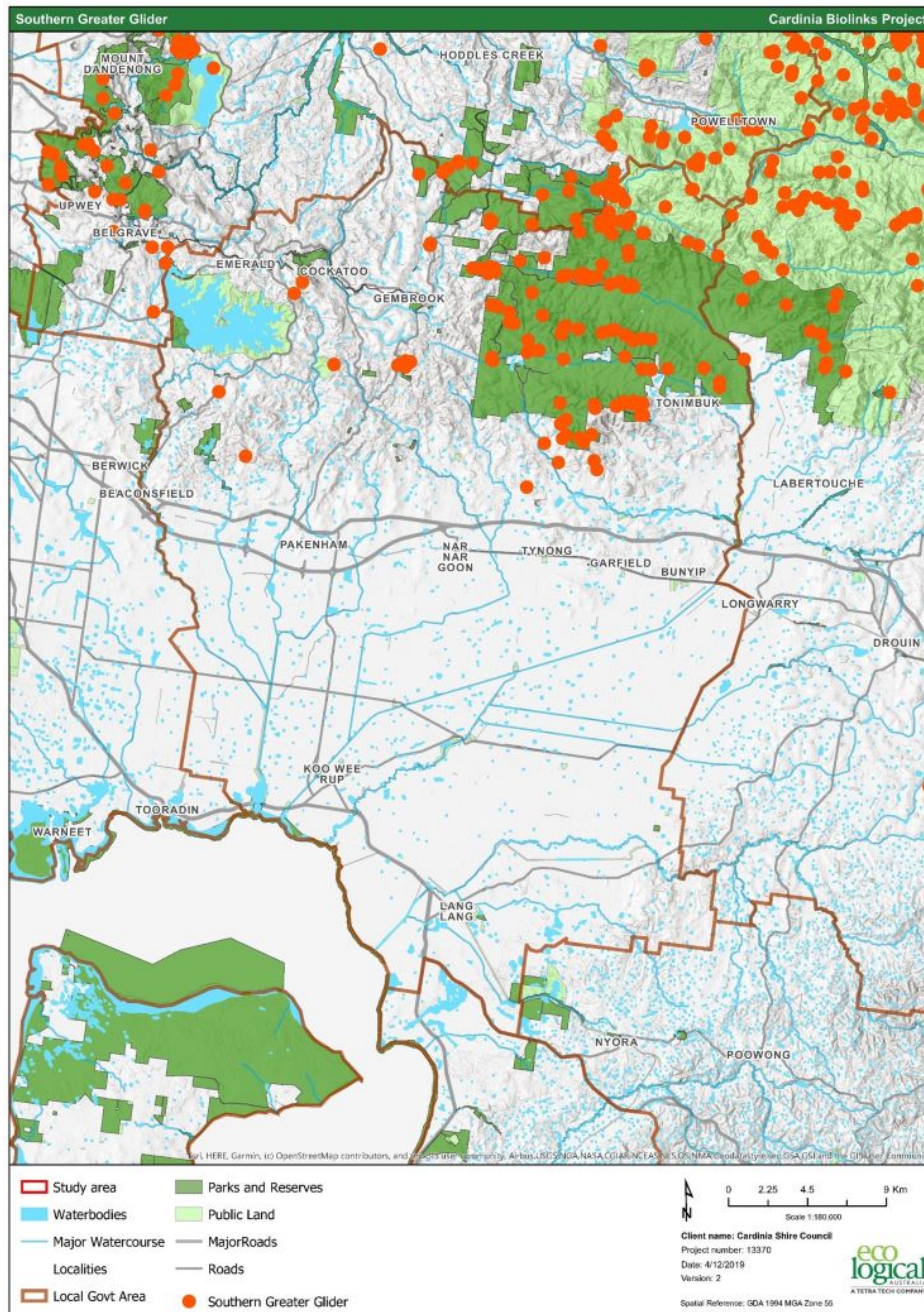
With very low tolerance of disturbance and urban environments, threats identified for the southern greater glider include logging, hyper-predation, high intensity and high frequency fires, barbed wire entanglement, competition for resources including hollows (particularly with sulphur-crested cockatoos), canopy loss resulting in heightened exposure to summer heat, and habitat loss and fragmentation. habitat loss and fragmentation is particularly relevant with regards to large, old, hollow-bearing trees and may be partially contributed to by the spread of phytophthora (TSSC 2016; WPSQ n.d.).

Recommended conservation management

- Installation of nest boxes
- Locking up domestic pets
- Removal of barbed wire fences
- Reduction of intensity and frequency of prescribed burns
- Consideration of the need for hollow-bearing tree retention, appropriate rotation cycles and retention of wildlife corridors between isolated patches when logging for hardwood production.
- Placement of constraints on forest clearance for areas with significant southern greater glider subpopulations to ensure retention of hollow-bearing trees and suitable habitat
- Development and upgrade of transport corridors to mitigation habitat loss and fragmentation
- Translocation of individuals to re-establish populations in suitable habitat
- Engaging the community to develop conservation covenants in areas of high conservation value for the species
- Conduct further research to gain a better understanding of the species' distribution, abundance and changes in these over time

- Conduct further research to gain a better understanding of the extent of impacts from threats to the species, efficacy of threat mitigation measures, the habitat requirements of the species and to aid in resolution of taxonomic uncertainties

Figure D5. Southern great glider population distribution across Cardinia Shire



Key references

Threatened Species Scientific Committee (TSSC). 2016. *Petauroides Volans (greater glider) Conservation Advice*, Department of Agriculture, Water and the Environment, Canberra. Available: <http://www.environment.gov.au/biodiversity/threatened/species/pubs/254-conservation-advice-20160525.pdf>. 5 February 2020.

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Superb lyrebird (*Menura novaehollandiae*)

Habitat

the superb lyrebird is a ground-dwelling species primarily found in rainforest and wet sclerophyll forests with a moist leaf litter layer, shaded by a tall mid and canopy layer (Menkhorst et al. 2017). When season conditions are favourable, dry sclerophyll forests, woodlands and scrublands may also be inhabited (Ashton and Bassett 1997). Using their powerful legs, superb lyrebirds forage for invertebrates in the leaf litter in open areas where the vegetation cover is low (< 30 cm tall), turning it over and burying the top layer (Maisey et al. 2019; Nugent et al. 2014). This accelerates the decomposition process, removing fire fuel load from the landscape and makes the superb lyrebird an important ecosystem engineer (Nugent et al. 2014). At night, birds roost high in trees and generally have a home-range of approximately 10 km in diameter (Menkhorst et al. 2017; Australian Museum 2018).

Habitat and structural connectivity requirements

Structural habitat and connectivity requirements for superb lyrebird are contiguous wet forest with a deep moist leaf litter and complex mid and high layer vegetation. Open areas with low vegetation is required for foraging.

Breeding

Male calls and displays from an approximately 1 m wide mound on the forest floor during Autumn and Winter (Menkhorst et al. 2017, Morcombe 2013). Timing of breeding is thought to coincide with leaf litter invertebrate abundance increasing due to winter rain (Morcombe and Stewart 2013). Nests are more likely to be sited near creeklines in wet forest or rainforest, where mid (1.5 – 2 m tall) and high (> 2 m tall) vegetation is more complex and the litter layer is deep (Maisey et al. 2019).

Distribution and key populations in Cardinia Shire

The superb lyrebird is found along the east coast of Australia from the border of Queensland and New South Wales down to Victoria, and in Tasmania. As shown in Figure D6, within Cardinia Shire, the superb lyrebird is found in the north, primarily in large areas of contiguous forest such as Bunyip State Park.

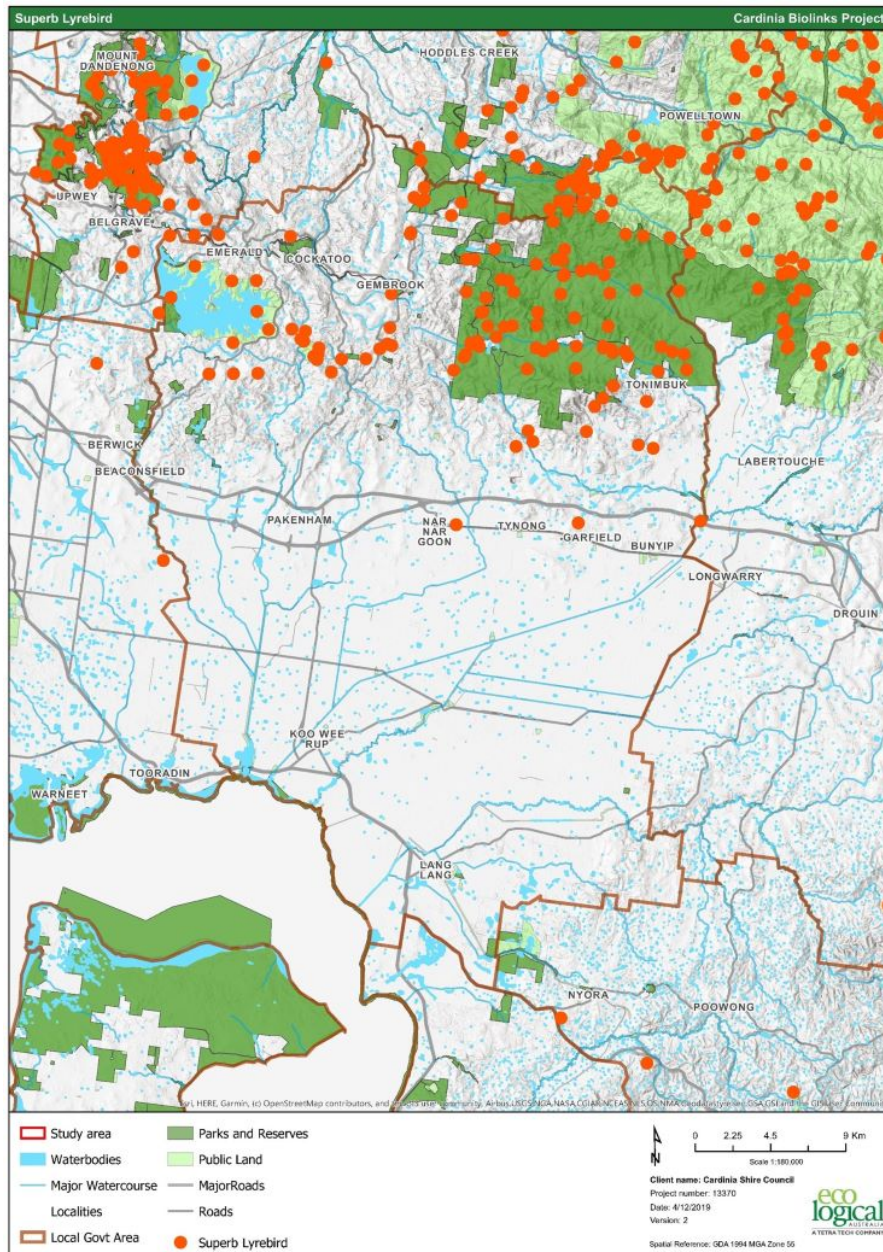
Threats to population

Principal threats to superb lyrebird are habitat loss associated with land clearing, introduced predators including European red fox and feral cat, inappropriate fire regimes.

Recommended conservation management

- Placement of constraints on forest clearance for areas with superb lyrebird populations.
- Consider fire regimes and the impacts of burns on superb lyrebird foraging. Unburnt and ground burnt sites support Superb Lyrebird foraging, canopy burnt sites do not (Nugent et al. 2014).
- Consider undertaking control methods for introduced predators and weeds.

Figure D6. Superb lyrebird population distribution across Cardinia Shire



Key references

Ashton, D.H. and Bassett, O.D. 1997. The effects of foraging by the superb lyrebird (*Menura novaehollandiae*) in *Eucalyptus regnans* forests at Beenak, Victoria. *Australian Journal of Ecology*, 22, 383- 394.

Australian Museum. 2018. Superb Lyrebird. Animal Factsheets. Available: <https://australianmuseum.net.au/learn/animals/birds/superb-lyrebird/>

Maisey et al. 2019. Habitat selection by the Superb Lyrebird (*Menura novaehollandiae*), an iconic ecosystem engineer in forests of south-eastern Australia. *Austral Ecology*, 44, 503-513.

Menkhorst et al. 2017. *The Australian Bird Guide*. CSIRO Publishing.

Morcombe, M. and Stewart, D. 2013. *The Morcombe & Stewart Guide to Birds of Australia. Mobile App*.

Nugent et al. 2014. Interactions between the superb lyrebird (*Menura novaehollandiae*) and fire in south-eastern Australia. *Wildlife Research*, 41, 203-211.

Blotched blue-tongued lizard (*Tiliqua nigrolutea*) and eastern blue-tongued lizard (*Tiliqua scincoides*)

Habitat

These diurnal ground dwelling lizard species occupy very similar habitats ranging from coastal heaths, wet and dry sclerophyll forests and woodlands (Cogger 2018). While there is much overlap in habitat for this species, eastern blue-tongued lizard is more often recorded in agricultural land and gardens than blotched blue-tongued lizard, which prefers wetter habitat and heathland (Dutson and Dutson 2016). Leaf litter, burrows and large objects on the ground such as rocks and logs provide shelter for these species at night (Australian Museum 2019).

Habitat and structural connectivity requirements

Structural habitat and connectivity requirements for blue-tongued lizards include contiguous woodland with tussock grasses, leaf litter, logs and rocks.

Breeding

Breeding occurs for most blue-tongued lizards between winter and early summer (Backyardbuddies 2020). Females give birth to live young rather than lay eggs (Backyardbuddies 2020).

Distribution and key populations in Cardinia Shire

Blotched blue-tongued lizards are distributed along the east side of New South Wales and Victoria; and all of Tasmania. Eastern blue-tongued lizards are distributed across northern and eastern Australia, excluding Tasmania. As shown in Figure D7, within Cardinia Shire, the actual distribution is relatively unknown as only scattered records exist and is unlikely to truly represent their range.

Threats to population

Principal threats to blue-tongued lizards include human interactions of an accidental nature such as mortality caused by mowing lawn, and predation by feral cat and domestic dogs.

Recommended conservation management

- Avoid removal of rocks, logs and leaf litter from woodlands and backyards.
- Avoid removal of woodland habitat and maintain corridors where this is not possible.
- Keep domestic pets inside or on leash.

Figure D7. Blue-tongue lizard population distribution across Cardinia Shire



Key references

Australian Museum. 2019. Animal Fact Sheet Blotched Blue-tongue Lizard. Available: <https://australianmuseum.net.au/learn/animals/reptiles/blotched-blue-tongue-lizard/>

Coggan, H.C. 2018. Reptiles and Amphibians of Australia. 7th edition. *CSIRO Publishing*. Melbourne.

Dutson, G. and Dutson, L. 2016. Microhabitat niche differentiation in sympatric eastern blue-tongued Lizard *Tiliqua scincoides* and blotched blue-tongued Lizard *Tiliqua nigrolutea* in Melbourne, Victoria. *The Victorian Naturalist*, Vol. 33:2.

Eastern yellow robin (*Eopsaltria australis*)

Habitat

Eastern yellow robins are found in a wide range of habitats, from dry woodlands to rainforests (Menkhorst et al. 2017). They are also common in parks and gardens; and are usually first seen perched on the side of a tree trunk or other low perch (Menkhorst et al. 2017). eastern yellow robin is a ground-foraging insectivore like the brown treecreeper, but the species is an open-cup nester and uses a sit-and-wait foraging strategy, so it is more dependent on a shrubby understorey or sub-canopy layer to provide perching and nesting sites (Debus 2006). Eastern yellow robins are also sedentary, maintain territories of 5–6 ha, and may occasionally live in cooperatively breeding groups formed through the retention of male offspring from previous breeding seasons (Higgins and Peter 2002; Debus 2006). Thus, natal dispersal movements are usually initiated soon after reaching independence sometime in November, but males may occasionally wait to initiate dispersal until a subsequent spring (Debus 2006).

Habitat and structural connectivity requirements

Habitat and structural connectivity requirements for eastern yellow robin areas of contiguous woodland with a tall shrub layer, sparse ground cover and vertical stems for perching.

Breeding

Breeding occurs between July – January in cup style nests made from fine bark and grass.

Distribution and key populations in Cardinia Shire

Eastern yellow robins are distributed along coastal and adjacent inland areas in south-east Australia. As shown in Figure D8, within Cardinia Shire, they are found quite widely distributed across the north.

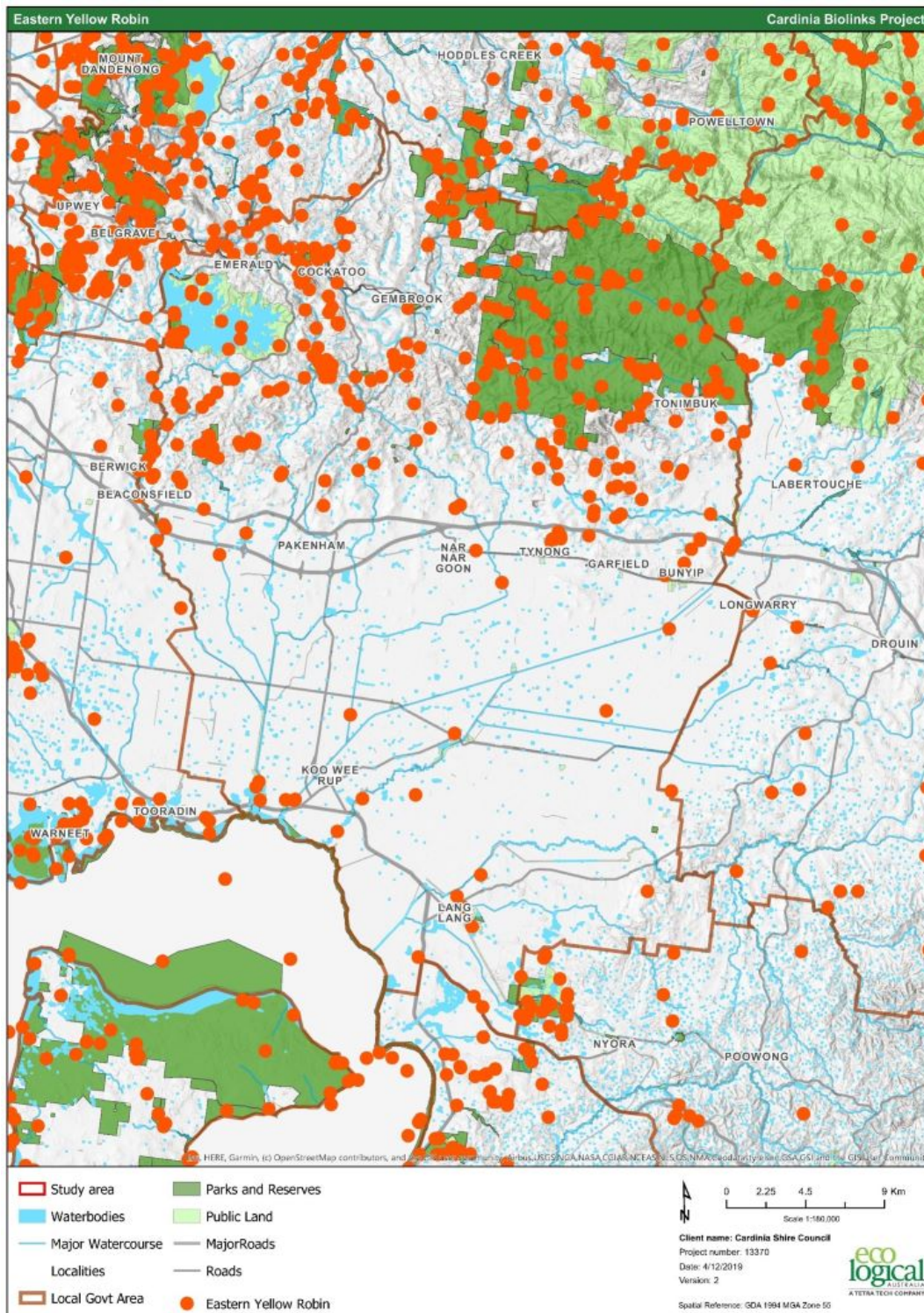
Threats to population

Principle threats to eastern yellow robin include predation by feral cat and habitat loss. Nest predation by currawongs may also influence successful recruitment for this species.

Recommended conservation management

- Maintain diverse and shrubby understory in woodland areas.
- Increase woodland habitat where possible and reduce habitat loss through land clearance.
- Monitor currawong populations and consider control methods when considered when nest predation becomes an issue.

Figure D8. Eastern yellow robin population distribution across Cardinia Shire



Key references

Debus, S.J.S. 2006. The role of intense nest predation in the decline of Scarlet Robins and Eastern Yellow Robins in remnant woodland near Armidale, New South Wales. *Pacific Conservation Biology*, 12:4, 279-287.

Higgins, P. J. and Peter, J. M. 2002. *Handbook of Australian, New Zealand and Antarctic Birds*, vol 6. Oxford University Press: Melbourne.

Menkhorst et al. 2017. *The Australian Bird Guide*. CSIRO Publishing.

Lace monitor (*Varanus varius*)

Habitat

The DELWP Advisory listed lace monitor is a large carnivorous reptile that lives in wooded habitats (Wilson and Swan 2013). It is an agile climber and due to its climbing ability, it feeds on a range of vertebrate and non-vertebrate species such as insects, birds, eggs, small reptiles and common ringtail possum, with this latter species being the principal prey item in eastern Victoria (Jessop et al. 2010, Wilson and Swan 2013).

Habitat and structural connectivity requirements

Structural habitat and connectivity requirements for lace monitor include contiguous woodlands with large tree hollows.

Breeding

Female lace monitor lay its eggs in arboreal and terrestrial termite mounds (Wilson and Swan 2013).

Distribution and key populations in Cardinia Shire

The lace monitor has a wide distribution across Victoria and South-eastern Australia. Figure D9 shows, that within Cardinia Shire, it is primarily in the north, associated with forest and woodland areas such as Bunyip State Park and Kurth Kiln Regional Park.

