Southern Brown Bandicoot Strategic Management Plan

for the former Koo Wee Rup Swamp Area

Project: 08-26

Prepared for:

Cardinia Shire Council, Casey City Council and Melbourne Water

Ecology Australia Pty Ltd

Flora and Fauna Consultants

www.ecologyaustralia.com.au

admin@ecologyaustralia.com.au

88B Station Street, Fairfield,

Victoria, Australia 3078

Tel: (03) 9489 4191

Fax: (03) 9481 7679

© 2009 Ecology Australia Pty Ltd

This publication is copyright. It may only be used in accordance with the agreed terms of the commission. Except as provided for by the Copyright Act 1968, no part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, without prior written permission of Ecology Australia Pty Ltd.

Document information

This is a controlled document. Details of the document ownership, location, distribution, status and revision history are listed below.

All comments or requests for changes to content should be addressed to the document owner.

Bioregion (for EA record keeping purposes): Gippsland Plain

Owner	Ecology Australia
Author	Bernadette Schmidt, Christina Renowden and Darren G. Quin
Location	J:\CURRENT PROJECTS\SBB Mgt Strategy 08-26\Report\Draft 3\Southern Brown Bandicoot Strategic Management Plan_Final.doc
Distribution	Ian Stevenson, Lachlan Marshall, William Steele; Cardinia Shire Council, City of Casey, Melbourne Water

Document History

Status	Changes	By	Date
Draft 0.1	First Draft	Bernadette Schmidt, Christina Renowden and Darren G. Quin	05/09/08
Draft 0.2	Second Draft	Bernadette Schmidt	19/12/08
Draft 0.3	Third Draft	Bernadette Schmidt	20/03/09
Final	Final Version	Bernadette Schmidt	03/04/09

Contents

Tables

Figures

Plates

Appendices

Executive Summary

Background Information and Objectives

Ecology Australia was commissioned by Cardinia Shire Council, City of Casey and Melbourne Water to develop a Strategic Management Plan for the Southern Brown Bandicoot (*Isoodon obesulus obesulus*) in the former Koo Wee Rup Swamp area. The south-eastern mainland sub-species is listed as Endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), has been nominated for listing under the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act), and is classified as Near Threatened in Victoria (DSE 2007a).

In the former Koo Wee Rup Swamp area, bandicoots have undergone a steady decline since the drainage of the Swamp; populations are now restricted to patches of remnant and exotic vegetation (generally small and somewhat isolated) in reserves, along waterways, railways, roadsides and on private property. Considering the broad, but patchy, distribution of bandicoots across the former Koo Wee Rup Swamp and the range of land uses and current management regimes (many of which are not compatible with the management requirements of bandicoots), there was a need to prepare a regional strategy to direct management actions across a variety of land tenures and uses within the former Koo Wee Rup Swamp area.

The plan was produced in close consultation with a technical advisory group comprised of representatives from relevant management agencies (e.g. City of Casey, Cardinia Shire Council, Melbourne Water, and the Department of Sustainability and Environment) and other stakeholders (e.g. Royal Botanic Gardens Cranbourne, Cardinia Environment Coalition, Mornington Peninsula and Western Port Biosphere Reserve Foundation and community groups).

The key objectives of the strategy were to:

- collate and review all available information relevant to the Southern Brown Bandicoot within the former Koo Wee Rup Swamp area and surrounds;
- diagnose the principal threats to bandicoot populations within the former swamp area;
- identify core populations/habitat, common habitat, potential habitats and existing or potential habitat links; and
- prioritise key management actions required to minimise threats, address constraints and ensure long-term viability of the bandicoot and protection of its habitat in the former Koo Wee Rup Swamp area.

Former Koo Wee Rup Swamp area

The great Koo Wee Rup Swamp was drained and cleared between the 1870s through to the 1960s. Drainage channels were excavated, and creeks and rivers were diverted and extensively channelised. Drainage of the swamp allowed for intensive agriculture, including cropping, grazing and market gardening, as well as residential development and an extractive industry. A sand

mining industry began with the removal of sand from the main drains. These land use practices continue in the study area to date. As a result, most of the native vegetation has been lost and hydrological systems severely modified and degraded.

The former Koo Wee Rup Swamp study area is essentially defined by the local government boundary of the Cardinia Shire Port Ward, located approximately 55 km east of Melbourne. The area extends from Lower Cardinia Creek in Officer South to Longwarry, in the north, and from Tooradin Drain to Lang Lang in the south. The Princes Highway forms the northern boundary. Areas of relevance immediately outside of the former Koo Wee Rup Swamp area include the eastern section of the City of Casey Balla Balla Ward.

Current distribution, population structure and habitat function

The precise range and distribution of bandicoots in the former Koo Wee Rup Swamp area has not yet been fully determined. Current knowledge of their distribution is built from the collation of records from a range of sources. Based on these records, four population 'clusters' were identified:

- Dalmore-Koo Wee Rup;
- Bayles;
- Cardinia-Rythdale; and
- Garfield-Longwarry

Within each population cluster, areas of: core habitat; 'common' habitat (or other habitat patches); and potential habitat; as well as habitat links between and within clusters, were identified.

Core habitat

Core habitat areas are those that support a core or source population of bandicoots, vital habitat attributes and are well connected to other areas of known habitat. These areas are critical for the long-term persistence of a cluster/s and require protection priority, security in perpetuity and a management regime focussed on the conservation of bandicoots. Currently, aside from two sites zoned as Public Conservation and Resource Zone, all of the areas classified as core habitat are not secured for conservation, and their zoning allows for management and land use practices not compatible with Southern Brown Bandicoot conservation. The use of planning controls is recommended in order to secure and protect core habitats (see also below). All core habitats are on public land, with the exception of the South Gippsland Railway Line around Koo Wee Rup.

Other habitat patches

Other habitat patches were defined as sites which are known to support bandicoots but may be poorly linked to other occupied sites and are not considered critical for the long-term persistence of clusters. The values of these patches are often constrained by their tenure (e.g. private property within residential zones), but also require protection and security in the long-term. As many of these patches are on private properties or public land not zoned for conservation (e.g. waterways zoned as Public Use, and Rural Living/Green Wedge Zones), habitat security cannot be

guaranteed. Therefore, the use of planning controls and amendments to the planning scheme are recommended to reflect conservation imperatives for bandicoots and provide habitat protection.

Habitat links

Existing and potential habitat links occur within and between clusters. Many of these links are formed by creeks and waterways owned and managed by Melbourne Water, or roadsides. As such, most habitat links identified are on public land. These links provide connectivity between or within clusters and are important for dispersal, movement of individuals and population viability. As with core habitat and habitat patches, zoning along most habitat links reflects land uses and management objectives other than conservation. Many links are also under threat from intensive cattle grazing and vegetation clearing for maintenance. A change to the planning schemes is considered the best way to protect these links. Recommendations are made to ameliorate threats, and key areas which require habitat enhancement and security are identified.

Potential landscape-scale habitat links or 'biolinks' were also identified within and beyond the Former Koo Wee Rup Swamp area. These links are important for connectivity between the Swamp area and other areas known to be occupied by bandicoots, such as the Royal Botanic Gardens in Cranbourne and populations at Drouin, Quail Island and Wonthaggi.

Potential habitat

Several areas of potential habitat were also identified. Much of this habitat is around Lang Lang and Nyora in the south-east section of the study area. There were also several patches identified in Koo Wee Rup, Monomeith, Cardinia, and Bunyip. Recommendations are made in regards to enhancing these habitats and the potential for future Southern Brown Bandicoot re-introductions.

Strategic Management Plan

The overall objective of the strategic management plan is to maximise the long-term viability of the Southern Brown Bandicoot in the former Koo Wee Rup Swamp area. As there are a range of land tenures and management issues across the study area, which are relatively complex, the success of the plan will depend on: the coordination amongst key stakeholders in implementing and monitoring the success of the plan; the long-term security of habitat; the amelioration of operating threats; and the amount of resources allocated to managing existing areas of habitat.