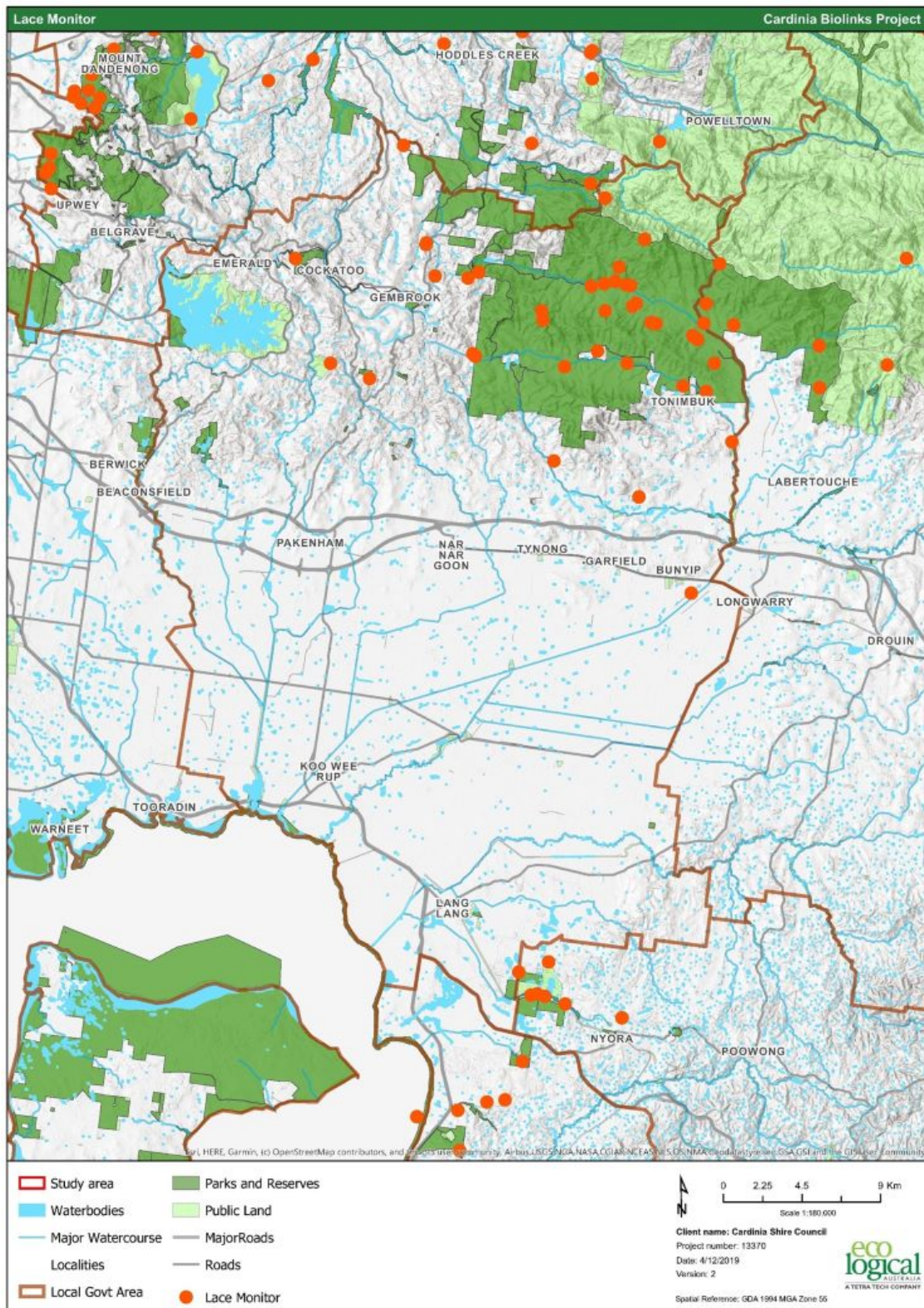
Threats to population

Principal threats to lace monitor are habitat and tree hollow loss associated with land clearing; and introduced predators.

Recommended conservation management

- Placement of constraints on woodland clearance, particularly where large hollows are present.
- Consider undertaking control methods for introduced predators.

Figure D9. Lace monitor population distribution across Cardinia Shire



Key references

Jessop, T., Urlus, J., Lockwood, T. and Gillespie, G. 2010. Preying Possum: Assessment of the Diet of Lace Monitors (*Varanus varius*) from Coastal Forests in Southeastern Victoria. *Biawak*, 4: 59 – 63.

Wilson, S and Swan, G. 2013. *A Complete Guide to Reptiles of Australia*. Reed New Holland Publishers.

Chocolate wattled bat (*Chalinolobus morio*)

Habitat

The chocolate wattled bat can be found in a variety of habitats such as forests, woodlands and farmland areas (DELWP 2017). It roosts during the day in tree hollows and artificial cavities in colonies of approximately 10 – 20 individuals (Menkhorst and Knight 2011; DELWP 2017). At night, they emerge from their roosts and forage for insects below the canopy (Menkhorst and Knight 2011). During winter when the weather is cooler, chocolate wattled bat will enter hibernation, lowering their body temperature as low as 10oC (DELWP 2017). This saves energy when food resources are low (DELWP 2017).

Habitat and structural connectivity requirements

Structural habitat and connectivity requirements for chocolate wattled bat include abundant tree hollows for roosting and canopy trees for foraging.

Breeding

Breeding occurs in late spring or early summer with young commonly born in October or November (Menkhorst and Knight 2011; DELWP 2017). The females form a maternal colony to help look after the young, which allows them to forage at night while some adults remain at the roost (DELWP 2017).

Distribution and key populations in Cardinia Shire

Chocolate wattled bat is distributed along eastern and southern Australia, Tasmania and isolated pockets in the Northern Territory and Western Australia (Menkhorst and Knight 2011). They are very common throughout Victoria and have been recorded in Melbourne suburbs (DELWP 2017). Figure D10 shows that within Cardinia Shire, the chocolate wattled bat is found in the north in Bunyip State Park and near Cardinia Reservoir.

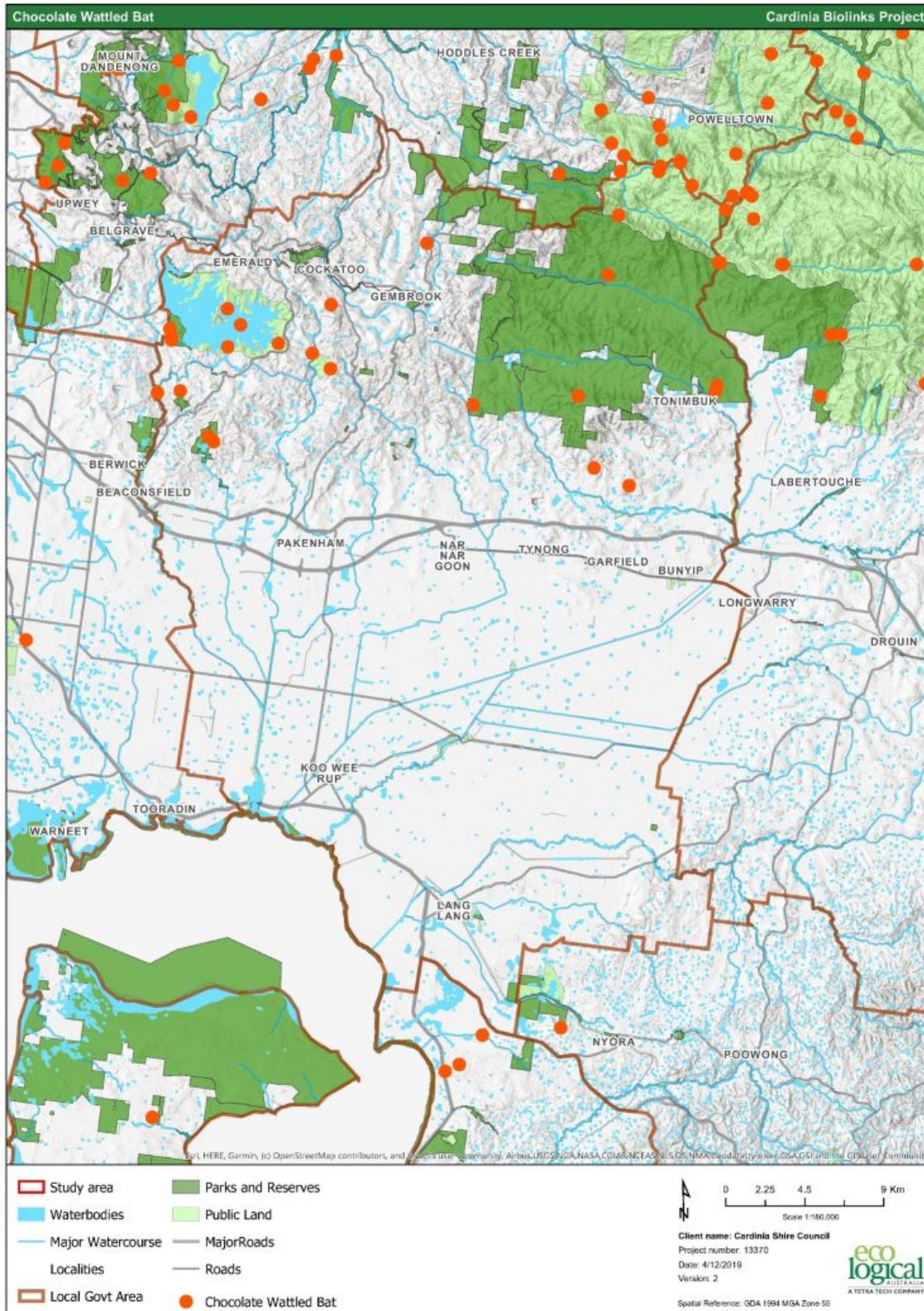
Threats to population

Principal threats to chocolate wattled bat are loss of roost trees and foraging habitat caused by land clearance.

Recommended conservation management

- Placement of constraints on woodland clearance, particularly where hollows are present.
- Encourage landholders to retain hollow bearing trees and foraging habitat.

Figure D10. Chocolate wattled bat population distribution across Cardinia Shire



Key references

DELWP. 2017. Our Wildlife Factsheet – Chocolate Wattled Bat. Available: https://www.wildlife.vic.gov.au/_data/assets/pdf_file/0023/92435/Chocolate-Wattled-Bat.pdf

Menkhorst, P. and Knight, F. 2011. *A field Guide to the Mammals of Australia*. Oxford University Press.

Superb fairy-wren (*Malurus cyaneus*)

Habitat

Superb fairy-wren is a common insectivorous bird species which inhabits a wide range of habitat types where suitable dense cover and low shrubs occur, this includes native and exotic vegetation (Menkhorst et al. 2017; Parson 2009). Includes forest with patches of bare ground, patchy shrublands and shrubby vegetation on the edge of wetlands (Menkhorst et al. 2017). They are common in urban parks and gardens (Menkhorst et al. 2017).

Habitat and structural connectivity requirements

Key habitat and structural connectivity requirements for superb fairy-wren include dense undergrowth of grass, bracken and shrubs.

Breeding

Breeding occurs between July and March, but more commonly between September and December (Morcombe and Stewart 2013). Spherical nests are hidden in grass clumps, low dense shrub or bracken and made from grass stems, rootlets and lined with feathers (Morcombe and Stewart 2013).

Distribution and key populations in Cardinia Shire

Superb fairy-wren are distributed widely along south-eastern Australia and Tasmania. Figure D11 shows, that within Cardinia Shire, they are quite common and distributed widely.

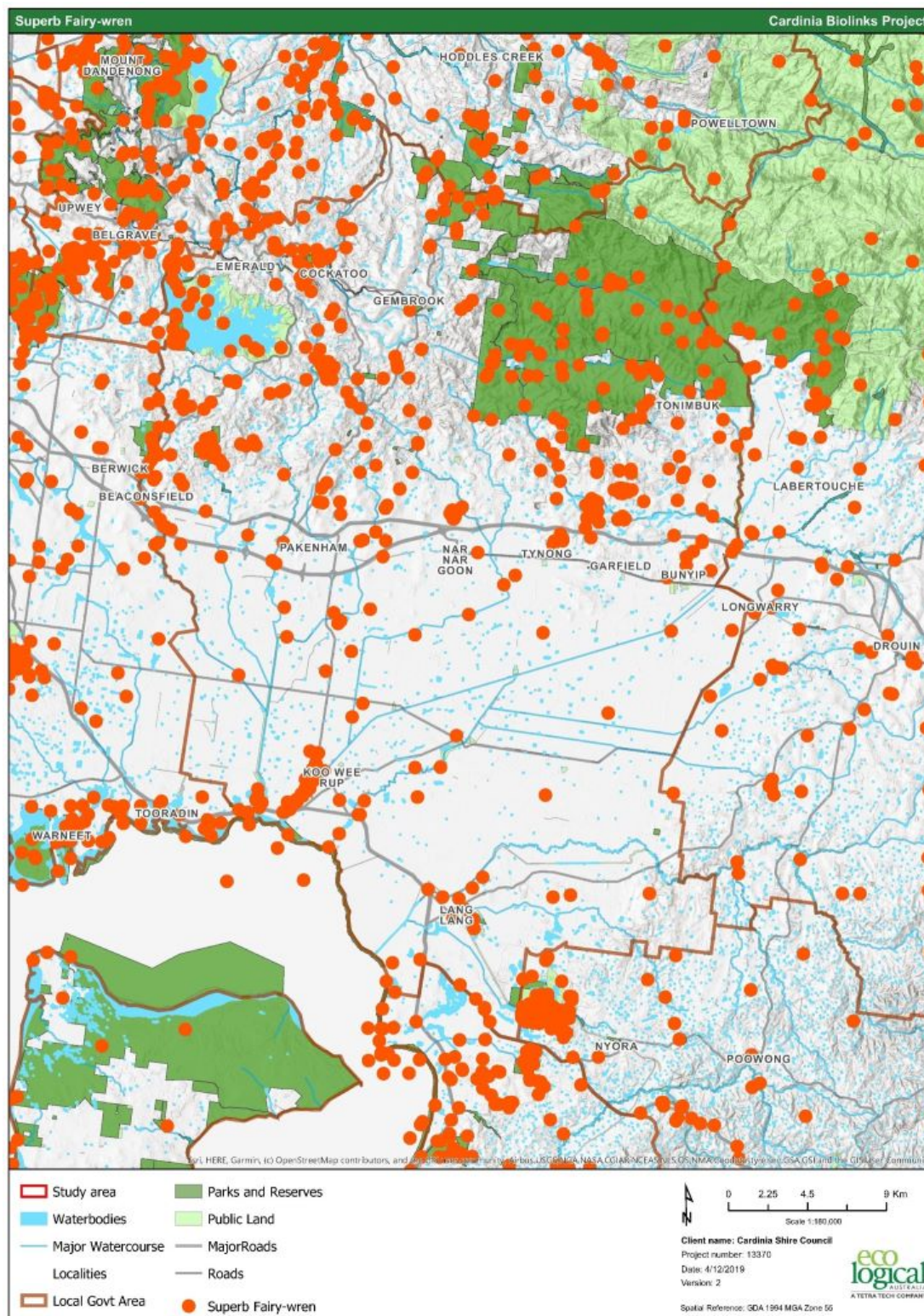
Threats to population

Principal threats to superb fairy-wren include loss of shrubby understory, domestic cats and carnivorous birds such as kookaburra, goshawk, butcherbird and currawong.

Recommended conservation management

- Maintain dense shrubby understory in woodlands, parks and reserves.
- Encourage homeowners to keep domestic cats indoors

Figure D11. Superb fair-wren population distribution across Cardinia Shire



Key references

- Menkhurst et al. 2017. The Australian Bird Guide. *CSRIO Publishing*.
- Morcombe, M. and Stewart, D. 2013. The Morcombe & Stewart Guide to Birds of Australia. *Mobile App*.
- Parsons, H.M. 2009. The effect of urbanisation on the superb fairy-wren (*Malurus cyaneus*). University of Wollongong. PhD Thesis.

Swamp skink (*Lissolepis coventry*)

Habitat

The FFG Act listed swamp skink inhabits low lying damp areas associated with freshwater swamps, wet heaths, sedge lands and saltmarshes (Robertson and Clemann 2015). They prefer micro-environments with a dense understorey with little to no overstorey (Robertson and Clemann 2015). In areas where overstorey species (approximately three meters tall) shade-out the ground storey, it reduces the quality of the habitat and swamp skinks may no longer be present (Robertson and Clemann 2015). In disturbed and degraded sites, swamp skink will use exotic vegetation which is similar in structure to its preferred native habitat (Robertson and Clemann 2015, Homan 2009). Dense, continuous low vegetation is used by swamp skinks for basking, foraging and shelter, along with the burrows of crustaceans (Robertson and Clemann 2015, Homan 2009). Rocks, logs and woody debris may provide refuge but are not always present at occupied sites (Robertson and Clemann 2015).

Habitat and structural connectivity requirements

Key habitat and structure connectivity requirements include low lying damp areas with dense, continuous low vegetation (1 m) and sparse overstorey.

Breeding

Swamp skink are diurnal and primarily a sedentary species which is active mostly during the warmer months between September to mid-April, while mating occurs in November (Robertson and Clemann 2015).

Distribution and key populations in Cardinia Shire

They are distributed primarily along the coastal areas of Victoria with a few populations occurring inland near Horsham, Ballarat, Sale and the outskirts of eastern Melbourne. Figure D12 shows that, within Cardinia Shire, a known population is present in Koo Wee Rup.

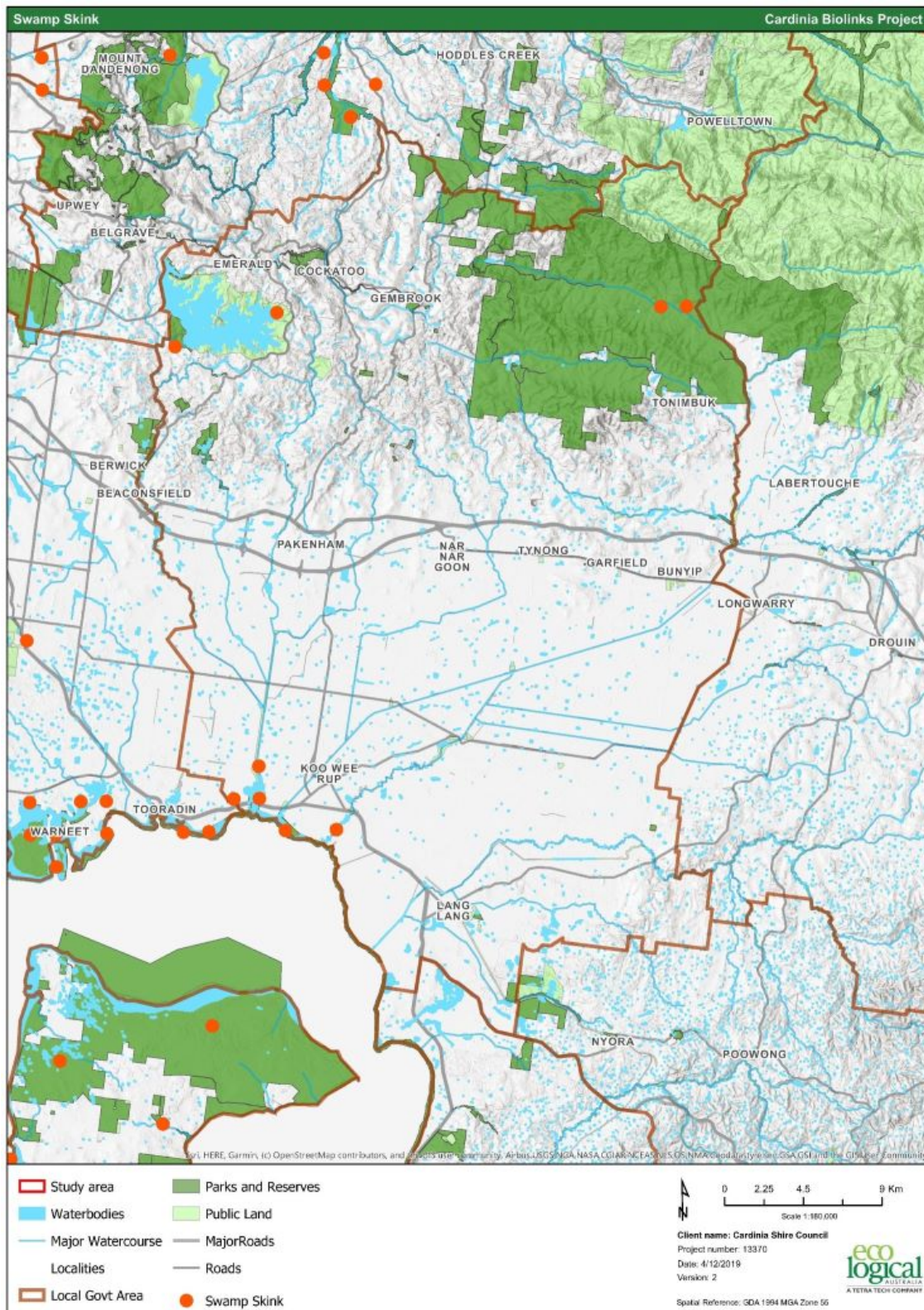
Threats to population

Key threats to swamp skink are land clearance and fragmentation, draining of wetlands, changes in hydrology of rivers and wetlands, degradation and weed invasion of riparian vegetation, infection of vegetation by cinnamon fungus, grazing pressure and trampling by stock and predation by feral cats and European red fox.