The approach taken for the strategic management plan was to:

1. identify the threats to bandicoots within the former Koo Wee Rup Swamp area;
2. state objectives aimed at ameliorating each of the identified threats;
3. prioritise management actions designed to achieve long-term conservation outcomes for bandicoots and recommendations for ceasing and/or minimising the threat; and
4. establish performance criteria, timing, monitoring and responsibility for each action.

In summary, the priority objectives for management which are applicable across the former swamp area within the next 1 - 5 years include:

1. Secure known habitat and habitat links (i.e. through amendments to the local planning scheme to ensure core habitats and links are protected for conservation).
2. Avoid future habitat loss and fragmentation (through rigorous assessments of upcoming developments, vegetation protection schemes and ceasing vegetation clearance along drains and roadsides where it is not deemed necessary).
3. Protect and enhance areas of known and potential habitats and remnant vegetation (e.g. cease livestock grazing on crown land, in riparian corridors and increase protection of remnant vegetation on private land).
4. Increase habitat connectivity within the former Koo Wee Rup Swamp area through habitat enhancement and/or rehabilitation.
5. Enhance habitat connectivity to important areas outside of the former Koo Wee Rup Swamp area through biolinks (e.g. to the Royal Botanic Gardens Cranbourne).
6. Increase the amount of habitat available through habitat creation/revegetation (e.g. adjoining existing core habitats).
7. Reduce predation pressures from foxes, feral cats and dogs.
8. Reduce degradation impacts by rabbits.
9. Increase the public profile of the Southern Brown Bandicoot and their conservation status and encourage community participation in conservation initiatives (e.g. establish a 'Friends of the Southern Brown Bandicoot' group).
10. Develop further research projects to increase knowledge of the distribution, abundance and ecology of bandicoots in the former Swamp area.

The key management actions in this plan will need to be developed into site-specific management plans in areas supporting the Southern Brown Bandicoot. Directions for developing site-specific management plans are provided.

This document also provides guidelines for council planners when evaluating information provided by a developer (e.g. triggers under the EPBC Act), survey protocols to monitor the outcome of management actions, and a summary of biodiversity benefits within the former Swamp area for other flora and fauna values.

The success of this management plan relies heavily upon the co-operation of stakeholders and management agencies in implementing actions towards the conservation of the Southern Brown Bandicoot. A Southern Brown Bandicoot management committee for the former Koo Wee Rup Swamp area will be established to oversee the implementation of this management plan and be the primary body responsible for sourcing and allocating funds, co-ordinating actions between stakeholders, ensuring the implementation of actions and monitoring the outcomes of the management actions.

1 Introduction

1.1 Project background

In April 2008, Ecology Australia Pty Ltd was commissioned by Cardinia Shire Council, City of Casey and Melbourne Water to develop a Strategic Management Plan for the Southern Brown Bandicoot in the former Koo Wee Rup Swamp area, south-east of Melbourne.

The Southern Brown Bandicoot (*Isoodon obesulus obesulus*) has undergone a dramatic decline in distribution and abundance across its range in south-eastern mainland Australia. Human activities such as agricultural, urban and industrial development and the introduction of mammalian predators have contributed to the decline of this species. Consequently, it is listed as Endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and classified as Near Threatened in Victoria (DSE 2007a), and has recently been nominated and recommended for listing under the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act) (FFGSAC 2009).

In the former Koo Wee Rup Swamp area, bandicoots have undergone a steady decline since the drainage of the Swamp and the clearance of large areas of native vegetation for agriculture and urban development. Populations are now restricted to fragmented and isolated remnants of vegetation in reserves, along waterways, railways, roadsides and on private property.

Considering the development pressures and ongoing threats to remaining habitat patches within the former Koo Wee Rup Swamp area (e.g. road upgrades, local infrastructure and ongoing farming practices), there was a need to produce a strategic landscape-scale management plan for the bandicoot in this location. In view of the type and extent of threats from developments within the study area, and the dispersal requirements and capabilities of the species, it is essential that any conservation initiatives take into account the surrounding landscape in order to provide the most viable conservation and management strategies for the species in the long-term. This strategic management plan aims to go beyond a site basis approach and to take a lead towards a co-ordinated, regional approach for conservation of the Southern Brown Bandicoot in the former Koo Wee Rup Swamp area.

1.2 Objectives

The ultimate objective of this plan is to maintain or increase the current known distribution and/or range of the Southern Brown Bandicoot within the former Koo Wee Rup Swamp area.

Specifically, the strategic plan aims to:

- compile and review all available information relating to the Southern Brown Bandicoot within the Koo Wee Rup Swamp area and surrounds (i.e. literature on the Southern Brown Bandicoot, particularly in the south-central region of Victoria, review current and proposed

development plans, land use changes in the area and research within the former Koo Wee Rup Swamp area);

- diagnose the principal threats to bandicoot populations within the study area;
- identify core areas, potential habitat patches and existing and potential habitat links;
- prioritise key management actions required to minimise threats and address constraints.

1.3 Stakeholders and consultative framework

Southern Brown Bandicoots in the former Koo Wee Rup Swamp area are distributed across various habitat types with differing land uses and land tenures, including conservation reserves, along roadsides and waterways and within private property in semi-rural and agricultural areas. As such, there are a number of different individuals, management agencies and organisations who are responsible for the management of bandicoots in the region.

To coordinate prospective management actions and facilitate communication between the various stakeholders, two groups have been set up, with representatives from the major stakeholders:

- **The Project Steering Group (PSG)** (responsible for funding and overseeing the project):
    - Cardinia Shire Council;
    - Melbourne Water; and
    - City of Casey.
- **The Technical Reference Group (TRG)**:
    - Department of Sustainability and Environment (DSE);
    - Chisholm Institute;
    - Mornington Peninsula and Western Port Biosphere Foundation;
    - Royal Botanic Gardens Cranbourne (RBGC); and
    - Cardinia Environment Coalition (CEC).

Other relevant Stakeholders include:

- **Federal Department of Environment Water, Heritage and the Arts (DEWHA):** Responsible for approval and permit conditions of any development works that may affect populations of the Southern Brown Bandicoot in the study area;
- **Department of Primary Industries (DPI):** Responsible for designing and delivering government policy and a range of government projects and initiatives to support the sustainable development of Victoria's primary industries and the management of natural resources;

- **Parks Victoria:** Relevant authority responsible for managing Victorias' national, state and regional parks and other reserves (e.g. some bushland reserves in the study area);
- **VicRoads:** Associated with road infrastructure projects within the study area which may affect bandicoot populations (e.g. Healesville-Koo Wee Rup Road upgrade, Bayles Bridges Upgrade, Manks Road Bridge upgrade);
- **VicTrack:** Government agency responsible for maintaining and managing the State's rail infrastructure not leased to the Director of Public Transport, including the management of commercial and business retail leases, rail and tram depots, railway stations and industrial estates under the Business Leasing Unit. The Community Leasing Unit of VicTrack is responsible for the delivery and management of community leases, including beautification and re-vegetation permits, which enable community groups to remediate and regenerate VicTrack land for greater biodiversity and improved visual amenity;
- **Western Port Catchment Landcare Network:** Landcare groups are independent community groups formed by volunteers with an interest in protecting and enhancing the natural resources of an area. Members are active in protecting vegetation remnants and waterways, revegetation works and weed and pest control. The Western Port Catchment Landcare Network coordinates 11 groups including Bunyip, Cardinia Catchment, Deep Creek and Bessie/Ararat Creek Landcare Groups. Other relevant groups include the Mt Lyall Landcare group;
- **Trust for Nature:** A private, non-governmental enterprise, formed in 1972 under the State *Victorian Conservation Trust Act 1972*. Trust for Nature strives to ensure that significant natural areas in private ownership are conserved. These aims are achieved by purchasing private land and managing it, establishing conservation covenants (land protection agreements) with private land owners and providing monitoring and support through stewardship programs. Land is often transferred to public estate or can be sold with a conservation covenant. The trust also enables people to donate land or money for conservation.