Recommended conservation management

- Maintain and develop areas of continuous low (1 m) vegetation (preferably native but can include some exotic).
- Prevent the removal of rocks, logs and some artificial structures from swamp skink habitat.
- Avoid overshadowing habitat areas with canopy trees and tall shrubs.
- Predator control such as feral cat and European red fox.
- Implement control measures to prevent the spread of pathogens when works are undertaken near known populations.
- If possible, fence off areas of swamp skink habitat on private land from stock to avoid trampling and grazing.
- Avoid chemical use in swamp skink habitat where possible.
- Maintain hydrological regimes near swamp skink habitat.

Figure D12. Swamp skink population distribution across Cardinia Shire



Key references

Robertson, P. and Clemann, N. 2015. 'Guidelines for management activities in Swamp Skink habitat on the Mornington Peninsula'.

Homan, P. 2009. Survival of vertebrate fauna in remnant vegetation patches and colonisation of revegetation areas in the La Trobe Valley, Victoria. *The Victorian Naturalist*, 126: 135 – 150.

Eastern pygmy possum (*Cercartetus nanus*)

Habitat

The DELWP Advisory listed eastern pygmy-possum inhabits a broad range of habitats including heathland, Banksia scrub and eucalypt forests, but woodland and heathy vegetation types are the most preferred (OEH 2020). eastern pygmy possum is a small nocturnal mammal which feeds on insects and the nectar and pollen of native banksia, for which it is an important pollinator, eucalyptus and callistemon plants (Van Dyck and Strahan 2008; OEH 2020).

Habitat and structural connectivity requirements

Habitat and structural connectivity requirements for eastern pygmy possum include contiguous woodland and heathy woodland, particularly with banksia and small tree hollows.

Breeding

Breeding can occur up to three times at any time of year when food resources are abundant but mainly occurs between November and March in Victoria (Ward 1990). Tree hollows are preferred for nesting, where small spherical nests are made from bark, but nests have also been found under a loose layer of bark, in rotten stumps, holes in the ground, abandoned bird-nests, ringtail possum (*Pseudocheirus peregrinus dreys*) or under grass tree (*Xanthorrhoea skirts*) (Law et al. 2013; OEH 2020). Home range size is variable; although typically less than 1 ha (Van Dyck and Strahan, 2008; OEH 2020), in forestry areas in New South Wales mean home range sizes of approximately 3 to 7 ha have been recorded (Law et al. 2013).

Distribution and key populations in Cardinia Shire

The eastern pygmy-possum is found in south-eastern Australia from southern Queensland to Tasmania. Figure D13 shows that, within Cardinia Shire, it can be found in the north where contiguous forest and woodland remain such as Kurth Kiln and near Tonimbuk

Threats to population

Principal threats to eastern pygmy possum include land clearance, changes in flowering patterns caused by climate change, changes in fire regimes which affect flowering food resources, competition and land degradation by European rabbit, and predation by feral cat and European red fox.

Recommended conservation management

- Protection of areas with known populations.
- Consider options for road crossing structures (overpasses and underpasses) to aid in dispersal where roads are a barrier.
- Develop and maintain a complex mid layer vegetation.
- Consider appropriate fire regimes to minimise loss of foraging habitat.
- Predator control such as feral cat, European red fox and European rabbit.

Figure D13. Eastern pygmy possum population distribution across Cardinia Shire



Key references

OEH 2020. 'Threatened species profile' - Eastern Pygmy Possum Profile. Available:

<https://www.environment.nsw.gov.au/threatenedspeciesapp/profile.aspx?id=10155>.

Law, B., Chidel, M., Britton, A. and Brassil, T. 2013. Response of eastern pygmy possums, *Cercartetus nanus*, to selective logging in New South Wales: home range, habitat selection and den use *Wildlife Research*. 40, 470–481.

Van Dyck, S. & R. Strahan. 2008. *The Mammals of Australia, Third Edition*. Reed New Holland.

Ward, S.J. 1990. Life-History of the Eastern Pygmy-Possum, *Cercartetus-Nanus* (Burramyidae, Marsupialia), in South-Eastern Australia. *Australian Journal of Zoology*. 38:287 – 304.

Appendix E. Functional connectivity improvements

Table E1. Improving habitat

Structural element	Description-for habitat provision and fauna movement	Groups	Connectivity improvements
Tree canopy	<p>The tree canopy is a critical habitat feature that contributes directly to habitat resources and structural connectivity for the birds, bats, and arboreal mammals (e.g. possums) that make use of it, but also indirectly for other wildlife by creating shade, leaf litter, and allowing groundcover and shrub species to grow beneath the canopy. They provide resources such as pollen, nectar, roost sites, hollows, and entire habitats for insect fauna, in turn providing food resources for insectivorous animals.</p> <p>Trees provide connectivity when they form part of a forest or woodland (habitat patches) but also when more widely spaced in open paddocks and roadsides. For example, birds will fly from paddock tree to paddock tree when crossing an open area.</p> <p>Indigenous and exotic tree species can provide a resource for wildlife, depending on where they are located in the environment and what features they have. Many birds are adapted to feeding only on the flowers of Australian tree species but flying foxes will eat the fruit from exotic species as well</p>	<p>Birds Arboreal mammals Flying foxes Insects</p>	<ul style="list-style-type: none"> • Encourage planting of native eucalypts by residents in their backyards • Use locally indigenous tree species in streetscape plantings or tree species with more habitat and resources for native animals (e.g. bark, hollows, nectar, pollen). • Increase tree canopy cover where needed through planting to aid in species dispersal. Revegetation in larger patches that are connected should be prioritised to increase overall patch size. • Aim to maintain mixed-aged stands by ensuring adequate recruitment is occurring, and supplement with plantings when necessary.
Shrubs	<p>Shrubs, or mid-storey, are an important structural element of habitat, as many bird species are adapted to using this layer of vegetation and forage closer to the ground, rather than in the canopy. For example, superb fairy-wrens live in family groups in shrubs, where they can hide from predators and build their nests, but also have easy access to insects on the ground. Shrubs can also be important in providing shelter for fauna when there are no trees or when there is limited groundcover.</p>	<p>Birds</p>	<ul style="list-style-type: none"> • Encourage planting of native understory species in parks and gardens, conservation reserves and by residents to provide habitat and protective cover for small birds. • Create a dense native understory where possible in parks and gardens to provide structural connectivity for shrub-dependent species (e.g. superb fairy-wrens) and reduce the impact of the Noisy miner on small birds and create cover for mammals.

Structural element	Description-for habitat provision and fauna movement	Groups	Connectivity improvements
	<p>Indigenous shrubs such as acacia, callistemon, grevillea and banksia provide food for nectar-feeding birds and attract native bees.</p> <p>Dense shrub cover is also important for mitigating impacts of noisy miners and facilitating connectivity for bird species sensitive to their aggressive behaviour.</p>		<ul style="list-style-type: none"> Remove exotic berry-producing species such as Privet and Asparagus fern to reduce nest predators, such as the pied currawong and encourage small birds to return.
Groundcover	<p>Groundcover comprises the layer of vegetation on the ground and includes grasses, herbs, forbs, rushes and sedges, as well as cryptogams (mosses, lichen and biological soil crusts). Native pasture can also be valuable groundcover, especially when it is un-grazed and contains few exotic species.</p> <p>Groundcover is an important resource for small mammals, reptiles, birds, frogs and invertebrates. It provides shelter from predators and weather, especially in the form of large tussocks. Groundcover is also a food source for native grazing herbivores such as wombats and macropods, however over-grazing can negatively affect the condition of groundcover.</p> <p>The extent of groundcover can depend on the vegetation community type, and there are many contributing factors including density of canopy and shrub species, geology, drainage, and abundances of herbivores. A variety of groundcover species with an element of patchiness will create habitat for a range of fauna.</p>	<p>Reptiles Mammals Ground-foraging birds Insects Frogs</p>	<ul style="list-style-type: none"> Encourage planting of native grasses and herbs, rather than traditional lawn, in residential gardens. Identify council areas with low density of groundcover for future revegetation. Consider the gap distance between habitat patches in reserves, parks and gardens and plant large tussock grasses where necessary to aid in species movement and create structural complexity across gaps. Create 'no-mow' areas in parks and gardens. Plant species can include: <ul style="list-style-type: none"> <i>Themeda triandra</i> <i>Microlaena stipoides</i> <i>Lomandra longifolia</i> <i>Atriplex semibaccata</i>
Leaf litter, logs and coarse wood debris	<p>Leaf litter, logs, and coarse-woody debris are a key habitat feature, providing shelter and food for a wide range of species. Fallen timber is used by echidnas and other mammals, birds, reptiles, frogs, fish and invertebrates for foraging, nesting, resting, perching, basking or escaping from</p>	<p>Reptiles, woodland birds, insects, fish mammals, frogs</p>	<ul style="list-style-type: none"> Add logs of varying size to habitat patches. Retain cut limbs and trunks of native trees removed as part of council arboricultural works and place in locations with few or no logs, focusing first on high priority core patches and linkages.

Structural element	Description-for habitat provision and fauna movement	Groups	Connectivity improvements
	predators. ¹ The diverse range of uses by wildlife is such that removal of woody debris has a negative effect on species diversity. Leaf litter provides micro-habitat for many invertebrates along with fungi and bacteria ² which provide essential ecosystem services by aiding in the decomposition of leaf litter and recycling of nutrients back into the environment. ³		<ul style="list-style-type: none"> • Educate residents about the benefits of leaf litter and the accumulation and logs in their backyard for fauna. • Educate residents about the importance of not collecting firewood or removing logs or fallen branches from reserves. • Allow leaf litter to accumulate in sections of parks and gardens. • Place logs around the edges of garden beds to create habitat for reptiles. • Use native mulch in garden beds to increase invertebrate biodiversity and provide a food source for insectivorous bird species.
Rocks	<p>Rocks, including rocky outcrops and surface rocks, provide habitat for a variety of fauna, but are especially important for reptiles. Snakes and lizards require rocks for basking to regulate their temperature. Rocks also act as shelter from predators and weather.</p> <p>Rocky habitats often contain high quality vegetation, as they have lower fertility for cultivation, but support native plants. Ideal rocky habitat would include rocks in a range of sizes, partially buried rocks, and rocks on top of each other, with some in the sun and some in the shade. This would provide a variety of shelter spots and temperatures for reptiles to exploit.</p>	Reptiles, insects	<ul style="list-style-type: none"> • Add rocks to habitat where there are few or no rocks. • Include rocks in a range of sizes, partially buried rocks and rocks on top of each other, with some in the sun and some in the shade.

¹ *Assessing wildlife habitat*. NSW Government: Office of Environment & Heritage. Accessed June 21, 2018. <http://www.environment.nsw.gov.au/research-and-publications/publications-search/assessing-wildlife-habitat-conservation-management-notes>

² "Removal of dead wood and dead trees – key threatening process listing". NSW Government: Office of Environment & Heritage. Accessed June 21, 2018. <http://www.environment.nsw.gov.au/determinations/DeadwoodRemovalKtp.htm>

³ Pascoal, Cláudia, and Fernanda Cássio. "Contribution of fungi and bacteria to leaf litter decomposition in a polluted river." *Applied and environmental microbiology* 70, no. 9 (2004): 5266-5273.

Structural element	Description-for habitat provision and fauna movement	Groups	Connectivity improvements
Tree hollows, fissures and cracks	<p>Tree hollows are critical habitat features that are often limiting because they take 100 years or more to form. Hollows form when fungi or chewing insects like termites get into the timber of the tree at weak points created by fire, lightning, snapped branches, attack from insects, etc. These factors, plus natural features in the bark of species, can also cause fissures and cracks that provide habitat.</p> <p>Hollows can be of varying sizes, sometimes extending the full length of a tree, and are common in dead trees.</p> <p>Many animals utilise tree hollows, fissures and cracks for shelter from predators and weather, and for raising young. Some examples include owls and parrots nesting in hollows, and small lizards living under bark and in cracks beneath the bark.</p>	Birds (especially parrots and nocturnal birds), arboreal mammals, microbats, reptiles, insects	<ul style="list-style-type: none"> • Protect and retain large old trees. • Identify where hollows may be lacking in the landscape and install artificial hollows (chainsaw or log). Nest boxes can be used in trees where hollow creation is not possible. Hollows created with a chainsaw are thermally superior to plywood nest boxes and may increase fauna utilisation. • Develop and implement a plan to create hollows using arboriculture modifications to limbs that facilitates and encourages hollow growth. • Develop a plan to address future hollow deficiency in relation to time for hollows to develop, by creating a timeline of tree planting events over a long period to maintain mixed age stands that allow hollows to develop at different rates.
Scattered and isolated trees	<p>Scattered trees are a common feature in urban landscapes that have been largely cleared for development and provide vital steppingstones for bird and bat species between habitat patches.⁴ They also provide shelter, nesting and food resources for animals and their propagules may assist in the regeneration of disturbed landscapes. Areas with scattered trees have also been documented to support greater species diversity and abundances compared to open space without scattered trees. The use of scattered trees varies among organisms, with some being infrequent users, and others completing a full lifecycle in scattered trees.⁵</p>	<p>Steppingstones for birds and bats.</p> <p>Food resource for birds, bats and insects.</p> <p>Shelter for birds, bats, some arthropods and terrestrial plants.</p>	<ul style="list-style-type: none"> • Protect and retain scattered trees. • Plant canopy species around scattered trees to increase patch size. • Revegetate the understorey and ground layer surrounding scattered trees
Waterbodies	<p>Waterbodies include rivers, creeks, wetlands, lakes and dams. They are important for two key reasons: they provide</p>	Frogs, waterbirds, other birds, aquatic	<ul style="list-style-type: none"> • Monitor water quality of creeks and waterways for pollution.

⁴ Prevedello, Jayme A., Mauricio Almeida-Gomes, and David B. Lindenmayer. "The importance of scattered trees for biodiversity conservation: A global meta-analysis." *Journal of Applied Ecology* 55, no. 1 (2018): 205-214.

⁵ Manning, Adrian D., Philip Gibbons, and David B. Lindenmayer. "Scattered trees: a complementary strategy for facilitating adaptive responses to climate change in modified landscapes?". *Journal of Applied Ecology* 46, no. 4 (2009): 915-919.

Structural element	Description-for habitat provision and fauna movement	Groups	Connectivity improvements
	<p>habitat for aquatic fauna and a source of drinking water for terrestrial fauna.</p> <p>Some examples of aquatic fauna include fish, turtles, platypus, crustaceans and macroinvertebrates. These animals require waterbodies with different characteristics, for example platypus require running water. Other factors influencing the suitability of waterbodies are depth, temperature, turbidity, water chemistry, submerged objects and substrate type.</p> <p>Waterbodies are used as a resource by mammals, they attract waterbird species that rely on water, and are often used by flying foxes as they increase humidity which is important for regulating body temperature.</p> <p>Healthy waterbodies generally have vegetated banks, submerged objects for in-stream habitat, and periods of wetting and drying.</p>	<p>and terrestrial mammals, turtles, fish, macroinvertebrates, crustaceans, flying foxes</p>	<ul style="list-style-type: none"> • Educate residents about the damage of household pollutants such as oil, detergent, fertiliser and grass clippings entering waterways. • Add rocks and logs to provide fish and frog habitat.
<p>Riparian and aquatic vegetation</p>	<p>The riparian zone is the area directly adjacent to water, extending from the water's edge up the banks and sometimes further. Riparian vegetation is generally different to vegetation in the surrounding area, as there is greater access to water and therefore the soil is generally more fertile. Many plants in the riparian zone cannot grow outside of it, such as some rushes and ferns.</p> <p>These high productivity areas provide habitat for animals that are partly dependent on water, like frogs and waterbirds. They can also be refuges for other animals during drier periods.</p> <p>The riparian zone is often damaged by stock having access, trampling vegetation and causing erosion of the bank. The riparian zone is also susceptible to weed infestation.</p>	<p>Frogs, waterbirds, water rats (Rakali)</p>	<ul style="list-style-type: none"> • Stabilise creek beds by planting trees along the bank. • Create structural complexity through planting a mix of trees, shrubs and ground cover. • Rehabilitate small areas rather than larger areas at any one time to ensure adequate habitat is available for fauna during the transitional stage from weedy to native. Some weeds can provide habitat for certain fauna species and their removal may have a negative short-term impact. Ensure native species have regenerated before completely removing weeds.

Structural element	Description-for habitat provision and fauna movement	Groups	Connectivity improvements
Bare ground	<p>Bare ground is often associated with degraded or poor habitats, and while they should not be extensive, areas of bare ground can be a positive attribute in the landscape. Bare ground provides an area for plants to disperse and establish, creating new ecosystems. Seedlings provide nutrient rich food for mammals and many invertebrates, such as spiders and beetles rely on bare ground to hunt and nest.⁶ Areas of bare ground provide warmth for reptiles and invertebrates, allowing for animals to warm up more quickly than under vegetation.⁷</p> <p>Some negative aspects of bare ground are that it can be readily colonised by weedy plant species that are of little benefit to native fauna species, and it is often undesirable in appearance. If the extent of the bare ground is considerable, this may be a sign of a poorly functioning habitat and suitable restoration efforts should be made.</p>	Plants, mammals, insects, arachnids, reptiles	<ul style="list-style-type: none"> • Include areas of bare ground in the design of green areas. • Monitor and remove weedy species that establish.

⁶ “The invertebrate biodiversity importance of bare ground habitat in mission sand and gravel quarry”. The Quarry Life Award. Accessed June 21, 2018. <https://www.quarrylifeaward.com/projects/united-kingdom/invertebrate-biodiversity-importance-bare-ground-habitat-mission-sand-gravel>

⁷ *Management of bare ground*. English Nature. Accessed June 21, 2018. <http://publications.naturalengland.org.uk/publication/86028>

Table E2. Improvements by dispersal guild (fauna group)

Dispersal guild	Habitat provision and enhancement	Structural connectivity	Barrier mitigation
Birds Open woodlands and grasslands	Native tree canopy – for canopy foraging species such as thornbills, and mobile species such as currawongs and kookaburras. Mainly eucalypts. <ul style="list-style-type: none"> • Mix tall/low shrub cover – shelter for small birds such as fairy wrens. • Leaf litter and large woody debris - for cover and foraging habitat for insectivorous birds. • Hollows – critical nesting resource for parrots and owls/owlet-nightjars. 	<ul style="list-style-type: none"> • Native grassy groundcover with gaps <20m • Native tree canopy with gaps <50 m • Nest boxes can be used in place of natural hollows if supply is a limiting factor (e.g. large hollows of powerful owl) but must be supported by an ongoing maintenance program.^{8 9} 	<ul style="list-style-type: none"> • Vegetated land bridges to link patches of habitat across major highways and freeways.¹⁰ • Native tree canopy along streetscapes bridging residential road barriers • Sound barriers where habitat or corridors are adjacent to high volume traffic noise (e.g. freeways)
Birds Riparian vegetation and forests	<ul style="list-style-type: none"> • Native tree canopy – for canopy foraging species such as treecreepers and honeyeaters • Mix tall/low shrub cover – shelter for small birds such as fairy wrens • Litter – contains insects for ground foraging birds • Hollows – critical nesting resource for parrots and owls/owlet-nightjars • Existing waterbodies or artificial wetlands with native riparian vegetation– for waterbirds such as swamphens, moorhens and herons. 	<ul style="list-style-type: none"> • Native trees and shrub cover with gaps <50m • Mosaic of vegetation with high structural complexity (e.g. groundcover, shrub, and tree cover) • Creating a forest structure requires denser vegetation, often with greater cover of canopy and shrubs than open woodlands. • Riparian vegetation consists of moisture-dependent species, some of which may be partially submerged, such as reeds. • Riparian vegetation should transition into the surrounding habitat to allow wildlife to move safely down to the water. 	<ul style="list-style-type: none"> • Vegetated land bridges and underpasses to link patches of habitat across major highways and freeways. • Sound barriers where habitat or corridors are adjacent to high volume traffic noise (e.g. freeways) • Length of culverts in waterways should be kept as short as possible so minimise breaks in the riparian vegetation.³

⁸ Cooke, Raylene., Wallis, Robert, and Webster, Alan. "Urbanisation and the ecology of powerful owls (*Ninox strenua*) in outer Melbourne, Victoria." *Ecology and Conservation of Owls* (2002): 100.

⁹ McNabb, E. D., and Jim Greenwood. "A Powerful Owl disperses into town and uses an artificial nest-box." *Australian Field Ornithology* 28, no. 2 (2011): 65.

¹⁰ VicRoads. "Fauna Sensitive Road Design Guidelines". (2012).

Dispersal guild	Habitat provision and enhancement	Structural connectivity	Barrier mitigation
Birds Backyards	<ul style="list-style-type: none"> • Native tree canopy – for canopy foraging species such as treecreepers and honeyeaters • Mix tall/low shrub cover – shelter for small birds such as fairy wrens • Flowering plants – attract nectar-feeding birds like honeyeaters, and insects that insectivorous birds such as willy wagtails eat. 	<ul style="list-style-type: none"> • Native trees, shrubs and groundcover plants in backyards and streetscapes. • Source of water (e.g. bird bath). • Nest boxes (parrots) • Creating habitat in backyards contributes to the overall connectivity in residential areas, so that birds have resources between larger patches of vegetation like parks and reserves. 	<ul style="list-style-type: none"> • Native tree canopy along streetscapes bridging residential road barriers • Permeable fencing or removal • Keeping cats indoors
Mammals Arboreal	<ul style="list-style-type: none"> • Native tree canopy – for canopy foraging and nesting species such as possums and gliders • Mix tall/low shrub cover • Hollows – critical nesting resource for most arboreal • House roofs – nesting in residential areas (possums only) 	<ul style="list-style-type: none"> • Tree canopy (preferably native) and shrubs (preferably native wattles) • Gliders can glide up to 50m between trees, so connectivity for these species require trees to be a maximum of 50m apart so they can move throughout the landscape for foraging and breeding. • Hollows or nest boxes 	<ul style="list-style-type: none"> • Mature connecting tree canopy along streetscapes. • Currently power and telephone wiring provide important connectivity across road barriers in residential areas. Removal and replacement with underground cabling will reduce connectivity. Retain some poles and cables at strategic locations. • Canopy bridges or ropes across major roads will allow movement for all arboreal mammals where habitat is bisected by a road. They can consist of a rope tunnel or rope ladder extended between poles above the road.³ • Glide poles on either side of the road will allow gliders to move across when trees are not available.¹¹ • Nest boxes create alternative nesting habitat for gliders.