Consultation

Close consultation with stakeholders, the Project Steering Group (PSG) and Technical Reference Group (TRG) has been essential to the development of this strategy, to represent the interests of management agencies and stakeholder groups and to provide a forum for the exchange of ideas. The inaugural meeting was held on 15 April 2008 with the PSG and TRG to gather information on the current distribution of the species from current records and local knowledge, to identify information gaps, and communicate past and current management activities in other areas. A second meeting of the TRG and PSG with relevant stakeholders was held on 5 August 2008 to discuss management options, the coordination of proposed management actions, and the development of the strategy. Upon completion of the management plan, a draft was provided to the PSG and TRG for comment. A third meeting of the PSG and TRG was held on 5 February 2009 to discuss these comments, before finalisation of the management plan.

2 Conservation status and legislative framework

The conservation status of the Southern Brown Bandicoot is as follows:

Australia

- Endangered - Federal *Environment Protection and Biodiversity Conservation Act 1999.*
- Near Threatened - National Action Plan for Marsupials and Monotremes (Maxwell et al. 1996)

Victoria

- Nominated and Recommended for listing by the Scientific Advisory Committee under the *Flora and Fauna Guarantee Act 1988* (FFGSAC 2008, 2009)
- Near Threatened - Advisory List of Threatened Vertebrate Fauna in Victoria (DSE 2007a)

2.1 Policy Framework

A variety of policy and legislative measures are relevant to the conservation of the Southern Brown Bandicoot in the former Koo Wee Rup Swamp area at Local, Regional, State and National levels; those most relevant to the bandicoot in the study area and summarised below. Other legislation which may influence management requirements are summarised in Appendix 1.

Federal *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)

The EPBC Act pertains to matters of National Environmental Significance which includes listed threatened species and ecological communities, listed migratory species, Commonwealth Marine Areas and Ramsar Wetlands.

A proponent is obliged to refer matters to the Department of Environment, Water, Heritage and the Arts (DEWHA) if such values may be affected by a proposed action. The Commonwealth Environment Minister decides whether there will be a significant impact and if the proposal will require assessment and approval. The Commonwealth can intervene to modify or block an action if it deems this necessary for the protection of a species or community of national significance. The act applies to public and private land.

A referral is necessary whenever a proposed action is considered likely to impact on an item of National Environmental Significance listed under the Act (see Section 11).

The Southern Brown Bandicoot is listed as Endangered under the EPBC Act. According to the EPBC Act, a 'population' of an Endangered species is defined as either:

- a geographically distinct regional population, or collection of local populations; or
- a population, or collection of local populations, that occurs within a particular bioregion (EPBC Act Significant Impact Guidelines 2006).

Considering the occurrence and distribution of bandicoots in Victoria, we consider the population within the former Koo Wee Rup Swamp area is a 'population of an endangered species,' as defined under the EPBC Act.

Any proposed development within the former Koo Wee Rup Swamp area which may impact on a population, or at least part of a population (as defined under the EPBC Act), of Southern Brown Bandicoots would require a referral to DEWHA (also see Section 11 for decision guidelines).

As per the requirements of the EPBC Act, a National Recovery Plan is currently in preparation.

Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act)

The FFG Act lists species and ecological communities recognized as rare or threatened in Victoria. There are also provisions for listing of threatening processes. If a species is listed under the FFG Act, the production of an Action Statement is required for the species management.

The FFG Act is the State's primary legislature for flora and fauna; however, it is dated and poorly tied to the planning process. It effectively does not apply to private land, but may have implications for private land to the extent planning authorities enforce.