¹¹ Goldingjay, Ross L., Brendan D. Taylor, and Tina Ball. "Wooden poles can provide habitat connectivity for a gliding mammal." Australian Mammalogy 33, no. 1 (2011): 36-43.

Dispersal guild	Habitat provision and enhancement	Structural connectivity	Barrier mitigation
Mammals Microbats and flying foxes	<ul style="list-style-type: none"> • Native tree canopy – for flying-fox roosts • Mix tall/low shrub cover – cover for microbats • Native tree canopy and shrub cover supporting insect food resources (microbats) • Hollows, fissures and cracks in bark – roosting habitat for microbats. • Caves and rock crevices – roosting habitat for microbats. • Existing waterbodies or artificial wetlands – for flying-fox roosts and foraging of insectivorous microbats. • Water for drinking 	<ul style="list-style-type: none"> • Native tree canopy and shrub cover. Also, other tree and shrub cover (microbats) and exotic fruit trees (flying-foxes) • Nest (roost) boxes (microbats) • Bats can travel considerable distances but are aided by vegetative cover providing food resources (insects, nectar, pollen) to fuel high energetic costs. • Roosting habitat for flying foxes needs to be within foraging distance of flowering eucalypts (up to 50km)¹² 	<ul style="list-style-type: none"> • Bat boxes can be used as an alternative roost option when hollows are not available.¹³ • Wildlife culverts under roads can aid movement of microbats³.
Mammals Ground dwelling	<ul style="list-style-type: none"> • Low shrub cover – structural complexity required for some small mammals such as antechinus, and nesting for echidnas. For Southern Brown Bandicoots this will include 50-80% foliage density in the 0.2-1 metre range • Native groundcover - providing protection from predators and weather, and nesting habitat • Leaf litter and large woody debris - for cover and foraging habitat for insectivores. 	<ul style="list-style-type: none"> • Dense native groundcover • Logs, rocks, and dense vegetation for shelter • Continuous habitat corridors • Dense shrub cover (swamp wallaby) • Open tall grassy areas (kangaroos) • High habitat structural complexity¹⁴ 	<ul style="list-style-type: none"> •

¹² Sunshine Coast Regional Council “Regional Flying-Fox Management Plan” (2016). Accessed 22 June, 2018.

<https://www.environment.gov.au/system/files/pages/4b63db66-1d8e-4427-91d1-951aff442414/files/schedule-2-grey-headed-flying-fox-management-plan.pdf>

¹³ Lewis, B.D. “Warrell Creek to Urunga: Microchiropteran Bat Management Strategy” (2013). Report prepared for Roads and Maritime Services by Lewis Ecological Surveys.

¹⁴ Barnett, J. L., R. A. How, and W. F. Humphreys. "The use of habitat components by small mammals in eastern Australia." *Austral Ecology* 3, no. 3 (1978): 277-285.

Dispersal guild	Habitat provision and enhancement	Structural connectivity	Barrier mitigation
Mammals Aquatic	<ul style="list-style-type: none"> Existing waterbodies or artificial wetlands with native riparian vegetation – for rakali and platypus. 	<ul style="list-style-type: none"> Riparian and in-stream aquatic vegetation Resting and feeding platforms Waterbodies that support platypus would ideally have at least 50m of riparian vegetation or other¹⁵, and contain permanent water. 	<ul style="list-style-type: none"> Water culverts will allow for movement of aquatic mammals in waterways that are bisected by a road. Design should consider flow velocity, potential build-up of debris and silt that could block the culvert³ and be a minimum of 20cm wide to allow platypus and rakali to fit through.⁷
Reptiles and amphibians	<ul style="list-style-type: none"> Leaf litter and large woody debris - for cover and foraging habitat for insectivorous reptiles. Native groundcover - providing protection from predators and weather, and nesting habitat. Rock cover - providing protection from predators and weather, and basking opportunities for body temperature regulation of reptiles. Existing waterbodies or artificial wetlands with native riparian vegetation – for frogs and turtles. Artificial habitat can be created using frog ponds, and use is maximised with good design e.g. high edge to area ratio to limit open water.³ 	<ul style="list-style-type: none"> Native groundcover (tussock grasses and herbs >30 cm height) with minimal gaps Unshaded bare ground, large rocks, and logs for basking Rocks piles, logs, and leaf litter for shelter. Artificial refuges such as roof tiles where natural rock cannot be used. Connectivity of waterbodies, wet depressions, and fringing and aquatic vegetation (frogs) Waterbodies that only contain water temporarily should be linked or give safe access to other sources of water for frogs and turtles to disperse to in dry periods.³ 	<ul style="list-style-type: none"> Structures that allow for movement between habitat including land bridges and underpasses. Removal of solid fencing or allow gaps at ground-level. Fencing can be used to funnel fauna into the corridor, and habitat enhancement elements should be included to encourage use³. Frog resistant fencing should be considered. Keeping cats indoors Permeable fencing or removal Sound barriers where habitat or corridors are adjacent to high volume traffic noise (e.g. freeways) Appropriate setback from development
Fish	<ul style="list-style-type: none"> Existing waterbodies, waterways or artificial wetlands with native riparian vegetation – creates habitat for aquatic macroinvertebrates that fish can eat and improves water quality. 	<ul style="list-style-type: none"> Waterbodies would ideally be interconnected and contain permanent water. Fringing and aquatic vegetation Submerged logs and branches In-stream detritus and rock 	<ul style="list-style-type: none"> Water culverts will allow for movement of fish in waterways that are bisected by a road. Design should consider flow velocity, potential build-up of debris and silt that could block the culvert and be a maximum

¹⁵ Brisbane City Council. "Platypus Conservation Action Statement". (2015).
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Dispersal guild	Habitat provision and enhancement	Structural connectivity	Barrier mitigation
	<ul style="list-style-type: none"> Aquatic vegetation and in-stream habitat elements (woody detritus, logs) 		<ul style="list-style-type: none"> of 6m long to allow for resting opportunities for fish. Fish ladders and rock ramps can also be used to allow connectivity for fish when there are barriers such as weirs.³
Insects	<ul style="list-style-type: none"> Leaf litter and large woody debris - for cover and food resource. Vegetation – habitat and food resources. Groundcover - providing protection from predators and weather. Rock cover - providing protection from predators and weather. Flowering plants – attract bees and butterflies. 	<ul style="list-style-type: none"> Many kinds of vegetation, including exotic, can provide connectivity for insects. Native tree and shrub canopy. All other habitat elements High habitat structural complexity 	<ul style="list-style-type: none"> Structures that allow for movement between habitat including land bridges and underpasses. Habitat enhancement elements should be included to encourage use.³
Plants Seed dispersed	<ul style="list-style-type: none"> Increase numbers of seed-dispersing animal vectors. 	<ul style="list-style-type: none"> Facilitate connectivity for seed dispersing bird species by providing shrub and tree canopy cover at appropriate intervals along corridors and within patches 	<ul style="list-style-type: none"> Land bridges and underpasses.
Plants Pollination	<ul style="list-style-type: none"> Habitat elements for insect, bird, and bat pollinators. 	<ul style="list-style-type: none"> Habitat for insect pollinators including native grasses, wildflowers, flowering trees. 	<ul style="list-style-type: none"> Land bridges and underpasses.
Fungi	<ul style="list-style-type: none"> Logs, litter, trees, canopy cover. 	<ul style="list-style-type: none"> Habitat and structural connectivity for insect and mammal dispersers 	<ul style="list-style-type: none"> Land bridges and underpasses.

Table E3. Addressing connectivity barriers (defined on a site by site basis)

Barriers	Description	Suggested action
Light	<p>Artificial night lighting can have impacts on terrestrial and aquatic ecosystems, such as altering ecological regimes, disrupting ecological processes and behaviour of fauna, causing increased mortality, and reducing both the fitness of populations and the ecological connectivity between them¹⁶. Impacts on wildlife increase with longer lighting hours and increased use of brighter, whiter lighting (via cheaper LED lighting). Light pollution includes:</p> <ul style="list-style-type: none"> • Street, park, and traffic lighting. • Building lighting. • Vehicle lights. <p>Impacts</p> <ul style="list-style-type: none"> • Barriers to movement and habitat use for species which avoid night lighting. • Altering movements and migration of birds and insects. • Increased risk of predation for species drawn to lights and for nocturnal animals. • Disrupted predator-prey dynamics. • Increased risk of vehicle-wildlife collisions for animals drawn to lit areas. • Increased animal stress levels and decreased fitness through changing of normal behaviour, energy levels, and circadian clocks. • Changes in reproductive behaviours and reduced reproductive success. • Altering plant photosynthesis and reproduction. <p>Examples</p>	<p>Solutions</p> <ul style="list-style-type: none"> • Incorporate the National Light Pollution Guidelines for Wildlife(44) • Using no or fewer lights. • Site lighting away from fauna habitat and movement corridors. • Using alternatives to lighting such as low-light LEDs installed in pavements, fluorescent or reflective paint. • Limit the time that lighting is used e.g. turn off lights when not needed – encourage lighting on timers for commercial buildings – particularly between 11pm to 4am.²⁰ • Reduce height of streetlights/lighting. • Use physical barriers (fencing or walls) or densely planted vegetation to block or reduce light pollution from roads and buildings entering fauna habitat e.g. wall barriers along freeways. • Apply structural changes to the design of lights, so that light does not spill into habitat or movement corridors or the sky above e.g. use aero screens on streetlights to reduce light spill. • Use narrow spectrum light sources which will reduce the number of species affected. • Using streetlights with reduced intensity (luminosity) where possible – reduce by >50%. • Use lighting that emits minimal ultra-violet light, peaks no higher than 550 nm, and avoids short wavelength white and blue wavelengths – use warm/yellow colour temperature (<4,200 kelvin) where required to balance blue light^{21 22}.

¹⁶ Longcore, Travis, and Catherine Rich. "Ecological light pollution." *Frontiers in Ecology and the Environment* 2, no. 4 (2004): 191-198.

²⁰ Davies, Thomas W., Jonathan Bennie, Dave Cruse, Dan Blumgart, Richard Inger, and Kevin J. Gaston. "Multiple night-time light-emitting diode lighting strategies impact grassland invertebrate assemblages." *Global change biology* 23, no. 7 (2017): 2641-2648.

²¹ Gaston, Kevin J., Jonathan Bennie, Thomas W. Davies, and John Hopkins. "The ecological impacts of nighttime light pollution: a mechanistic appraisal." *Biological reviews* 88, no. 4 (2013): 912-927

²² Artificial lighting and wildlife Interim Guidance: Recommendations to help minimise the impact artificial lighting. Bat Conservation Trust, 2014.

http://www.bats.org.uk/pages/bats_and_lighting.html

44 National Light Pollution Guidelines for Wildlife Including Marine Turtles, Seabirds and Migratory Shorebirds, Commonwealth of Australia 2019

Barriers	Description	Suggested action
	<ul style="list-style-type: none"> Disrupting movement (and pollen dispersal) and increased mortality for insects drawn to streetlights.¹⁷ Passing vehicle lights can reduce the ability of frogs to see at night which can take from a few minutes to hours to recover from, causing frogs to cease moving during this time.¹⁸ Impairing the vision of nocturnal predators and reducing their foraging success.¹⁹ 	<ul style="list-style-type: none"> Strategically planning the types of development and associated human activities adjacent to protected areas. Plan for “dark areas” for fauna refuge in wildlife corridors. Reduce building light pollution particularly for tall residential/commercial buildings. Avoid tall buildings or developments with high light pollution adjacent to movement corridors. Consider the impact of nightwork construction lighting on wildlife and implement mitigation measures such as screens where practicable. Use online tools to determine low-impact lighting solutions²³ <p>Limitations</p> <ul style="list-style-type: none"> Light pollution has complex interactions with ecological processes and species and may even have positive effects in some cases. It is an area where future research is needed. Managers need to keep up-to-date with current research. Solutions for reducing impacts must be balanced against other needs such as road and community safety.
Fences	<ul style="list-style-type: none"> Fences are a common sight across the landscape; however many styles cause negative impacts to native wildlife through restricted movement leading to disruptions in migration, feeding, breeding and social patterns of native fauna, and in some cases death. Conversely, fences can also have a positive effect. Barrier fencing along roadsides can funnel wildlife into fauna crossing structures, preventing road mortality. <p>Impacts</p>	<p>Solutions</p> <ul style="list-style-type: none"> Use funnel fencing to divert fauna into culverts or underpasses near roads. Ensure fences that are designed to keep wildlife out such as above, are suitably designed, e.g. floppy top, chain mesh and pinned down skirting to discourage climbing animals and kangaroos. Frog-resistance fences need to be dug down to a depth of at least 100mm.

¹⁷ Eisenbeis, Gerhard, Andreas Hänel, M. McDonnell, A. Hahs, and J. Breuste. "Light pollution and the impact of artificial night lighting on insects." Ecology of cities and towns: a comparative approach Cambridge University Press, New York, New York, USA (2009): 243-263.

¹⁸ Andrews, Kimberly M., J. Whitfield Gibbons, Denim M. Jochimsen, and J. Mitchell. "Ecological effects of roads on amphibians and reptiles: a literature review." Herpetological Conservation 3 (2008): 121-143.

¹⁹ Gaston, Kevin J., Jonathan Bennie, Thomas W. Davies, and John Hopkins. "The ecological impacts of nighttime light pollution: a mechanistic appraisal." Biological reviews 88, no. 4 (2013): 912-927.

²³ Longcore, Travis, Airam Rodríguez, Blair Witherington, Jay F. Penniman, Lorna Herf, and Michael Herf. "Rapid assessment of lamp spectrum to quantify ecological effects of light at night." Journal of Experimental Zoology Part A: Ecological and Integrative Physiology (2018). <https://fluxometer.com/ecological/?mode=d65&group=insect>

Barriers	Description	Suggested action
	<ul style="list-style-type: none"> Barrier to movement for any species that cannot pass under, over or through the fence, limiting the movement of animals and reproductive success of a species. Changes in feeding and social patterns. Restrictions to biodiversity range causing overabundance. Injury or mortality caused by non-wildlife friendly fences. Road mortality due to lack of barrier fencing along roadsides. <p>Examples</p> <ul style="list-style-type: none"> Funnel fencing proved successful for herpetofauna (frogs/reptiles) and small/medium sized mammals.²⁴ Entanglement of fauna in barbed wire or mesh. 'Fence-hanging' of kangaroos caught between two rows of plain wire. Bird collision with fencing wires results in mortality.²⁵ Increasing the visibility of fences may prevent collisions. Many species use the exact same route for movement through the landscape, which can be disrupted by the erection of fences. 	<ul style="list-style-type: none"> Do not use barbed wire; instead, use plain wire. Leave a 30 to 50 cm gap between the bottom wire and the ground to enable fauna to pass underneath. Paling fences should not extend the entire length of the property to enable fauna to pass underneath. Ensure that the fence is visible to fauna by attaching reflective/colourful tags at 30 cm intervals and use borderline (white plastic coated) wire or white tape for the top strand. Cover the top strand of barbed wire fences with polypipe to minimise the risk of injury/death or remove the barbed wire completely. Use low height fences and plant trees on either side of the fence for fauna to easily pass over. Post and rail fencing is the most wildlife-friendly. Avoid erecting fences on ridgelines, near fruiting or flowering trees, across wildlife corridors, or over dams or waterways. Consider if a fence is necessary. Install Bandicoot 'flaps' on suburban fencing to enable Bandicoots to enter but deter snake access <p>Limitations</p> <ul style="list-style-type: none"> It is difficult to monitor the effect of fences on private property on the movement of wildlife. Therefore, increasing community awareness about wildlife-friendly fences will be the most effective form of prevention. Road barrier fencing may be difficult and costly to install and maintain.
Traffic	<ul style="list-style-type: none"> Collisions with wildlife can be fatal and the costs associated significant. Road-kill rates may differ on large high-volume roads compared with smaller low-volume roads and where roads dissect 	<p>Solutions</p> <ul style="list-style-type: none"> Adjusting driver speed by installing temporary or permanent reduce speed signs.

²⁴ Taylor, Brendan D., and Ross L. Goldingjay. "Roads and wildlife: impacts, mitigation and implications for wildlife management in Australia." *Wildlife Research* 37, no. 4 (2010): 320- 331.

²⁵ Summers, R. W. "The lengths of fences in Highland woods: the measure of a collision hazard to woodland birds." *Forestry: An International Journal of Forest Research* 71, no. 1 (1998): 73-76.

Barriers	Description	Suggested action
	<p>areas of intact habitat. The impact of road mortality may also differ dependent on the species and population size.</p> <p>Impacts</p> <ul style="list-style-type: none"> • Reduced species dispersal due to vehicle mortality. • Vehicle mortality may lead to a decline in population size. Threatened species are at higher risk of changes to population size. • High volumes of traffic increase the likelihood of vehicle-induced road mortality. • Some animals may display an aversion to roads caused by traffic noise which can reduce mortality rates but also reduce abundance. • Seasonal variations in road mortalities may occur in species that crossroads during their breeding season. <p>Examples</p> <ul style="list-style-type: none"> • Ground-dwelling amphibians, mammals and reptiles are at a higher risk of the negative effects caused by road mortalities on populations compared to flying animals such as birds. • Birds are at risk of being killed while foraging for seeds along the roadside.²⁶ • Increased traffic volume reduces the success of amphibians crossing roads. 	<ul style="list-style-type: none"> • Lower speed limits in known fauna hotspots between dusk and dawn. • Speed reductions are best achieved when used with other devices such as rumble strips or speed humps that force or encourage drivers to slow down. • Install fauna crossing signs in fauna hotspots. • Increase driver awareness of the hazards of driving at dusk and dawn. • Install frog-resistant fences in high-volume crossing areas. <p>Limitations</p> <ul style="list-style-type: none"> • Increasing public awareness and enforcing lowered speed limits to reduce wildlife mortality may be difficult to achieve. • With an increasing population size leading to more road users, impacts to fauna may continue or increase despite mitigation.
Sound	<p>Anthropogenic (man-made) noise pollution is a side-effect of increased human population size and urbanisation. Traffic and construction are examples of the types of noise pollution which have direct impacts on wildlife, through the interference of auditory cues, and altered behaviour and physiological responses. Broader impacts include changes to reproductive success, movement patterns and habitat use, survival and foraging efficiency. The extent to which noise effects a species seems to be species-specific.</p> <p>Impacts</p> <ul style="list-style-type: none"> • Infrequent noise can result in increased energy costs associated with flight behaviour, increased vigilance and loss of foraging time. 	<p>Solutions</p> <ul style="list-style-type: none"> • Strategically plan the types of development and associated human activities adjacent to protected conservation areas. • Plant roadside trees with high leaf density to absorb noise. • Build green roofs on top of buildings to absorb noise. • During construction projects, consider using sound-absorbing walls or mufflers to reduce noise generated from machinery. • Avoid generating excessive noise during the mating season, especially around wetlands and conservation areas. Schedule works outside of this time. • Consider re-routing trucks away from sensitive areas.

²⁶ Department of Main Roads, Planning, Design and Environment Division 2002. *Fauna sensitive road design*. <https://www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Fauna-sensitive-road-design-volume-1.aspx>

Barriers	Description	Suggested action
	<ul style="list-style-type: none"> • Frequent noise can critically affect an animal's daily energy use, reducing reproductive ability and survival. • Changes in vocalisation and missed auditory cues impact an animal's: • Risk of predation due to changes in anti-predator behaviour. • Reproductive success through missed mating calls (e.g. frogs). • Habitat avoidance or abandonment can occur in noisy environments. • Examples • Changes in the vocal behaviour of some birds, mammals, frogs and insects in response to noise. • Increased heart rate, changes in metabolism and hormone balance are some of the physiological responses to noise.¹² 	<ul style="list-style-type: none"> • Install noise reducing barriers around major roads to reduce traffic noise. • Identify noise-producing facilities in the municipality and look at ways to reduce their impact, e.g. quitter machines and sounds barriers. • Carefully plan and assess future developments to address their noise-producing ability. <p>Limitations</p> <ul style="list-style-type: none"> • Anthropogenic noise is a part of modern society and cannot be totally removed. However, steps to reduce noise pollution wherever possible should be taken. • Installation of sound barriers along roadsides may be costly and could become a barrier to species movement and should therefore be carefully considered before installation
Human activity	<p>Human activity as a barrier to wildlife is a significant and far-reaching threat with many potential impacts, ranging from construction of a new housing estate, to people walking their dogs in a park. While some species have been able to adapt to the changes caused by human presence - such as possums living in roofs rather than hollow-bearing trees and moving throughout developed areas by using powerlines - most are affected negatively by human activity due to fear and avoidance. This applies to terrestrial and flying fauna.</p> <p>Impacts</p> <ul style="list-style-type: none"> • Reduced movement and dispersal due to avoidance of areas of human activity, which can potentially lead to decreased reproductive success and gene flow. • Altered diet and/or reduced food availability due to gardens containing non-indigenous plants, animals having access to rubbish, and people feeding wild animals in parks etc.²⁷ • Poor health of individuals caused by stress.²⁸ 	<p>Solutions</p> <ul style="list-style-type: none"> • Promote the use of indigenous plants in parks and gardens to provide a food resource for native animals and create better connectivity of vegetation patches. • Discourage the feeding of and interaction with native wildlife. • Consider disturbance buffers, placement of high activity areas (such as playgrounds) and availability of resources for fauna (e.g. nest boxes, dense vegetation, water sources) when designing open spaces and other developments. • Monitor important/at-risk populations so declines are detected before they are lost completely. • Educate people about local fauna to promote community awareness and pride, which can lead to better environmental outcomes. <p>Limitations</p> <ul style="list-style-type: none"> • Solutions which involve human behaviour changes are often difficult to integrate.

²⁷ Chamberlain, Daniel E., Arthur R. Cannon, M. P. Toms, D. I. Leech, B. J. Hatchwell, and K. J. Gaston. "Avian productivity in urban landscapes: a review and meta-analysis." *Ibis* 151, no. 1 (2009): 1-18.

²⁸ Ditchkoff, Stephen S., Sarah T. Saalfeld, and Charles J. Gibson. "Animal behaviour in urban ecosystems: modifications due to human-induced stress." *Urban ecosystems* 9, no. 1 (2006): 5-12.

Barriers	Description	Suggested action
	<ul style="list-style-type: none"> Habitat loss and fragmentation causing populations to decrease. Spread of disease.²⁹ <p>Examples</p> <ul style="list-style-type: none"> Introduction of cycling and dog walking to a wetland increased the flight response of birds more than when only walkers were present, and effectively reduced the size of the wetland through disturbance buffers.³⁰ Decrease in gene flow between populations of the same species that are separated by a human-induced barrier.³¹ When vegetation is fragmented throughout a developed area, the distance between and size of remaining patches is a limiting factor in what species can move from patch to patch, e.g. birds may easily fly between patches, whereas frogs cannot move large distances to find water. Human activity can facilitate the spread of weeds by transporting seeds and plant material. This can reduce the quality of habitat when invasive plants outcompete native plant species. 	<ul style="list-style-type: none"> Use of effective disturbance buffers can require large amounts of space which may not be available.
Predation	<p>Introduced predators, including foxes and domestic cats and dogs, are one of the biggest threats to native wildlife in Australia and directly cause the deaths of millions of animals every day. Predators also act as a barrier for wildlife through a phenomenon known as the 'landscape of fear', whereby the presence of a predator can determine the behaviour, distribution, foraging, nesting, movement and timing of activity of prey species in the same area.</p> <p>Impacts</p> <ul style="list-style-type: none"> Mortality of native fauna directly caused by introduced predators (including pets) through hunting. 	<p>Solutions</p> <ul style="list-style-type: none"> Promote the Safe Cat, Safe Wildlife program and enforce cat curfews to keep cats indoors between sunset and sunrise as a minimum. Inside-only cats are the safest option for wildlife. Enforce dog leash laws (especially in vegetated areas such as along Steele Creek and in Queens Park) with signage, patrols and fines. Create/maintain as much habitat as possible to provide shelter for native fauna, including dense vegetation close to the ground and taller trees. Educate the community about native species in the local area, their importance and the impact of pets as predators. This could include

²⁹ Brearley, Grant, Jonathan Rhodes, Adrian Bradley, Greg Baxter, Leonie Seabrook, Daniel Lunney, Yan Liu, and Clive McAlpine. "Wildlife disease prevalence in human-modified landscapes." *Biological Reviews* 88, no. 2 (2013): 427-442

³⁰ Weston, Michael A., Mark J. Antos, and Hayley K. Glover. "Birds, buffers and bicycles: a review and case study of wetland buffers." *Victorian Naturalist*, The 126, no. 3 (2009): 79.

³¹ Lee, Tristan, Kyall R. Zenger, Robert L. Close, Marilyn Jones, and David N. Phalen. "Defining spatial genetic structure and management units for vulnerable koala (*Phascolarctos cinereus*) populations in the Sydney region, Australia." *Wildlife Research* 37, no. 2 (2010): 156-165.

Barriers	Description	Suggested action
	<ul style="list-style-type: none"> • Mortality of native fauna indirectly caused by introduced predators through disease (e.g. toxoplasmosis in cats³²) and stress from predator avoidance. • Habitat in developed areas can have many edges due to fragmentation, and predators often exploit the edges of habitat as the fauna there is more exposed and therefore more vulnerable³³. • Reduced movement and dispersal, or total exclusion from an area of fauna as a result of the landscape of fear created by the presence of introduced predators. <p>Examples</p> <ul style="list-style-type: none"> • Cats preying on nests at the edges of urban bushland because of ease of access and ability to move quickly between habitat and streets³⁴. • Predation of southern brown bandicoots by foxes has restricted the extent of bandicoots around suburban Melbourne to a couple of isolated populations³⁵. • Birds dispersing within a developed area are at higher risk of predation by cats while moving between patches of habitat with low connectivity. 	<p>birdwatching in the local parks, interpretive signage, news articles, etc.</p> <ul style="list-style-type: none"> • Encourage people to get help if they find an animal injured by their pet by calling Wildlife Victoria on 8400 7300. <p>Limitations</p> <ul style="list-style-type: none"> • Cat curfews are difficult to police, and many people object to them which may lead to disputes. • Controlling foxes in urban areas is often not feasible as more foxes will always replace those that are removed unless a much wider control program is implemented.
Pests and weeds	<p>Pest animals and weedy vegetation are a major threat to the environment by contributing to the degradation of the landscape and decline in some species. Pest animals' impact native fauna through predation, competition for food and shelter, habitat destruction and spreading diseases, while weedy vegetation competes with native flora for space, light and nutrients. Eradication is generally difficult and costly once they are established.</p>	<p>Solutions</p> <ul style="list-style-type: none"> • Remove weedy plant species in small patches once native vegetation has re-established. • Remove weeds from areas with small infestations first, then progressively move to more heavily infested areas. • Create and implement a pest animal management plan for the removal of key target species including deer, rabbits, feral cats and foxes from council land.

³² Hartley, W. J., and J. P. Dubey. "Fatal toxoplasmosis in some native Australian birds." *Journal of Veterinary Diagnostic Investigation* 3, no. 2 (1991): 167-169

³³ Chalfoun, Anna D., Frank R. Thompson, and Mary J. Ratnaswamy. "Nest predators and fragmentation: a review and meta-analysis." *Conservation biology* 16, no. 2 (2002): 306-318

³⁴ Luck, Gary W., Hugh P. Possingham, and David C. Paton. "Bird responses at inherent and induced edges in the Murray Mallee, South Australia. 2. Nest predation as an edge effect." *Emu* 99, no. 3 (1999): 170-175.

³⁵ Coates, T. D., and C. J. Wright. "Predation of southern brown bandicoots *Isodon obesulus* by the European red fox *Vulpes vulpes* in south-east Victoria." *Australian Mammalogy* 25, no. 1 (2003): 107-110.

Barriers	Description	Suggested action
	<p>Impacts</p> <ul style="list-style-type: none"> • Pest animals can cause soil erosion in areas that are degraded due to the difficulty in keeping them out until the area is revegetated. • Many weeds are unpalatable to native species or contain very little nutrients compared with native species. <p>Examples</p> <ul style="list-style-type: none"> • Pest animals such as the European rabbit contribute through grazing pressure to the degradation of vegetation that native species such as the bilby rely on.³⁶ • Exotic weed species account for 15% of all flora in Australia and are currently spreading faster than they can be controlled.³⁷ 	<p>Limitations</p> <ul style="list-style-type: none"> • It can be difficult to completely eradicate weed and pest species from the urban landscape due to high levels of habitat disturbance. • Maintenance of weed-infested areas can be costly.
Pollution	<p>Pollution comes in many forms and is an unfortunate by-product of humans' everyday lives. Waste materials generated from households, industry, cars, lawn chemicals and sewerage pollute our environment. Pesticides, fertilisers, animal waste and stormwater run-off can make their way into our waterways leading to algal blooms which can have a severe impact on native wildlife and aquatic ecosystems, as well as human health and pets. Types of pollution:</p> <ul style="list-style-type: none"> • Exhaust fumes • Stormwater run-off • Fertiliser and pesticides • Plastics and non-recyclable rubbish • Metals and pollutants from roads <p>Examples</p> <ul style="list-style-type: none"> • Toxins associated with algal blooms pose a serious threat to wildlife and have been associated with deaths in fish and some types of birds including, songbirds, ducks, gulls, pheasants and hawks.³⁸ 	<p>Solutions</p> <ul style="list-style-type: none"> • Construct wetlands/bioretention swales and raingardens to capture stormwater pollution. • Install green roofs on top of current and future buildings to capture incident rainfall and reduce stormwater run-off. • For new developments and pavement upgrades, use permeable pavement to capture stormwater run-off. • Educate households on how to recycle effectively. Consider making a comprehensive leaflet with pictures of common household wastes and their recyclability. • Install more permanent recycle bins across the municipality. • Support and encourage 'green' building and new community accreditation schemes • Encourage businesses to become greener, with offsets for greener developments. • Educate the community on the environmental impact of pesticides and fertilisers that are used in their gardens.

³⁶ "Feral animals in Australia". Department of Environment and Energy. Accessed September 7, 2018. <http://www.environment.gov.au/biodiversity/invasive-species/feral-animals-australia>

³⁷ "Why are weeds a problem?". Department of Environment and Energy. Accessed September 7, 2018. <http://www.environment.gov.au/biodiversity/invasive/weeds/weeds/why/index.html>

³⁸ "Pollution". The National Wildlife Federation. Accessed June 21, 2018. <https://www.nwf.org/Educational-Resources/Wildlife-Guide/Threats-to-Wildlife/Pollution>

Barriers	Description	Suggested action
	<ul style="list-style-type: none"> Traffic pollution is associated with many illnesses and can particularly affect children attending schools with high levels of traffic pollution.³⁹ 	<ul style="list-style-type: none"> Organise community clean-up days similar to Clean-Up Australia. Encourage the community to drive less, thereby reducing traffic pollution. Encourage the community to dispose of their animal waste correctly. Plant native drought-tolerant plants in community areas and encourage native household gardens to reduce water use. <p>Limitations</p> <ul style="list-style-type: none"> Complete removal of pollutants from the environment is a very challenging task and requires an extreme change in the way humans live and produce goods. Community education will be vital to the success of any future initiatives. Installation of stormwater treatments may be costly and limited in effectiveness. Managers should therefore choose the most applicable and cost-effective stormwater treatment for the area to be treated.
Roads	<p>Roads can pose a considerable barrier to the movement of wildlife through the fragmentation of habitat, leading to changes in foraging, reproduction and social behaviours. Threatened species may be those at highest risk of road barrier effects adding to further population declines. Wildlife attempting to cross from one side of the road to the other face a dangerous task. The loss of vegetation on roadsides removes the safe passage that trees provide, leading to an increase in vehicular mortality.</p> <p>Impacts</p> <ul style="list-style-type: none"> Roads create a barrier to the movement of fauna which may alter their behaviour, resulting in: <ul style="list-style-type: none"> Changes to foraging. Disruptions to migration or home-range use and possibly changed social structure and reduced reproduction. Altered gene flow. Vehicle mortality may reduce population size. 	<p>Solutions</p> <ul style="list-style-type: none"> Consider the impact of road extensions or upgrades to remnant vegetation and fauna hotspots and plan to reduce or avoid impacts at the project concept stage where possible. Implement wildlife crossing structures such as underpasses, culverts and canopy bridges in fauna hotspots to reduce vehicle induced mortality. Use funnel fences to divert fauna into crossing structures. Build culverts with a ledge to increase fauna use when water is present in the culvert. Increase the canopy cover and shrub cover along roadsides and median strips to increase safe passage across roads where this meets fire management prescriptions. Install animal visual and audible deterrent devices Place rocks and logs at the entrance of culverts and ensure protective cover such as trees or shrubs are also provided Install animal crossing awareness signage for motorists

³⁹ Rickwood, P., & Knight, D. *The health impacts of local traffic pollution on primary school age children*. Australian Cities Research Network, 2009. <https://opus.lib.uts.edu.au/bitstream/10453/12700/1/20090055530K.pdf>

Barriers	Description	Suggested action
	<ul style="list-style-type: none"> Removal of vegetation for roads may affect population dynamics/size due to loss of habitat size/structure and food resources. Road size influences fauna crossing. Small birds are less likely to cross larger roads than smaller roads due to a lack of cover. Amphibians are at higher risk of mortality crossing larger roads due to their slow speed. <p>Examples</p> <ul style="list-style-type: none"> The removal of habitat and subsequent reduction in habitat quality caused by the construction of roads may lead to a decrease in population size and changes to population dynamics. Vehicular mortality may also lead to decreases in population size.⁹ Roads can act as a barrier to movement potentially preventing fauna movement and altering gene flow, leading to inbreeding.⁹ Wildlife crossing structures such as overpasses, underpasses, culverts and rope bridges are effective in reducing the number of mortalities due to fauna attempting to cross the road.^{9 40} An increase in small bird and bats overpass utilisation was associated with increased vegetation structure. 	<ul style="list-style-type: none"> Plant native wildlife corridors along roadsides to improve connectivity between patches of remnant vegetation. Corridors should be at least 100 m wide where possible to reduce the impact of edge effects. A progressive transition to provide vegetated corridors on adjacent private land is a longer term preferable sustainable environmental outcome. Plant more shrubs close together to aid in dispersal of small birds and bats that move only short distances between shrubs. <p>Limitations</p> <ul style="list-style-type: none"> The construction of culverts and underpasses may be costly and is limited to new roads and road upgrades due to long construction time. Increasing vegetation to a size which will influence the safe passage of fauna crossing takes time and planning.
Buildings	<p>Buildings are an obvious barrier to native fauna, especially for movement of terrestrial, non-flying wildlife, however some impacts are less apparent and can affect all kinds of animals and ecological processes.</p> <p>Impacts</p> <ul style="list-style-type: none"> Loss of suitable habitat through clearing of vegetation when buildings are constructed reduces food and shelter resources for wildlife. Fragmentation of habitat by buildings can impact movement, dispersal and migration, and can isolate populations which may negatively impact reproductive success and gene flow Construction of buildings creates many of the threats already discussed, including light, noise, soil and water pollution, and erosion. 	<p>Solutions</p> <ul style="list-style-type: none"> Plant green roofs and walls, which can provide the following benefits: <ul style="list-style-type: none"> Longer roof lifespan Improved sound insulation Reduced heating and cooling requirements Reduced and slowed stormwater runoff Capture of gaseous and particulate pollutants Alleviation of urban heat island effects Increased biodiversity.

⁴⁰ Saving Animals: Compton Road Effect”. Griffith University. Accessed June 20, 2018. <https://www.griffith.edu.au/research/impact/compton-road-wildlife-corridor>.

Barriers	Description	Suggested action
	<ul style="list-style-type: none"> Excavation during building construction will disturb the soil which can destroy the 'seed bank' (seeds stored in the soil before germination) and create an area for weeds to colonise. Altered runoff and groundwater processes by limiting the area of soil available to absorb rainwater and diverting a large proportion of rainwater to stormwater. <p>Examples</p> <ul style="list-style-type: none"> When vegetation is fragmented throughout a developed area, the distance between and size of remaining patches is a limiting factor in allowing species to move from patch to patch, e.g. birds may easily fly between patches, whereas frogs cannot move large distances to find water. Construction of buildings can involve localised erosion which can lead to polluted runoff entering waterways where it can affect amphibians, fish, aquatic macroinvertebrates and aquatic mammals such as rakali. 	<ul style="list-style-type: none"> Information on green walls and roofs is provided by the government in the Your Home guide at http://www.yourhome.gov.au/materials/green-roofs-and-walls Promote the use of indigenous plants in parks and gardens to provide a food resource for native animals and create better connectivity of vegetation patches between buildings (see the City of Moonee Valley Planting Guide for Residents). Consider building design and the impact of buildings on birds. Buildings with glass may result in an increase in bird deaths. Glass with UV coat treatments, ceramic frit patterns, vertical lines no wider than 2 inches apart can reduce bird deaths. Other design considerations include: <ul style="list-style-type: none"> Reducing artificial light near glass buildings Adding slide screens Avoiding transparent passageways or tunnels that can trap birds See solutions for mitigating sound, light and pollution impacts on wildlife and apply them to building construction, especially if near existing habitat. Offset loss of habitat by enhancing vegetated areas with habitat features such as nest boxes, particularly if hollow bearing trees were removed for building construction, and creation of frog and waterfowl habitat with ponds/wetlands. <p>Limitations</p> <ul style="list-style-type: none"> Green walls and roofs may be costly to install and maintain and may not be a viable option for some existing buildings due to structural constraints such as drainage.
Aggressive species	Some species are more adaptable than others in urban areas and have been very successful in dominating the little habitat remaining. These species, though often native, compete with less-successful species and can also be aggressive towards humans. A common example is magpies, which pose a risk to the public through swooping. Another example is the noisy miner, which outcompetes other native bird species. Noisy miners have been listed as a key threatening process	<p>Solutions</p> <ul style="list-style-type: none"> Promote a shrubby understorey in vegetated areas, including acacias, to provide shelter and safe habitat for smaller birds, as

Barriers	Description	Suggested action
	<p>under the Commonwealth <i>Environment Protection and Biodiversity Conservation Act 1999</i>.</p> <p>Impacts</p> <ul style="list-style-type: none"> Noisy miners live in large groups and share the same kind of habitat as many other, smaller native birds such as pardalotes, silvereyes and eastern spinebills, however noisy miners will exclude these other species from an area through aggression and dominance of resources. This means there is a lower variety of birds to perform ecological functions such as pollination and seed dispersal and can limit the distribution of these species in the wider area. 	<p>noisy miners prefer open areas with eucalypts where they can get a view of their territory and forage on the ground.⁴¹</p> <ul style="list-style-type: none"> Culling is the most effective and humane method of reducing noisy miner numbers and can result in rapid improvement of habitat condition and re-establishment of other native bird species.^{42 43} <p>Limitations</p> <ul style="list-style-type: none"> Culls, especially of native species, can be controversial and opposed by the public. Community engagement and education on the issue is important in gaining acceptance.
In stream barriers	<p>There can be many barriers in disturbed or altered waterways that can prevent fish movement. These include weirs, culverts and concrete channels. Of the 83 species of freshwater fish in south-eastern Australia, half migrate at least once as part of their life cycle.</p> <p>Impacts</p> <ul style="list-style-type: none"> In-stream barriers reduce connectivity which can reduce or prevent dispersal, isolating populations and preventing gene flow. In-stream barriers can affect aquatic mammals, crustaceans and turtles. <p>Examples</p> <ul style="list-style-type: none"> In-stream barriers can alter the flow velocity in waterways which is a limiting factor in fish migration through culverts. Flow direction can be a limiting factor which is altered by in-stream barriers. Concrete channels can act as barriers by changing water velocity, while also containing very little habitat to provide food and shelter for fish and aquatic macroinvertebrates. 	<p>Solutions</p> <ul style="list-style-type: none"> Design culverts to improve fish movement through waterways in urban areas. Some examples of good culvert design are: Culverts that are as wide as the original stream bed to maintain natural water velocity, and to prevent build-up of debris that can act as a further barrier Culverts should ideally be less than 6 m long, or if longer, should include rest areas for fauna and features to stop water velocity from increasing Let in as much natural light as possible Use baffles (energy dissipaters) to regulate flow. This can also create short bursts of high velocities to aid fish movement Use a natural substrate that does not impede water flow and creates habitat for aquatic macroinvertebrates. Consider use of fish ladders and rock ramps (structures to aid movement of fish over or around in-stream barriers such as culverts or weirs) if there is a known species that would benefit from these.

⁴¹ Hastings, Richard A., and Andrew J. Beattie. "Stop the bullying in the corridors: can including shrubs make your revegetation more Noisy Miner free?". *Ecological Management & Restoration* 7, no. 2 (2006): 105-112.

⁴² Debus, S. J. S. "The effect of Noisy Miners on small bush birds: an unofficial cull and its outcome." *Pacific Conservation Biology* 14, no. 3 (2008): 185-190.

⁴³ Clarke, Michael F., and Marilyn J. Grey. "Managing an over-abundant native bird: the noisy miner (*Manorina melanocephala*)." *Temperate Woodland Conservation and Management* (2010): 115-126.

Barriers	Description	Suggested action
		<p>Limitations</p> <ul style="list-style-type: none"> • Expert advice should be sought if baffles, fish ladders or rock ramps are to be used so that they are effective and do not pose a danger to wildlife.