In contrast to other states in Australia, the Southern Brown Bandicoot has not been protected by state legislation, which until recently was rejected for listing under the FFG Act. A nomination for listing of this species was assessed by the Scientific Advisory Committee in 1990 and 1991. However, at the time of the nomination, some authorities considered that the species was still well protected in a network of flora and fauna reserves and therefore was not under immediate threat in Victoria (Menkhorst and Seebeck 1990). It was consequently assessed as ineligible for protection under the FFG Act (FFGSAC 1991).

Another nomination was recently prepared by biologists concerned about ongoing declines and threats across its range in Victoria (Rolf Willig pers. comm.). In October 2008, the Scientific Advisory Committee made a preliminary recommendation for listing (FFGSAC 2008) and in February 2009, made a final recommendation for listing (FFGSAC 2009), on the basis that it satisfies two criteria under the FFG Act. The listing is yet to be finalised.

Victoria's Native Vegetation Framework 2002 (DNRE 2002)

Victoria's Native Vegetation Framework 2002 (DNRE 2002) is a policy for the protection, enhancement and revegetation of native vegetation, aimed at achieving a reversal across the landscape of the state's native vegetation decline. The Framework is based on the principle of 'Net Gain', where all losses of vegetation must be offset. Net Gain is the desired outcome whereby the vegetation to be lost is outweighed by offsets, leading to overall gains in vegetation. The policy applies to both public and private land and is now incorporated into the Victorian Planning Provisions. For the clearing of native vegetation, clause 52.17 of the planning scheme requires proposals to demonstrate the three-stage process of Net Gain. The planning authority requires the first two stages of Net Gain to be adequately addressed, before offsets are considered:

1. Avoid all adverse impacts and vegetation losses as a first priority whenever possible

2. If vegetation losses and adverse impacts are unavoidable, losses must be minimised through careful planning
3. Identify and implement appropriate offsets for the vegetation to be lost.

The offsets required for the removal of a remnant patch of vegetation depends on the quality, extent and conservation significance of the vegetation being lost. The quality is assessed against the relevant Ecological Vegetation Class (EVC) benchmarks, and the conservation significance of a patch is influenced by the conservation status of the EVC within the bioregion (DSE 2008a). Consideration is also given to whether the vegetation supports habitat for rare or threatened fauna and flora species, or other attributes such as ecological/heritage values. These factors can effectively increase the conservation significance of the vegetation and the offset required. In particular, if the vegetation constitutes the best 50 % of habitat for a threatened species in a bioregion, then the conservation significance of the vegetation to be lost is considered to be 'very high' and offsets must be at a minimum, twice the area of vegetation to be lost.

Considering the paucity of bandicoot records in the east Gippsland Plain bioregion, and that the majority of records in the South-central subpopulation are within the study area, it is considered that habitat within the former Koo Wee Rup Swamp study area constitutes some of the best 50 % of habitat in the bioregion.

If in future, vegetation loss will impact upon the Southern Brown Bandicoot habitat, Net Gain offsets would apply to:

- Loss or alteration of a remnant patch; and
- Loss of large old trees.

In regards to the potential loss of bandicoot habitat, Net Gain is a good mechanism for habitat protection and the offset of losses (see also section 11).

2.2 Relevant Overlays under the Cardinia Shire Planning Scheme in the former Koo Wee Rup Swamp area

There are three overlays relevant to bandicoot conservation within the former Koo Wee Rup Swamp area: Environmental Significance (ESO), Significant Landscape (SLO) and Vegetation Protection (VPO) Overlays.

There are several areas within the former Koo Wee Rup Swamp area that are covered by an ESO:

- McNamara Road between Wattletree Road and Bunyip Avenue, Bunyip (ESO1).
- The Inlets (e.g. Cardinia Creek, Moodys Inlet, Toomuc/Deep Creeks and adjoining properties downstream of the South Gippsland Highway) (ESO2);
- Railway line between Ti-tree Road in Garfield and McNamara Road (ESO3); and
- Lang Lang Bushland Reserve (ESO3).