Appendix F. Opportunities to create safer landscapes

Table F1. Planting design for fuel management zones to create safe landscapes

Topic	Description	Action						
Address bushfire threat to people and property	The construction of biolink corridors that increase biomass can increase fire intensity. Vegetation selection that has a higher flammability or is poorly designed close to a dwellings poses an increased risk to people and property. Fires moving along uninterrupted vegetation corridors are more difficult to control compared to corridors with fuel breaks.	<p>Solutions</p> <ul style="list-style-type: none"> • Functional biolink corridors are to be setback 150 metres from new and existing dwellings and buildings. • Clause 44.06 identifies a vegetation bushfire site assessment area extending 150 metres from the development to assess bushfire hazard. • For dwellings constructed prior to 2009, clause 52.12 Bushfire Protection Exemptions allows a cleared zone of 10m around dwellings, followed by a cleared understorey zone to 50m where there is a Bushfire Management Overlay, or a cleared understorey zone to 30m where there is no Bushfire Management Overlay. • For dwellings constructed after 2009, the defendable space is defined in the Bushfire Management Plan in the permit based on the distances defined in clause 53.02 Bushfire Planning. The specifications include; <ul style="list-style-type: none"> - Grass must be short cropped and maintained during the declared fire danger period. - All leaves and vegetation debris must be removed at regular intervals during the declared fire danger period. - Within 10 metres of a building, flammable objects must not be located close to the vulnerable parts of the building. - Plants greater than 10 centimetres in height must not be placed within 3 metres of a window or glass feature of the building. - Shrubs must not be located under the canopy of trees. - Individual and clumps of shrubs must not exceed 5 square metres in area and must be separated by at least 5 metres. - Trees must not overhang or touch any elements of the building. - The canopy of trees must be separated by at least 5 metres. - There must be a clearance of at least 2 metres between the lowest tree branches and ground level. - refer to cross section figure 10 demonstrating defendable space design in the text • A summary of minimum setback distances that are consider a Fire Danger Index of 100 and Bushfire attack level of 12.5 is extracted below; <table border="1" data-bbox="779 1342 1951 1433"> <thead> <tr> <th data-bbox="779 1342 1115 1433">Slope</th> <th data-bbox="1115 1342 1532 1433">Vegetation type</th> <th data-bbox="1532 1342 1951 1433">Distance (metres) for bushfire attack level '12.5'</th> </tr> </thead> <tbody> <tr> <td style="height: 20px;"> </td> <td> </td> <td> </td> </tr> </tbody> </table>	Slope	Vegetation type	Distance (metres) for bushfire attack level '12.5'			
Slope	Vegetation type	Distance (metres) for bushfire attack level '12.5'						

Topic	Description	Action		
		All upslopes and flat land (0 degrees)	Forest	48
			Woodland	33
			Scrub	27
			Shrubland	19
			Rainforest	23
			Grassland	19
		Downslope >0 to 5 degrees	Forest	57
			Woodland	41
			Scrub	31
			Shrubland	22
			Rainforest	29
			Grassland	22
		Downslope >5 to 10 degrees	Forest	69
			Woodland	50
			Scrub	35
			Shrubland	25
			Rainforest	36

Topic	Description	Action																					
		<table border="1" data-bbox="779 284 1951 742"> <tr> <td data-bbox="779 284 1115 347"></td> <td data-bbox="1115 284 1529 347">Grassland</td> <td data-bbox="1529 284 1951 347">25</td> </tr> <tr> <td data-bbox="779 347 1115 438">Downslope >10 to 15 degrees</td> <td data-bbox="1115 347 1529 438">Forest</td> <td data-bbox="1529 347 1951 438">82</td> </tr> <tr> <td data-bbox="779 438 1115 499"></td> <td data-bbox="1115 438 1529 499">Woodland</td> <td data-bbox="1529 438 1951 499">60</td> </tr> <tr> <td data-bbox="779 499 1115 560"></td> <td data-bbox="1115 499 1529 560">Scrub</td> <td data-bbox="1529 499 1951 560">39</td> </tr> <tr> <td data-bbox="779 560 1115 620"></td> <td data-bbox="1115 560 1529 620">Shrubland</td> <td data-bbox="1529 560 1951 620">28</td> </tr> <tr> <td data-bbox="779 620 1115 681"></td> <td data-bbox="1115 620 1529 681">Rainforest</td> <td data-bbox="1529 620 1951 681">45</td> </tr> <tr> <td data-bbox="779 681 1115 742"></td> <td data-bbox="1115 681 1529 742">Grassland</td> <td data-bbox="1529 681 1951 742">28</td> </tr> </table> <ul style="list-style-type: none"> <li data-bbox="730 790 2000 877">• Planting outside of the defensible space area but within the 150 metre fire behaviour site assessment area could consider limited environmental outcomes by designing plantings that are isolated and spatially distant. Planting design should be considered on a site by site basis with references to the following resources; <ul style="list-style-type: none"> <li data-bbox="824 885 1664 914">• CFA Riparian land and bushfire. Resource document version 2. (2017) <li data-bbox="824 927 1693 956">• CFA Landscaping for bushfire. Garden design and plant selection. (2011) <li data-bbox="730 970 2033 1417">• The guideline documents provide the following advice: <ul style="list-style-type: none"> <li data-bbox="824 1010 1128 1038">• All vegetation will burn <li data-bbox="824 1051 1899 1080">• Spatial distance and separation between plants is fundamental to control for fire behaviour <li data-bbox="824 1093 1823 1121">• Fire behaviour and vegetation goals can be achieved through careful planting design <li data-bbox="824 1134 1993 1222">• Identify that risk can be substantially reduced by increasing the separation between assets and vegetation and the management of both vertical and horizontal vegetation structure (i.e. removal of ladder fuels) <li data-bbox="824 1235 2033 1264">• Avoiding revegetation within a distance likely to expose buildings to unacceptable levels of radiant heat <li data-bbox="824 1276 1912 1374">• Assessment of a plants characteristics in terms of 'firewise' plants for managed gardens. Six characteristics to consider include; plant branching pattern, texture and density, leaf type (including (a) fineness, size, shape and (b) content of oils/waxes/resins) and retention of dead material <li data-bbox="824 1386 1939 1415">• Replacing unmanaged weedy grassed areas with firewise plants that to reduce overall biomass 		Grassland	25	Downslope >10 to 15 degrees	Forest	82		Woodland	60		Scrub	39		Shrubland	28		Rainforest	45		Grassland	28
	Grassland	25																					
Downslope >10 to 15 degrees	Forest	82																					
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	Scrub	39																					
	Shrubland	28																					
	Rainforest	45																					
	Grassland	28																					

Topic	Description	Action
		<ul style="list-style-type: none"> • Working with natural resource management agencies and fire services to distinguish perceived as opposed to actual risks from bushfire. • Other reference documents include; Plants described by the Australian Plant Society which could be considered as part of a risk assessment in the CFA Landscaping for bushfire 'plant selection key.' can be found on their website www.apsvic.org.au - Fuel managed zones can also be incorporated using features such as internal property tracks to create a 'fuse break' for a potential running fire (refer to cross section diagram in 9.3.2).

Table F2. Vegetation management opportunities to influence fire behaviour at a landscape scale within a biolink

Treatment name	Private/public land	Details	Practicality to implement	Constraints and impacts to the natural environment
1. Fire break	Private and public land	Complete removal of trees, shrubs and ground storey vegetation. Ongoing mechanical slashing.	After initial cost ongoing maintenance can be cost effective	Significant initial cost for tree removal. All native habitat is removed
2. Earth plough fire break	Private and public land	Complete removal of trees, shrubs and ground storey vegetation. Ongoing cultivation of soil in fire danger period.	After initial cost ongoing maintenance can be cost effective.	Specific machinery required. Not an option on slopes due to erosion issues. All native habitat is removed
3. Mechanical slashing all understorey vegetation	Private and public land	Modification of shrub and ground storey vegetation.	Highly cost-effective treatment option	*Only remaining habitat is within the tree canopy
4. Removal of select vegetation strata	Typically applied to private land but can be applied to private land	Clumping of shrubs, separation of trees to influence fire behaviour (refer to Table 6, c53.02. -lists nine vegetation management opportunities)	Initial cost to selectively thin tree canopy.	*Limited vegetation habitat is retained in the tree and shrub storey
5. Removal of weed species to impact biomass within native bushland	Private and public land	Plants that are not indigenous to the Shire can proliferate and elevate biomass. Non-native species typically elevate biomass compared to natives (i.e. Sweet Pittosporum, Blackberry and Broom species). Target removal of larger weeds which reduces the overall biomass of the site which will impact fuel loads.	Targeted removal of selected weed species is slow and can be costly.	Where target weed species have infested an area significant biomass reduction can be achieved over a larger area.
6. Graze vegetation with stock	Private land	Stock graze ground storey and shrub vegetation. Tree storey vegetation also gradually impacted through trampling and stock grazing around tree root plates.	Highly cost effective.	*Stock grazing is difficult to control and is indiscriminate, removing native species and weed species.

Treatment name	Private/public land	Details	Practicality to implement	Constraints and impacts to the natural environment
7. Fuel reduction burning	Typically applied to public land. Potentially can be applied to private land.	Controlled cyclic burning ground storey and understorey vegetation for fuel reduction to influence fire behaviour.	Time and resource consumptive.	*Burning more frequently than the tolerable fire interval will more likely change the species composition to fire obligate species. While still providing habitat for some species, likely to lead to an overall reduction in diversity of native species. Burning weeds requires follow up weed control maintenance. Difficulties in risk management and controlling post burn actions when burning on private land.
8. Candling specific species of Eucalypt trees	Typically applied to public land	Controlled low intensity burning of Eucalypt tree bark to reduce the bark hazard of flying bark embers during a fire.		Lower environmental impact activity. Species living in habitats within the bark (i.e. micro bats) impacted.
9. Ecological burning 1	Public land	Low intensity burning of under storey and shrub storey vegetation within tolerable fire intervals (TFI) of the specific vegetation. Burning in mosaics to create multi-aged vegetation classes. Investigate future opportunities with 'cultural fire practise burning' by traditional owners.	Time and resource consumptive.	At a landscape scale vegetation that is burnt in a mosaic can reduce overall quantity of biomass. Ecological burning is an optimal method to enhance flora and fauna habitats. Vegetation TFI varies dependant on the type. 'Cultural fire practise burning' by traditional owners is an untested management technique on Cardinia's public land.
10. Ecological burning 2	Private land	Low intensity burning of under storey and shrub storey vegetation within tolerable fire intervals (TFI) of the specific vegetation. Burning in mosaics to create multi-aged vegetation classes. Investigate future opportunities with 'cultural fire practise burning' by traditional owners.		At a landscape scale vegetation that is burnt in a mosaic can reduce overall quantity of biomass. Ecological burning is an optimal method to enhance flora and fauna habitats. Vegetation TFI varies dependant on the type. 'Cultural fire practise burning' by traditional owners is an untested management technique on Cardinia Shire's private land.

Treatment name	Private/public land	Details	Practicality to implement	Constraints and impacts to the natural environment
				Difficulties in risk management and controlling post burn actions when burning on private land.
11. Planting lower flammability species	Private and public land	Utilise CFA fire-wise species in planting design to influence fire behaviour. Could be used to improve connectivity of vegetation while still influencing fire behaviour. Modify planting strata.	Cost effective	Cost effective Non-native species may not provide the same habitat value as native species but would be preferential to complete clearing.

**denotes potential to target weedy areas as a priority which has an overall environmental benefit*

Strategic and tactical access roads where vegetation management works can be targeted

- Strategic access roads
 - Beaconsfield - Emerald Road
 - Wellington Road
 - Belgrave - Gembrook Road
 - Emerald Monbulk Road
 - Healesville - Koo Wee Rup Road (Cockatoo - Woori Yallock)
 - Healesville - Koo Wee Rup Road (Pakenham - Cockatoo)
 - Gembrook Road
 - Gembrook - Launching Place Road
 - Officer Road
 - Leppitt Road
- Tactical access roads
 - Macclesfield Road
 - Snell Road
 - Fogarty Road
 - Moore Road
 - Tonimbuk Road
 - Mcdonald's Drain Road East

Appendix G. Assessment of unconstructed roads

Background

A desktop assessment of Cardinia Shire's unconstructed government roads was undertaken by ELA to determine the environmental values they contain and potential threats to biodiversity.

The assessment methodology has been based on the unconstructed government road assessment method provided by the shire. Using high-resolution aerial imagery, spatial datasets and the outputs of the land cover classification (undertake as part of the connectivity study), each road reserve without a formalised road or track was assessed against the criteria outlined in Table G1.

Table G1. Assessment criteria for Cardinia Shire's unconstructed roads

Assessment component	Description	Value
Woody vegetation cover	Woody vegetation cover across road casements based on land cover dataset (e.g. remote sensing analysis).	<ul style="list-style-type: none"> • % cover
Vegetation origin	The origin of the vegetation within the road casement.	<ul style="list-style-type: none"> • native • native and planted • native and introduced
Habitat type	The structure of the dominant vegetation within the road casement.	<ul style="list-style-type: none"> • grassland • scattered trees/shrubs • woodland/forest • scrub • wetland/riparian • other
Connectivity	The context of the road within the context of the connectivity network, being either part of a large habitat patch (core area), a linear pathway or series of steppingstones (corridor) or isolated without connectivity.	<ul style="list-style-type: none"> • core area • corridor • isolated
Distance	The length of the road casement without a formal track or road.	<ul style="list-style-type: none"> • meters
Land use	The current, dominant land use within the road casement.	<ul style="list-style-type: none"> • no disturbance • grazed/cropped • road • driveway • track • other
Security	Whether the roadside is fenced or not.	<ul style="list-style-type: none"> • fenced • unprotected • other
Likelihood of development	The likelihood land could be developed based on proximity to urban areas and land zoning.	<ul style="list-style-type: none"> • high • moderate • low

The results of the assessment have been collated into a spatial dataset. Figure G1 shows the location of unconstructed roads in Cardinia Shire. Table G2 presents the complete dataset for each

road identified. Note: Due to the desktop type assessment, there are some gaps in the data collected, and this will appear as a blank field in Table G2.

Figure G1. Unconstructed roads in Cardinia Shire



Table G2. Unconstructed road assessment dataset

ID	Name	Locality	Vegetation origin	Habitat type	Connectivity	Length (m)	Land use	Security	Develop	Veg cover (%)
1	Twin Creeks Rd	Pakenham Upper	N	W	Link	407	Driveway	UP	M	4
2	Twin Creeks Rd	Pakenham Upper	N	W	Core	383	None	UP	L	5
3	Unnamed	Pakenham Upper	NI	W	Core	264	Other	UP	L	2
4	Unnamed	Pakenham Upper	N	W	Core	589	None	UP	H	5
5	Dorothy Lane	Gembrook	N	W	Core	634	Driveway	UP	M	4
6	Unnamed	Emerald	N	W	Core	1460	None	UP	L	5
7	Buckland Lane	Pakenham Upper	NI	W	Link	392	Driveway	UP	H	4
8	Unnamed	Pakenham Upper	N	W	Core	427	None	F	L	5
9	Unnamed	Cockatoo	NP	W	Core	1183	None	UP	L	5
10	Unnamed	Pakenham Upper	N	W	Core	1071	None	O	L	5
11	Unnamed	Gembrook	N	W	Core	227	None	O	L	5
12	Unnamed	Mount Burnett	NP	G		188	Grazed	UP	L	1
13	Weatherhead Hill Trk	Tynong North	N	W	Core	325	Driveway	UP	H	4
14	Unnamed	Cockatoo	NI	W	Link	3000	Other	UP	L	2
15	Unnamed	Pakenham Upper	N	W	Core	1084	None	O	L	5
16	Unnamed	Beaconsfield Upper	NI	R	Link	202	Grazed	UP	L	3
17	Carne Rd	Pakenham Upper	N	W	Link	325	Other	F	L	5
18	Unnamed	Gembrook	N	W	Core	225	Other	UP	L	4

ID	Name	Locality	Vegetation origin	Habitat type	Connectivity	Length (m)	Land use	Security	Develop	Veg cover (%)
19	Unnamed	Gembrook	N	W	Link	494	Driveway	UP	L	4
20	Unnamed	Gembrook	N	W	Link	663	None	UP	M	5
21	Unnamed	Gembrook	NI	W		136	Grazed	UP	L	1
22	Unnamed	Pakenham Upper	N	W	Core	663	Track	UP	L	3
23	Unnamed	Beaconsfield Upper	N	W	Core	485	Other	UP	L	5
24	Joffre Pde	Cockatoo	N	W	Core	542	None	UP	H	4
25	Unnamed	Garfield	N	W	Link	383	Grazed	UP	L	3
26	Unnamed	Pakenham Upper	N	W	Core	439	Track	UP	L	4
27	Unnamed	Mount Burnett	NI	S	Link	775	Grazed	UP	L	2
28	Unnamed	Nar Nar Goon North	NI	W	Link	1066	Grazed	UP	L	3
29	Four Mile Trk	Tynong North	N	W	Core	4050	None	O	H	5
30	Unnamed	Gembrook	N	W	Link	1216	Grazed	UP	L	3
31	Weatherhead Rd	Tynong North	NI	W	Link	624	Grazed	UP	L	3
32	Unnamed	Cockatoo	N	W	Core	786	None	UP	H	4
33	Hillside Rd	Cockatoo	N	W	Link	906	None	F	M	5
34	Unnamed	Emerald	N	W	Core	430	Driveway	O	H	4
35	Unnamed	Tynong North	NI	S	Isolated	342	Grazed	UP	L	1
36	Steering Wheel Trk	Gembrook	N	W	Core	2154	None	O	L	5
37	Forbes Rd	Nar Nar Goon North	NI	W	Link	1579	Grazed	UP	L	2

ID	Name	Locality	Vegetation origin	Habitat type	Connectivity	Length (m)	Land use	Security	Develop	Veg cover (%)
38	Pettigrew Rd	Garfield North	N	W	Core	891	None	O	H	5
39	Godfrey Lane	Officer	NI	S		360	Grazed	F	L	3
40	Unnamed	Pakenham	N	W	Core	344	None	UP	L	5
41	Topp Rd	Tonimbuk	N	W	Isolated	518	None	UP	L	5
42	Topp Rd	Tonimbuk	N	W	Link	518	Road	UP	M	4
43	Unnamed	Mount Burnett	N	W	Core	1177	None	F	L	5
44	Mulberry Trk	Gembrook	N	W	Core	198	None	UP	L	5
45	Unnamed	Gembrook	N	W	Core	1104	None	O	L	5
46	Dallas St	Emerald	NP	W		114	Other	UP	L	3
47	Unnamed	Officer	N	W	Core	571	None	UP	M	5
48	Larmour Rd	Pakenham	NI	S		393	Grazed	UP	H	1
49	Unnamed	Beaconsfield	NI	W	Core	524	Other	UP	L	4
50	Unnamed	Gembrook	NI	W		165	Grazed	UP	L	3
51	Unnamed	Beaconsfield Upper	N	W	Core	442	Driveway	UP	H	3
52	Unnamed	Tynong North	NI	W	Isolated	1951	Grazed	UP	L	2
53	Hatfield Rd	Pakenham	NI	W	Isolated	459	Grazed	UP	L	4
54	Unnamed	Gembrook	NP	S	Link	670	Grazed	UP	L	2
55	Unnamed	Tonimbuk	NI	S	Isolated	413	Other	O	H	1
56	Unnamed	Officer	N	W	Core	240	None	UP	H	5

ID	Name	Locality	Vegetation origin	Habitat type	Connectivity	Length (m)	Land use	Security	Develop	Veg cover (%)
57	Unnamed	Officer	N	W	Core	540	Grazed	UP	H	5
58	Unnamed	Officer	N	W	Core	400	None	UP	L	5
59	Unnamed	Nar Nar Goon North	NI	W		1418	Track	UP	H	1
60	Williams Rd	Gembrook	N	W	Core	9165	None	O	L	5
61	Unnamed	Tonimbuk	NI	W	Link	1486	Track	UP	H	3
62	Unnamed	Dewhurst	NI	S	Link	833	Grazed	UP	L	2
63	Unnamed	Cockatoo	N	W	Core	1014	Other	UP	H	3
64	Unnamed	Tonimbuk	NI	W	Link	604	Grazed	UP	H	3
65	Unnamed	Tonimbuk	NI	S	Isolated	334	Other	O	H	1
66	Unnamed	Gembrook	N	W	Core	1010	Road	UP	H	4
67	Unnamed	Gembrook	NI	W	Link	1250	Grazed	UP	L	1
68	Pershing Av	Cockatoo	N	W	Core	259	None	UP	H	5
69	Unnamed	Tonimbuk	NI	S	Isolated	238	Grazed	O	H	1
70	Unnamed	Emerald	N	W	Link	195	Other	UP	L	3
71	Unnamed	Gembrook	NP	W	Link	206	Other	F	L	2
72	Garfield North Rd	Garfield North	NI	W	Core	314	Driveway	UP	L	4
73	Unnamed	Tynong North	N	W	Link	237	Driveway	UP	H	5
74	Unnamed	Tynong North	N	W	Link	765	Driveway	UP	L	4
75	Unnamed	Tonimbuk	N	W	Core	194	Other	UP	L	4

ID	Name	Locality	Vegetation origin	Habitat type	Connectivity	Length (m)	Land use	Security	Develop	Veg cover (%)
76	Unnamed	Tynong North	NP	W	Core	1727	Driveway	UP	L	3
77	Unnamed	Nangana	N	W	Core	2757	Track	O	H	4
78	Unnamed	Cockatoo	NI	W		286	Other	UP	H	2
79	Unnamed	Officer	N	W	Link	404	Other	UP	M	3
80	Gembrook - Launching Place Rd	Gembrook	N	W	Core	424	None	O	L	5
81	Soldiers Rd	Gembrook	N	W	Core	800	None	O	L	5
82	Craik Rd	Beaconsfield Upper	NI	W		251	Track	UP	H	1
83	Unnamed	Cockatoo	NI	S		1310	Grazed	UP	M	1
84	Unnamed	Emerald	N	W	Core	1114	Driveway	UP	L	5
85	Unnamed	Tonimbuk	NI	W	Core	646	Track	UP	H	3
86	Unnamed	Tonimbuk	N	W	Core	239	None	F	L	5
87	Unnamed	Tonimbuk	NI	S	Isolated	1688	Track	UP	H	1
88	Unnamed	Cockatoo	NI	G		1876	Grazed	UP	M	1
89	Unnamed	Avonsleigh	NI	W	Link	696	Other	UP	L	4
90	Norbury Rd	Beaconsfield Upper				518	Driveway	UP	L	1
91	Unnamed	Tonimbuk	N	W	Core	3071	None	O	L	5
92	Unnamed	Tonimbuk	N	W	Core	2633	None	O	M	3
93	Unnamed	Cockatoo	NI	S		458	Grazed	UP	M	1

ID	Name	Locality	Vegetation origin	Habitat type	Connectivity	Length (m)	Land use	Security	Develop	Veg cover (%)
94	Merretts Rd	Avonsleigh	N	W	Link	535	Track	UP	M	5
95	Orchard Lane	Avonsleigh	N	W	Link	147	Grazed	UP	L	3
96	Unnamed	Mount Burnett	NP	G		827	Grazed	UP	L	1
97	Town Rd	Gembrook	NI	S		156	Grazed	UP	H	1
98	Unnamed	Pakenham Upper	NI	W	Core	1004	Driveway	UP	H	2
99	Unnamed	Nar Nar Goon North	N	W	Link	608	None	O	L	5
100	Carne Rd	Pakenham Upper	NI	S	Link	1062	Other	F	L	4
101	Unnamed	Gembrook	NI	S	Isolated	434	Grazed	UP	L	1
102	Unnamed	Cockatoo	N	W	Core	112	None	UP	L	5
103	Unnamed	Nar Nar Goon North	N	W	Link	604	Driveway	UP	M	4
104	Barongarook Rd North	Maryknoll	N	W	Link	735	Track	UP	H	5
105	Unnamed	Cockatoo	NP	W	Link	270	Other	UP	M	4
106	Unnamed	Officer	N	W	Core	375	Other	UP	L	3
107	Unnamed	Gembrook	N	W		162	None	UP	H	5
108	Trevor Rd	Nar Nar Goon North	NI	W		812	Driveway	UP	H	3
109	Wilks Rd	Officer	N	W	Core	390	None	UP	L	5
110	Haunted Gully Rd	Officer	N	W	Core	604	None	UP	H	5
111	Unnamed	Avonsleigh	N	W	Core	391	Driveway	O	H	5
112	Unnamed	Cockatoo	N	W	Core	1067	Track	UP	H	4