The aim of the **ESO1** (Northern Hills) is to protect: the significant environmental landscape values and to ensure no impacts on environmental values; the interesting landscape; remnant vegetation; and habitat of botanical or zoological significance and water quality.

The **ESO2** (Western Port) covers the saltmarsh and mangrove communities of Western Port Bay, and aims to protect these significant features through sensitive design and development.

ESO3 (Other Significant Sites) aims to ensure that: the habitat values of the sites are not diminished by the incremental removal of vegetation or inappropriate development; and development is sensitively designed and sited to reinforce the existing environmental values of the area.

There are three areas with a SLO: eight kilometres of shoreline of Westernport Bay between Tooradin and Koo Wee Rup (adjoining the south side of the South Gippsland Highway) (SLO2); and the Lang Lang Bushland Reserve and Lang Lang Nature Conservation Reserve in Lang Lang (both SLO3).

The aims of the **SLO2** (Western Port) are to: conserve and enhance the landscape quality of Western Port; conserve and enhance the flora, fauna and ecological processes of Westernport Bay; and encourage harmonious development.

The aims of the **SLO 3** (Lang Lang/Heath Hill) are to: protect and enhance the environmental, scenic and visual values of the area; protect and conserve habitat for flora and fauna which contributes to the significant landscape; ensure that any new development is located and designed to avoid detrimental affects on key characteristics of the landscape; and maintain vegetation as an important element of the landscape.

There is a Vegetation Protection Overlay (**VPO1**) over two areas in Cardinia and four areas in Bunyip: Ballarto Road in Cardinia; and the Railway line between McNamara Road and Henry Road in Bunyip; A'beckett Road; Doran Road; and Chambers and Flett Road in Bunyip.

The aim of the **VPO1** (in Low Density Residential Zone) is to: protect and conserve existing vegetation as an important element of the character of low density residential areas.

There are two other overlays in the former swamp area: Floodway (FO) and Land Subject to Inundation (LSIO) Overlays.

The purposes of a **FO** are to: identify waterways, major floodpaths, drainage depressions and high hazard areas which have the greatest risk and frequency of being affected by flooding; ensure any development maintains the free passage of temporary flood water; and protect water quality and waterways as a natural resource in accordance with State Environment Protection Policies (SEPP). FOs apply to most of the drains, creeks and other watercourse within the study area (see section 8).

The purposes of a **LSIO** are to: identify land in a flood storage or flood fringe area affected by the 1 in 100 year flood or any other area determined by the floodplain authority; ensure any development maintains the free passage of temporary flood water; and protect water quality and waterways as a natural resource in accordance with SEPP. LSIOs apply to most of the former swamp area.

ESO1 and SLO2 also apply to the small section of the City of Casey Balla Balla ward, which is part of the broader study area at Tooradin, into which numerous bandicoot records extend from Dalmore. Much of this area is also covered by LSIOs.

3 Study Area

The study area is essentially defined by the local government boundary of the Cardinia Shire Port Ward (Figure 1). This area is located approximately 55 km east of Melbourne, at its eastern limit, and extends from Lower Cardinia Creek in Officer South to Longwarry, in the north, and from Tooradin Station Road to Lang Lang and Heath Hill in the south. The Princes Highway forms the northern boundary of the study area. Areas of relevance immediately outside of the former Koo Wee Rup Swamp area include the eastern section of the City of Casey Balla Balla Ward.

The entire region in which the study area is situated has been vastly modified since European settlement. A long land use history of intensive agriculture, including cropping, grazing and market gardening, as well as residential development, has resulted in the loss of most of the native vegetation and in severe alterations to the hydrology of the region. The great Koo Wee Rup Swamp which once covered the study area was drained and cleared, commencing in the 1870s and continuing through to the 1960s, during which time, there were at least twelve floods (Yugovic and Mitchell 2006). Drainage channels were dug, and creeks and rivers were diverted and extensively channelised, to make the land suitable for farming. A sand mining industry commenced with the excavation of sand from the main drains, and continues in the study area to date. In 1878, the South Gippsland Railway line was constructed which runs parallel to the south-western border of the study area, through the townships of Dalmore, Koo Wee Rup, Monomeith and Lang Lang. An operational railway line intersects the north-eastern section of the study area, passing through Nar Nar Goon, Tynong, Garfield and Bunyip.