ID	Name	Locality	Vegetation origin	Habitat type	Connectivity	Length (m)	Land use	Security	Develop	Veg cover (%)
113	Unnamed	Cardinia				298	Grazed	UP	L	1
114	Unnamed	Gembrook	N	W	Core	1150	Track	O	M	5
115	Unnamed	Bunyip North	NI	W	Link	724	Grazed	UP	L	3
116	Unnamed	Bunyip North	NI	W	Link	1077	Grazed	UP	H	2
117	Unnamed	Cardinia				1354	Track	F	H	1
118	Unnamed	Gembrook	N	W	Core	550	None	O	L	5
119	Unnamed	Garfield North	N	W	Core	2442	None	O	M	5
120	Unnamed	Cardinia	NI	Sc		897	Grazed	F	L	1
121	Unnamed	Vervale				1004	Grazed	UP	H	1
122	Unnamed	Maryknoll	NP	W	Link	265	Driveway	UP	H	4
123	Unnamed	Gembrook	N	W	Core	116	None	F	L	5
124	Unnamed	Cockatoo	N	W	Link	483	None	F	L	5
125	Unnamed	Longwarry				1012	Grazed	UP	H	1
126	Backhouse Rd	Gembrook	N	W	Core	3236	Other	UP	M	3
127	Unnamed	Pakenham Upper	N	W	Core	224	None	O	L	5
128	Unnamed	Nar Nar Goon North				598	Other	UP	L	1
129	Unnamed	Pakenham Upper	N	W	Core	988	Track	UP	L	4
130	Ulmer Rd	Emerald	N	R	Link	420	Grazed	UP	L	5
131	Unnamed	Tynong				405	Grazed	UP	H	1

ID	Name	Locality	Vegetation origin	Habitat type	Connectivity	Length (m)	Land use	Security	Develop	Veg cover (%)
132	Unnamed	Garfield	NI	W		253	Other	UP	L	3
133	Finlay Lane	Garfield	NI	W	Link	1235	Grazed	F	M	3
134	Unnamed	Garfield	NI	W	Link	807	Other	F	M	2
135	Unnamed	Garfield North	NI	G		542	Grazed	UP	H	2
136	Unnamed	Gembrook	N	W	Core	1160	None	UP	L	4
137	Lupton Trk	Tynong North	N	W	Core	1436	None	O	L	5
138	Jolley Rd	Tonimbuk	N	W	Link	1016	Track	UP	H	4
139	Anderson Rd	Bunyip				310	Driveway	UP	L	1
140	Granite Lane	Tynong				321	Other	UP	L	1
141	Unnamed	Tynong				1699	Grazed	UP	H	1
142	Canty Lane	Pakenham				392	Grazed	UP	L	1
143	Unnamed	Tynong	NI	W	Isolated	1515	Grazed	F	M	3
144	Unnamed	Beaconsfield Upper	NI	W	Core	383	Other	UP	H	4
145	Unnamed	Bunyip	NP	W	Link	821	None	UP	H	3
146	Unnamed	Bunyip	NI	W	Link	444	Grazed	UP	H	3
147	Quigley Rd	Tynong	N	W	Isolated	1052	None	UP	L	5
148	Unnamed	Beaconsfield Upper	N	W	Core	334	None	UP	L	5
149	Unnamed	Bunyip	NI	W	Isolated	638	Grazed	UP	H	3
150	Unnamed	Bunyip	NI	S	Link	533	Grazed	F	H	3

ID	Name	Locality	Vegetation origin	Habitat type	Connectivity	Length (m)	Land use	Security	Develop	Veg cover (%)
151	Unnamed	Pakenham Upper	NI	W	Link	873	Driveway	UP	L	2
152	Unnamed	Bunyip				385	Grazed	UP	L	1
153	Unnamed	Bunyip	NI	W	Isolated	705	Other	UP	H	3
154	Spencer Av	Emerald	NI	W		241	Driveway	UP	H	1
155	Henderson Rd	Cockatoo				145	Grazed	UP	L	1
156	Hope St	Bunyip	NI	S		447	Grazed	UP	H	1
157	Unnamed	Cora Lynn				1418	Grazed	F	M	1
158	Reed Av	Beaconsfield Upper	N	W	Core	310	None	UP	M	5
159	Harold St	Cockatoo	N	W	Link	231	Driveway	UP	H	3
160	Unnamed	Iona				1815	Grazed	UP	H	1
161	Unnamed	Cockatoo	N	W	Core	301	Other	UP	L	5
162	Unnamed	Tynong	N	W	Isolated	377	Other	UP	H	3
163	Unnamed	Gembrook	N	W	Core	2598	None	O	L	5
164	Unnamed	Bunyip	NP	W	Isolated	633	Other	UP	H	3
165	Unnamed	Bunyip North	NI	W	Link	1092	Grazed	UP	L	4
166	Unnamed	Gembrook	N	W	Core	1338	None	O	L	5
167	Unnamed	Garfield	NI	S		619	Other	UP	H	2
168	Unnamed	Tynong	NI	Sc	Link	529	Grazed	UP	L	3
169	Unnamed	Dalmore				377	Grazed	UP	L	1

ID	Name	Locality	Vegetation origin	Habitat type	Connectivity	Length (m)	Land use	Security	Develop	Veg cover (%)
170	Unnamed	Modella	N	W	Link	1071	Other	F	H	3
171	Unnamed	Cora Lynn				1002	Other	UP	H	1
172	Unnamed	Pakenham Upper	N	W	Core	918	None	O	L	5
173	Unnamed	Modella	NI	S		878	Grazed	UP	H	2
174	Unnamed	Bayles				328	Road	UP	L	1
175	Unnamed	Emerald	N	W	Link	495	None	F	H	5
176	Unnamed	Longwarry				925	Grazed	UP	H	1
177	Gowen Lea Rd	Dalmore				587	Grazed	UP	L	1
178	Bench Rest Trk	Gembrook	N	W	Core	719	None	O	L	5
179	Unnamed	Beaconsfield Upper				523	Grazed	UP	L	1
180	Unnamed	Gembrook	N	W	Core	3354	None	O	H	5
181	Unnamed	Nar Nar Goon North	N	W		284	Grazed	UP	L	1
182	Unnamed	Catani	NI	S		1058	Other	F	H	1
183	Unnamed	Gembrook	N	W	Core	1146	None	UP	L	4
184	Unnamed	Yannathan				3983	Grazed	UP	H	1
185	Unnamed	Iona	NI	S		4991	Other	F	H	1
186	Calder Rd	Nangana	N	W	Core	1269	Track	UP	L	4
187	Mcnabs Rd	Bayles				1013	Grazed	UP	L	1
188	Unnamed	Modella				867	Grazed	F	L	1

ID	Name	Locality	Vegetation origin	Habitat type	Connectivity	Length (m)	Land use	Security	Develop	Veg cover (%)
189	Unnamed	Nyora	NI	W	Link	383	Grazed	UP	L	3
190	Nyora Estate Rd	Nyora	NI	S	Isolated	1598	Grazed	UP	L	3
191	Unnamed	Lang Lang East				515	Driveway	UP	L	1
192	Scanlons Drain Rd	Catani	NI	S	Isolated	1306	Grazed	F	H	2
193	Unnamed	Cardinia				314	Grazed	UP	H	1
194	Mcdonalds Rd	Caldermeade				1860	Grazed	UP	H	1
195	Unnamed	Pakenham South				550	Road	UP	H	1
196	Unnamed	Tynong North	N	W	Isolated	1337	Other	UP	L	3
197	Bassed Rd	Garfield North	N	W	Link	326	Road	UP	H	4
198	Unnamed	Heath Hill	NI	S	Link	627	Driveway	O	H	3
199	Unnamed	Yannathan	NI	W	Link	2868	Grazed	UP	H	4
200	Unnamed	Gembrook	N	W	Isolated	634	None	F	L	5
201	Unnamed	Catani				1678	Grazed	UP	L	1
202	Unnamed	Lang Lang	NI	Sc		153	Grazed	UP	L	2
203	Mccolls Rd	Modella	N	W	Link	1094	Track	F	M	4
204	Unnamed	Gembrook	N	W	Isolated	483	Grazed	UP	M	4
205	Unnamed	Gembrook	NI	Sc	Link	284	Track	UP	L	3
206	Unnamed	Dalmore				322	Grazed	UP	L	1
207	Unnamed	Koo Wee Rup				249	Driveway	UP	H	1

ID	Name	Locality	Vegetation origin	Habitat type	Connectivity	Length (m)	Land use	Security	Develop	Veg cover (%)
208	Unnamed	Catani				1103	Driveway	UP	L	1
209	Unnamed	Koo Wee Rup	NI	R	Link	2364	Grazed	UP	L	2
210	Unnamed	Bunyip North	N	W	Link	1239	Track	UP	L	5
211	Cameron Rd	Lang Lang				1900	Grazed	UP	M	1
212	Unnamed	Officer	NI	W		239	Driveway	UP	H	3
213	Unnamed	Officer	NI	W		488	Grazed	UP	L	3
214	Unnamed	Bunyip North	NI	S	Isolated	1568	Track	UP	H	1
215	Unnamed	Bunyip North	NI	W	Link	2030	Grazed	UP	L	1
216	Unnamed	Yannathan				1235	Grazed	UP	H	1
217	Backhouse Rd	Gembrook	N	W	Core	2121	Grazed	O	L	4
218	Unnamed	Lang Lang				551	Grazed	UP	H	1
219	Stanlake Rd	Lang Lang				244	Driveway	UP	H	1
220	Unnamed	Officer	NI	S	Link	985	Other	UP	H	3
221	Unnamed	Nar Nar Goon North	NI	S		624	Grazed	UP	M	2
222	Unnamed	Lang Lang				973	Driveway	UP	L	1
223	Unnamed	Lang Lang	NI	W	Core	3400	Grazed	O	M	3
224	Unnamed	Lang Lang	N	W	Core	532	Track	UP	M	4
225	Mills Rd	Tynong North	N	S	Link	313	Driveway	UP	L	3
226	Unnamed	Lang Lang	NI	W	Core	1235	Track	UP	M	3

ID	Name	Locality	Vegetation origin	Habitat type	Connectivity	Length (m)	Land use	Security	Develop	Veg cover (%)
227	Unnamed	Nyora				1207	Grazed	UP	H	1
228	Unnamed	Lang Lang	NI	S		985	Other	UP	H	2
229	Wallaby Ct	Garfield North	N	W	Link	2388	Grazed	F	L	4
230	Unnamed	Tynong North	N	W	Link	1017	Grazed	UP	M	4
231	Unnamed	Lang Lang				653	Driveway	UP	H	1
232	Unnamed	Dalmore	NI	Sc		280	Other	UP	L	2
233	Hook Rd	Nyora	NI	W	Isolated	1171	Grazed	F	L	4
234	Unnamed	Pakenham Upper	N	W	Isolated	326	None	O	L	5
235	Unnamed	Heath Hill	NI	W	Isolated	1541	Driveway	UP	H	3
236	Unnamed	Heath Hill	NI	W	Isolated	410	Driveway	UP	H	3
237	Unnamed	Caldermeade	NI	S	Link	448	Grazed	F	L	2
238	Unnamed	Caldermeade				435	Grazed	UP	H	1
239	Unnamed	Dalmore				1559	Grazed	F	L	1
240	Unnamed	Lang Lang East	NI	W	Link	1460	Grazed	UP	M	3
241	Unnamed	Caldermeade				414	Grazed	UP	H	1
242	Unnamed	Lang Lang	NI	S	Link	1173	Grazed	F	H	3
243	Unnamed	Lang Lang	NI	S	Link	1718	Grazed	UP	M	2
244	Unnamed	Heath Hill	NI	W	Link	1622	None	UP	H	3
245	Unnamed	Lang Lang East	NP	S	Link	904	Grazed	UP	L	3

ID	Name	Locality	Vegetation origin	Habitat type	Connectivity	Length (m)	Land use	Security	Develop	Veg cover (%)
246	Unnamed	Yannathan				2841	Grazed	UP	H	3
247	Unnamed	Heath Hill	NI	W	Link	1283	Grazed	F	L	3
248	Unnamed	Monomeith				2019	Grazed	UP	M	1
249	Unnamed	Lang Lang East	N	W	Link	674	None	O	H	4
250	Unnamed	Lang Lang East	NI	S	Link	1370	Grazed	UP	H	3
251	Carpenter Rd	Officer	N	W	Core	709	None	UP	L	5
252	St Georges Rd	Beaconsfield Upper	N	W	Core	521	Track	UP	M	5
253	Unnamed	Bunyip	N	Sc	Link	842	Track	F	H	3
254	Mcdonalds Trk	Lang Lang				1402	Grazed	UP	H	1
255	Unnamed	Longwarry	NI	S	Link	440	Grazed	UP	L	2
256	Games Rd	Yannathan				1276	Track	F	H	1
257	Mckenzie Rd	Beaconsfield Upper	NI	W	Core	319	Driveway	UP	L	4
258	Unnamed	Beaconsfield Upper	NI	S		705	Driveway	UP	M	2
259	Unnamed	Monomeith				948	Driveway	UP	H	1
260	Unnamed	Yannathan				657	Road	UP	H	1
261	Unnamed	Koo Wee Rup	NI	Sc	Link	816	Grazed	UP	L	1
262	Unnamed	Gembrook	NP	S		255	Other	UP	L	1
263	Unnamed	Lang Lang	NI	S	Link	1894	Grazed	F	H	2

ID	Name	Locality	Vegetation origin	Habitat type	Connectivity	Length (m)	Land use	Security	Develop	Veg cover (%)
264	Unnamed	Lang Lang	NI	S	Link	1085	Track	UP	L	3
265	Unnamed	Pakenham				1958	Road	UP	H	1
266	Unnamed	Pakenham South				1683	Grazed	UP	H	1
267	Bastin Rd	Bunyip				778	Grazed	UP	H	1
268	Hamilton Rd	Emerald	N	W	Isolated	344	Driveway	UP	M	4
269	Unnamed	Garfield				1023	Grazed	UP	H	1
270	Belgrave Av	Cockatoo				159	Other	UP	L	0
271	Unnamed	Garfield	N	W	Link	575	Track	F	H	4
272	Unnamed	Garfield	NI	W	Link	840	Grazed	UP	M	2
273	Unnamed	Longwarry	NI	S	Link	1011	Grazed	UP	H	4
274	Unnamed	Heath Hill	NI	W	Isolated	2683	Grazed	UP	L	3
275	Unnamed	Pakenham				2116	Road	UP	H	1
276	Poplar Cr	Emerald	N	W	Core	480	None	UP	M	4
277	Unnamed	Koo Wee Rup				1360	Track	F	H	1
278	Gould Rd	Gembrook	NI	S		596	Driveway	UP	H	2
279	Unnamed	Officer South	NI	Sc	Link	1388	Grazed	F	L	2
280	Unnamed	Cora Lynn				1278	Track	UP	L	1
281	Mcnamara Rd	Bunyip	NI	S		897	Grazed	UP	H	1
282	Rythdale Rd	Rythdale				908	Driveway	F	H	1

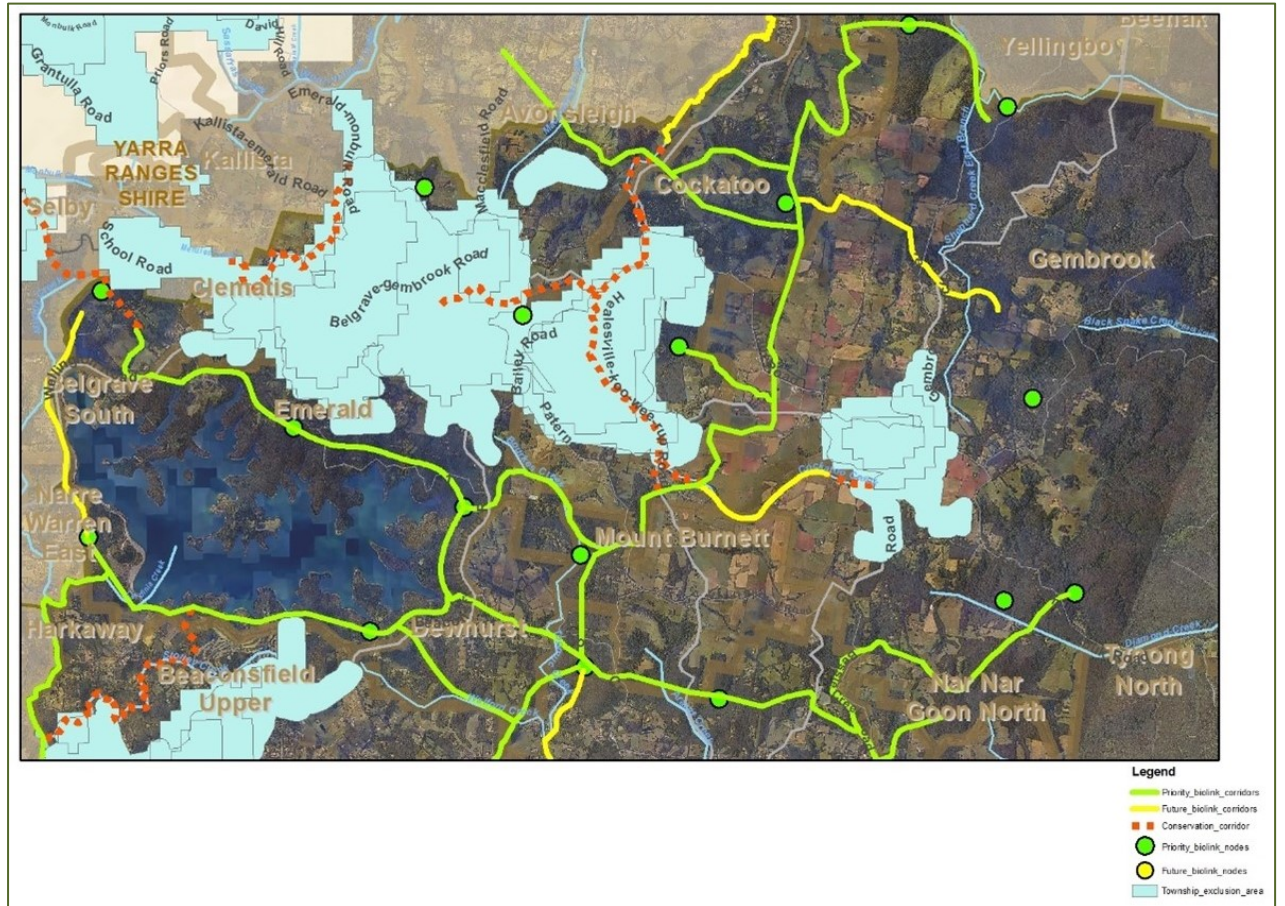
ID	Name	Locality	Vegetation origin	Habitat type	Connectivity	Length (m)	Land use	Security	Develop	Veg cover (%)
283	Lindhe Lane	Lang Lang	NI	W	Link	2995	Grazed	UP	H	3
284	Unnamed	Bunyip North	NI	S	Link	946	Driveway	UP	H	3
285	Unnamed	Nar Nar Goon North	N	W	Link	486	Track	UP	L	5
286	Unnamed	Iona				378	Track	F	L	1
287	Unnamed	Bayles				1051	Grazed	UP	M	2
288	Unnamed	Nar Nar Goon North	NI	S		1851	Grazed	UP	H	2
289	Unnamed	Pakenham				366	Grazed	UP	H	1
290	Unnamed	Bayles				485	Other	UP	L	1
291	Unnamed	Gembrook	NI	S		679	Track	UP	H	1
292	Unnamed	Bunyip				694	Grazed	UP	H	1
293	Unnamed	Bunyip	N	W	Isolated	603	Grazed	UP	H	3
294	Unnamed	Tynong				1539	Grazed	UP	L	1
295	Unnamed	Monomeith	NP	S		404	Grazed	UP	H	1
296	Unnamed	Nar Nar Goon North	NP	W	Link	374	Driveway	UP	L	4
297	Unnamed	Nyora	NI	W	Isolated	920	Grazed	UP	L	2
298	Unnamed	Nar Nar Goon	NI	R	Link	941	None	UP	L	4
299	Unnamed	Heath Hill	NI	S	Link	682	Other	F	L	4
300	Unnamed	Officer South	N	Sc	Link	1163	Grazed	F	L	4
301	Unnamed	Monomeith				2323	Grazed	UP	H	1

ID	Name	Locality	Vegetation origin	Habitat type	Connectivity	Length (m)	Land use	Security	Develop	Veg cover (%)
302	Unnamed	Catani				1275	Road	UP	H	1
303	Pancake Creek Rd	Gembrook	NI	S		1492	Grazed	UP	L	1
304	Grey Rd	Gembrook	NI	W	Link	579	Driveway	UP	H	3
305	Gembrook - Tonimbuk Rd	Gembrook	N	W	Core	2707	None	O	L	5
306	Unnamed	Koo Wee Rup				1667	Other	F	H	1
307	Unnamed	Lang Lang	NI	S		291	Grazed	UP	H	2
308	Warner Rd	Nar Nar Goon North	N	W	Link	969	Other	O	L	4
309	Tower Rd	Beaconsfield Upper	N	W	Core	640	Other	UP	L	4
310	Unnamed	Emerald	N	W	Isolated	288	Track	F	L	4
311	Unnamed	Garfield	NI	S		478	Other	UP	H	2
312	Key Lane	Pakenham				1342	Grazed	UP	H	1
313	Unnamed	Lang Lang	NI	S	Core	5429	Grazed	UP	L	3
314	Mcgregor Lane	Lang Lang	NI	W	Core	5198	Grazed	UP	H	3
315	Unnamed	Gembrook	N	W	Link	1385	Other	UP	H	4
316	Unnamed	Lang Lang				1696	Grazed	UP	H	1
317	Unnamed	Tynong				197	Grazed	UP	L	1
318	Unnamed	Garfield				904	Grazed	UP	H	1

Appendix H. Connectivity implementation mapping

The biolink plan connectivity implementation mapping will be available via a weblink, Figure H1, gives an example of the detailed mapping.

Figure H1. Demonstration map of biolink implementation for northern Gembrook



Appendix I. Legislative summary

Planning and Environment Act 1987 clauses that support the development of strategic habitat and wildlife corridors which are detailed in the biolink plan include:

- Clause 12.01s Protection of biodiversity
- Clause 13.02 Bushfire planning
- Clause 14.02-1S Water - Catchment planning and management
- Clause 19.02-6S Community infrastructure - open space
- Clause 21.02-2 Municipal strategic statement - Environment: Landscape
- Clause 21.02-3 Environment: Biodiversity
- Clause 21.02-5 Open Space
- Clause 21.02-7 Aboriginal cultural heritage
- Clause 21.03-2 Settlement and housing - Urban growth area
- Clause 21.07-7 Koo Wee Rup
- Clause 35.05 Green Wedge Zone A
- Clause 35.06 Rural Conservation Zones
 - Schedule 1 to clause 35.06 Rural Conservation Zone
- Clause 35.07 Farming Zone
- Clause 36.03 Public Conservation and Resource Zone
- Clause 37.01 Special Use Zone -Schedule 1 to the Special Use Zone
- Clause 37.01 Special Use Zone -Schedule 7 to the Special Use Zone
 - The biolink plan responds to the Special Use Zone by identifying biolink initiatives are voluntary opportunities. The biolink plan advocates that due to the priority for agricultural production, specifications for southern brown bandicoot habitat in terms of section 8.3.6 (creek setbacks) are counterproductive to this purpose. In the context of biolinks in these areas the installation of native shelter belts of 10 metres wide to support farm ecosystem services and sustainable farming practises would be a suitable habitat outcome
- Clause 42 Environmental and Landscape Overlays
 - Schedule 1 to clause 42.01 Environmental Significance Overlay: Northern Hills
 - Schedule 4 to clause 42.01 Environmental Significance Overlay: Pakenham North Ridge
- Clause 42.02 Vegetation Protection Overlay
 - Schedule 1 to clause 42.02 Vegetation Protection Overlay: Low Density Residential
 - Schedule 2 to clause 42.02 Vegetation Protection Overlay: Hills Townships
- Clause 42.03 Significant Landscape Overlay
 - Schedule 1 to clause 42.03 Significant Landscape Overlay: Puffing Billy Tourist Railway Scenic Corridor
 - Schedule 3 to clause 42.03 Significant Landscape Overlay: Lang Lang/Heath Hill
- Clause 43.04 Heritage and built form overlays - Development Plan Overlay
 - Schedule 7 to clause 43.04 Development Plan Overlay: Pakenham North-East Residential Precinct (Deep Creek)
 - Schedule 11 to clause 43.04 Development Plan Overlay:
 - Schedule 11 to clause 43.04 Development Plan Overlay: Lot 1, TP 711091S, Nash Road, Bunyip
 - Schedule 16 to clause 43.04 Development Plan Overlay: Cardinia Motor Recreation and Education Park
- Clause 52.12 Particular provision – Bushfire Protection Exemptions
 - The biolink plan responds to c52.12 by incorporating the provisions in 52.12 to define the vegetation setbacks from buildings at a property scale and informs the biolink design principles to create safe landscapes in Appendix F.

- Clause 52.16 Particular provision – Native Vegetation Precinct Planning
 - The biolink plan responds to c52.16 by identifying additional corridor linkages that can connect to vegetation which is identified as protected in the Native Vegetation Precinct Plan. By increasing the patch size of the protected vegetation, the biolink corridor will increase the variety of species that will successfully utilise habitat.
- Clause 52.17 Particular provision – Native Vegetation
 - The biolink plan responds to c52.17 by providing mapped information on the value of the native vegetation as habitat and the importance of individual vegetation corridors to connect species at a landscape scale. Vegetation identified as significant within the biolink plan will inform land managers on the most important areas to retain and enhance biodiversity.
- Clause 53.02 Particular provision - Bushfire Planning
 - The biolink plan responds to c. 53.02 by incorporating the provisions in 53.02 to define the vegetation setbacks from buildings at a property scale and informs the biolink design principles to create safe landscapes in Appendix F.

The Cardinia Shire Biolink Plan has been developed in line with legislation that was current as at November 2020. As this is a 10-year plan, it is acknowledged that legislation may change during the lifetime of the plan, and as such, may contradict or conflict with this plan.

As the responsible authority for planning decisions across the shire, Council has a critical role in protecting and conserving biodiversity through the Victorian Planning Provisions (VPP) under the *Planning and Environment Act 1987* and other legislation, regulations and policies and as such will ensure we meet our legislative requirements.

Appendix J. Summary of bushfire risk measures

The table below represents a summary of the bushfire risk measures that have been considered within the plan in the establishment of biolink corridors.

Risk management description	Specific measure that has been implemented to consider bushfire risk within the plan
Management principles identified in the plan which guide decision making where there are conflicts between fire management and conservation works	Defines an overarching management principle; "Where there is a conflict between proposed voluntary new conservation works and an increased bushfire safety risk to people and property the management direction must always accede to not increase the risk to people and property as a result of the new works beyond acceptable levels as defined by the Municipal Fire Management Planning Committee." Refer to Section 9.1

Improved incorporation of the *Metropolitan Bushfire Management Strategy (2020)* and the house risk priority areas into the biolink plan. Text references to the strategy in Sections 8, 9.3.1, 9.3.3 and 10.4 including;

Risk management description	Specific measure that has been implemented to consider bushfire risk within the plan
Terrestrial biolink corridors have avoided 'extreme,' 'very high' and 'high risk' townships and settlement areas.	<ul style="list-style-type: none"> • Terrestrial corridors located within these defined risk areas within townships were removed from the plan • Modelled corridors close to the townships of Emerald, Cockatoo, Upper Beaconsfield, Gembrook and Maryknoll were sited further away from these townships.
Conservation corridors have been added and identified within townships along the riparian waterways and 'high' risk asset areas	Conservation corridors along waterways and in terrestrial areas specify no increase in the extent of the riparian zone. (Including Cardinia Creek, Menzies Creek, Cockatoo Creek, Stoney Creek and Back Creek waterways).
No corridors are identified within DELWP bushfire risk asset management zones on public land (i.e., No corridors are located in defined Asset management zones and Bushfire moderation zones.)	Corridors were removed from these defined management zones. Which will meet state fuel management initiatives, such as programmed fire breaks and fuel management burning.
Avoidance of strategic and tactical fire access roads	Biolinks modelled along strategic and tactical access roads were removed. Collaborative opportunities with the local CFA brigades will investigate bolstering fuel reduction works at biolink – access road intersections.

Utilising the draft computer modelling, each individual biolink corridor was post-processed and reviewed from a desktop assessment at approximately 1:6,000 scale to test the location of the corridor to be considerate of achieving the project goals of sustainable connected corridors for species which are also safe to people and property. Refer to the mapping and section 8 and section 9.3.1 This included the assessment and where required realignment or removal of corridors to consider.

Risk management description	Specific measure that has been implemented to consider bushfire risk within the plan
<p>Identifying the most sustainable corridor alignment that does not conflict with the 150m bushfire site assessment area from buildings and dwellings (defined within clause 44.06 of the Bushfire management overlay). Where biolink corridor realignments could not avoid an intersection with the 150m building setback (or 'setback zone'), these intersections were minimised.</p>	<p>150 metre 'setback zones' were allocated to all registered and visibly mapped buildings within the shire. The assessment resulted in amending the alignment of 88% of priority corridors to achieve in descending order of preference:</p> <ol style="list-style-type: none"> 1. complete avoidance of the 150m setback zone or; 2. where corridors could not completely avoid the 150m setback zone they were aligned a maximum distance from buildings to minimise intersecting with the setback zone. Appendix F identifies biolink corridors are to be set back 150m from existing and new dwellings and defines that no revegetation outcomes for complete structural or functionally connected corridors are proposed within the setback zone. There may be opportunities for native plantings that are isolated and spatially distant within this area to be determined on a site-by-site basis (refer cross section Figure 10) or; 3. in locations where the pattern of rural development was too dense to achieve an uninterrupted pathway to avoid the 150m setback zone for most of the corridor, the biolink was redefined as a modified 'conservation corridor' which defines no large-scale revegetation priorities are to be sought along these corridors. (refer Section 8.2.1)
<p>Corridors were sited to consider fire risk to people and property at a local level</p>	<ul style="list-style-type: none"> • Modelled corridors were moved and aligned within low lying creek gullies and waterways which represent a comparatively lower fire risk to dryer terrestrial areas. Gullies and waterways are generally located a greater distance from developed and agricultural areas which are generally located in dryer property locations. • To minimise the bushfire risk from prevailing north westerly dominated extreme bushfire weather patterns, priority was placed to align corridors to the south eastern aspect of a property and minimise siting corridors on the north western property aspect. Where corridors were located along the north western aspect, as a preference these are located within low lying creek gullies and waterways. • Prioritising alignment within public reserves managed for conservation. • Prioritising rural properties with intact vegetation located away from dwellings and agricultural zones. • Consideration of the number of points of property egress during a fire event

Risk management description	Specific measure that has been implemented to consider bushfire risk within the plan
<p>Projects to increase the extent of biolink corridors will be informed by the DELWP bushfire risk modelling analysis. The modelling will provide information on the impact to assets because of increasing the extent of the biolink corridor. The risk modelling considers vegetation extent, fire history (fuel loads since last fire), flame height at a fire danger index of '130', house loss probability, fuel type, and ember attack. Refer to Section 9.3.1.</p> <p>Results will determine if increasing the biolink corridor extent will either increase risk or have no impact to the surrounding landscape.</p>	<p>All landscape scale revegetation proposals will include the results of the risk analysis in the 'Revegetation - vegetation protection bushfire risk site assessment' which will be presented to and reviewed by the MFMPC (refer Section 10.4 decision support matrix).</p>

Risk management description	Specific measure that has been implemented to consider bushfire risk within the plan
<p>Liaison with the Municipal Fire Management Planning Committee on proposed large-scale revegetation and vegetation protection works will ensure bushfire risk to people and property is considered at the planning stage.</p>	<p>A decision support matrix will guide proposals in mapped 'high,' 'Moderate-low' and 'lowest risk' landscapes.</p>
	<p>A revegetation / vegetation protection project bushfire risk site assessment has been created to aid in MFMPC decision making. The assessment captures and reviews all the environmental and risk mapped data.</p>

Appendix K. Options for the safe design of riparian planting from assets

Table 7 (page 25) extracted from CFA Riparian Land and Bushfire' DELWP (2017).

Table 7 – Comparison of options for planning the separation of new riparian revegetation areas from assets

Options		Relative effect of options on #			Basis of option and limitations
Location	Revegetation options (based on current planning and building controls for new building as a guide)	Embers	Radiant heat	Flame contact	
All areas	<p>Avoid revegetation unless the vegetation meets one or more criteria for very low threat as set out in Step 1 of Worksheets 1 and 3:</p> <ul style="list-style-type: none"> ▪ Vegetation more than 150 m from the building ▪ Single areas less than 1 ha in area and not within 100 m of other vegetation that does not meet the criteria for very low threat ▪ Multiple areas less than 0.25 ha in area or strips less than 20 m wide and not within 20 m of the building, or each other, or other vegetation that does not meet the criteria for very low threat ▪ Grassland less than 100 mm in height during the Fire Danger Period ▪ Vegetation meets the standards for 'defendable space' as set out in <i>Standard planning permit conditions</i> for new houses located in the BMO (CFA 2014b) or low overall fuel hazard (DSE 2010) 	●	●	●	Based on exemptions for very low threat in AS 3959:2009 (with separation increased to 150 m to align with the assessment area specified in current Victorian planning controls). These criteria may underestimate the threat of ember attack from more extensive and more contiguous vegetation.
<p>Bushfire Management Overlay (BMO) areas (Higher bushfire risk)</p> <p>Bushfire Prone Areas (BPA) (Moderate to high bushfire risk)</p>	<p>Using Worksheet 3 (Appendix 3) as a guide, avoid revegetation within a distance likely to expose buildings to radiant heat beyond the following levels:</p> <ul style="list-style-type: none"> ▪ Existing houses: minimum of 12.5 kW/m² (unless they have been built in accordance with AS 3959:2009 as indicated by the building permit) ▪ 'Vulnerable uses' (such as schools): minimum of 10 kW/m² (as specified for new development in the BMO) 	●	●	●	Based on AS 3959:2009 as set out in Tables 2 and 3 of Clause 52.47 of all planning schemes. May over or underestimate radiant heat compared with Method 2 of AS 3959:2009
Other areas not included in the BMO or BPA and where revegetation which meets exemptions for size and distribution set out in Step 1 of Worksheets 1 and 3	<p>Avoid revegetation within:</p> <ul style="list-style-type: none"> ▪ 50 metres of buildings in the BMO ▪ 30 metres of buildings located elsewhere 	●	●	●	The '10/30 or 10/50 rules (exemptions)' (Clause 52.48 of planning schemes) May underestimate the setback required for riparian areas May overestimate setbacks in urban areas or for isolated bushland areas
Where a more site-specific solution is required	Avoid revegetation within a distance likely to expose buildings to unacceptable levels of radiant heat	●	●	●	Method 2 of AS 3959:2009 provides scope for an experienced fire planner to vary inputs into setback calculations to better reflect site conditions or acceptable risk including FFDI, likely peak fuel hazard, slope and extent of vegetation present as well as the radiant heat exposure target

Larger dots represent a greater relative effect on bushfire impacts, smaller dots represent a smaller relative effect

Appendix L. Estimating vegetation setbacks

Appendix 3 (page 37): worksheet 3 – estimating vegetation setbacks extracted from ‘CFA Riparian Land and Bushfire’ DELWP. (2017).

This worksheet will help you to plan your revegetation or management of existing riparian vegetation to minimise bushfire threat to houses or other buildings where people live and congregate, and where slopes are less than 20°. It is based on current planning and building controls for new houses and should be regarded as the minimum required for bushfire safety. Seek expert advice as needed.

Step 1: Does or will your vegetation pose a very low threat?

- Vegetation more than 150 m from the building
- Single areas less than 1 ha in area and not within 100 m of other vegetation#
- Multiple areas less than 0.25 ha in area or strips less than 20 m wide and not within 20 m of the building, or each other, or other vegetation#
- Grassland less than 100 mm in height during the declared Fire Danger Period
- Vegetation meets the standards for ‘defendable space’ as set out in *Standard planning permit conditions* for new houses located in the BMO (CFA 2014b) or low overall fuel hazard (DSE 2010)

‘Other vegetation’ refers to vegetation not meeting the requirements of this step

- Yes This vegetation poses a very low threat from radiant heat
- No Go to Step 2

Step 2: What is the slope under the vegetation located within 150 m?

- Upslope (fire would burn downhill towards the building)
- Flat
- Flat to 5°
- 5° to 10°
- 10° to 15°
- 15° to 20°
- More than 20°

Appendix 4 will help you to estimate slope

Step 3: What is the class (at maturity) of vegetation located within 150 m?

- Forest
- Woodland
- Shrubland
- Scrub
- Mallee
- Rainforest
- Grassland

Refer to *Vegetation Classes: Victorian Bushfire Management Overlay* (CFA 2014)

Step 4: What is the level that you want to reduce the bushfire threat to?

Threat	Minimum suggested for
<input type="checkbox"/> Low	Vulnerable uses eg schools or where evacuation may be required (10 kW/m ² max) and older houses (12.5 kW/m ² max)
<input type="checkbox"/> Medium to High	May be appropriate for relatively new houses built to bushfire standards (check planning or building permit)
<input type="checkbox"/> Very High	If only protection from flames required (eg track)

Step 5: Select the separation between the vegetation and the assets

Use the following table to select the separation required to reduce the threat from radiant heat in for each combination of slope, vegetation class and bushfire threat level.

SLOPE	VEGETATION CLASS	THREAT LEVEL				
		LOW 10 kW/m ²	LOW 12.5 kW/m ²	MEDIUM 19 kW/m ²	HIGH 29 kW/m ²	VERY HIGH 40 kW/m ²
		Separation/Defendable space (metres)				
All upslopes 0 degrees	Forest	60	48	35	25	19
	Woodland	40	33	24	16	12
	Shrubland	25	19	13	9	7
	Scrub	35	27	19	13	10
	Mallee	23	17	12	8	6
	Rainforest	30	23	16	11	8
Downslope >0 to 5 degrees	Forest	70	57	43	32	24
	Woodland	50	41	29	21	15
	Shrubland	28	22	15	10	7
	Scrub	40	31	22	15	11
	Mallee	26	20	13	9	7
	Rainforest	36	29	20	14	10
Downslope >5 to 10 degrees	Forest	85	69	53	39	31
	Woodland	62	50	37	26	20
	Shrubland	32	25	17	11	8
	Scrub	45	35	24	17	12
	Mallee	30	23	15	10	7
	Rainforest	46	36	26	18	13
Downslope >10 to 15 degrees	Forest	105	82	64	49	39
	Woodland	75	60	45	33	25
	Shrubland	36	28	19	13	9
	Scrub	50	39	28	19	14
	Mallee	35	26	18	11	8
	Rainforest	60	45	33	23	17
Downslope >15 to 20 degrees	Forest	125	98	78	61	50
	Woodland	95	73	56	41	32
	Shrubland	41	31	22	15	10
	Scrub	55	43	31	21	15
	Mallee	40	29	20	13	9
	Rainforest	70	56	42	29	22
Downslope >20 degrees	Grassland	55	32	23	15	11

Source: Tables 2 and 3 of clause 52.47 of all planning schemes which are based on AS 3959:2009

Appendix M. Summary of effectiveness of Council, community and educational research biodiversity monitoring programs

Indicator species common name	Indicator species name	Citizen science voluntary monitoring (opportunities for shire wide surveys. Participant expertise in species identification varies).	Programmed Council monitoring. (Council reserve system is limited across the shire)	University graduate voluntary monitoring. (opportunities for shire wide surveys. Students have specialist species monitoring skills)
Growling grass frog	<i>Litoria raniformis</i>	Surveys can provide meaningful data	Limited to Council reserves with Growling Grass Frog habitat	Surveys can provide meaningful data
Powerful owl	<i>Ninox strenua</i>	Limited monitoring opportunities anticipated except to expert fauna groups	Limited to Council reserves with Powerful Owl habitat	Opportunities for specialist surveying for this species
Southern brown bandicoot	<i>Isodon obesulus obesulus</i>	Surveys can provide meaningful data	Surveys can provide meaningful data	Surveys can provide meaningful data
Platypus	<i>Ornithorhynchus anatinus</i>	Surveys can provide meaningful data	Limited to waterways located along Council reserves	Surveys can provide meaningful data
Southern greater glider	<i>Petauroides volans</i>	Limited monitoring opportunities anticipated except to expert fauna groups	Limited to Council reserves with Powerful Owl habitat	Surveys can provide meaningful data
Superb lyrebird	<i>Menura novaehollandiae</i>	Surveys can provide meaningful data	Surveys can provide meaningful data	Surveys can provide meaningful data
Blue-tongued lizards	<i>Tiliqua nigrolutea and scincoides</i>	Surveys can provide meaningful data	Most efficient to use other monitoring sources	Surveys can provide meaningful data
Eastern yellow robin	<i>Eopsaltria australis</i>	Surveys can provide meaningful data	Most efficient to use other monitoring sources	Surveys can provide meaningful data
Lace monitor	<i>Varanus varius</i>	Surveys can provide meaningful data	Most efficient to use other monitoring sources	Surveys can provide meaningful data

Indicator species common name	Indicator species name	Citizen science voluntary monitoring (opportunities for shire wide surveys. Participant expertise in species identification varies).	Programmed Council monitoring. (Council reserve system is limited across the shire)	University graduate voluntary monitoring. (opportunities for shire wide surveys. Students have specialist species monitoring skills)
Chocolate wattled bat	<i>Chalinolobus morio</i>	Limited monitoring opportunities anticipated except to expert fauna groups	Surveys can provide meaningful data	Surveys can provide meaningful data
Superb fairy wren	<i>Malurus cyaneus</i>	Surveys can provide meaningful data	Most efficient to use other monitoring sources	Surveys can provide meaningful data
Swamp skink	<i>Lissolepis coventryi</i>	Limited monitoring opportunities anticipated except to expert fauna groups	Limited to Council reserves with Swamp Skink habitat	Surveys can provide meaningful data
Agile antechinus	<i>Antechinus agilis</i>	Limited monitoring opportunities anticipated except to expert fauna groups	Limited to Council reserves with Agile antechinus habitat	Surveys can provide meaningful data
Swamp wallaby	<i>Wallabia bicolor</i>	Surveys can provide meaningful data	Most efficient to use other monitoring sources	Surveys can provide meaningful data
Eastern pygmy possum	<i>Cercartetus nanus</i>	Limited monitoring opportunities anticipated except to expert fauna groups	Limited to Council reserves with Eastern pygmy possum habitat	Surveys can provide meaningful data