Although vast areas of land were cleared for farming and housing, remnants of the former vegetation are still present along some waterways, roadsides and railway lines, on private properties and in small conservation and bushland reserves throughout the region.

The study area is within the Gippsland Plain Bioregion, characterised by a climate of cool wet winters and warm dry summers. Climate data from Tooradin indicates that the warmest month is January, with a mean maximum temperature of 25.9 °C and the coldest month is July, with a mean minimum temperature of 3.8 °C. Annual rainfall is approximately 855 mm, with the highest falls in May (Bureau of Meteorology Data).

Former Koo Wee Rup Swamp Area

The study area lies over the former Koo Wee Rup Plain which encompassed a number of swamp complexes, including the Koo Wee Rup Swamp, Dalmore Swamp and Tobin Yallock Swamp. Yugovic and Mitchell (2006) have determined the past vegetation, geology, extent and probable boundaries of the former swamp complexes from historic documents and vegetation remnants. The extent of these swamp complexes, as proposed by Yugovic and Mitchell (2006) covers the area from approximately the modern township of Clyde to Modella and Bunyip, south of the Princes Highway.

The great Koo Wee Rup Swamp was the largest swamp in Victoria, and was composed of distinct inner swamp and outer swamp zones. It was contiguous with the Dalmore Swamp which formed a western extension of the outer swamp. Together, they formed a major wetland complex, covering c. 30,000 ha of east to west orientation. While Koo Wee Rup and Dalmore swamps were contiguous with one another, Tobin Yallock Swamp to the south was separated by grasslands and woodlands, which were extensive along the southern margins of the two contiguous swamps (Yugovic and Mitchell 2006).

The outer swamp was characterised by dense, closed scrub, approximately four to six meters in height, dominated by Swamp Paperbark (*Melaleuca ericifolia*), growing on mineral clay soils. Localised sand ridges in the outer swamp are likely to have supported Swampy Woodland with an overstorey of Swamp Gum (*Eucalyptus ovata*) and an understorey of *Melaleuca*, intersected by channels of water (Yugovic and Mitchell 2006).

The inner swamp was formed on organic peat and was distinct from the outer swamp in that it was relatively open. Covering approximately 13,000 ha, it was dominated by reeds and rushes, most likely Common Reed (*Phragmites australis*) and *Scirpus* sp. The inner swamp was permanently inundated, with ground water moving slowly through the peat, and held in small lake-like cells of open water which were separated by dense swathes of reeds and rushes. The lake-like cells in the inner swamp would have supported a mosaic of Reed Swamp, Aquatic Herbland and Aquatic Sedgeland (Yugovic and Mitchell 2006).

The Koo Wee Rup Swamp is thought to have been fed by approximately ten creeks and rivers. Swamp Paperbark Scrub extended back along these creeks. The Bunyip River was the main watercourse feeding the swamp, with its headwaters in the Central Highlands (Yugovic and Mitchell 2006). Water was channelled from the Bunyip River as it entered the swamp upon construction of the Bunyip River Main Drain in 1889. It was later connected to the Bunyip Drain which was used with four smaller drains, to drain the Swamp (DPI 2008). Yugovic and Mitchell (2006) propose that the Lang Lang River possibly connected with the swamp on the southern margin, and then left the swamp. All streams and rivers, except for this one, dissipated within the Koo Wee Rup Swamp complex. Formerly, seven watercourses drained the swamp. Yallock Creek, originating from the inner swamp at Bayles, was the main drainage outlet.

Dalmore Swamp was primarily fed by Cardinia Creek and also by Gum Scrub, Toomuc and Deep Creeks, which converged within the swamp. With the drainage of the swamps the feeder creeks were realigned and straightened. They were channelled into six parallel drains, which flow out to the Western Port Bay Ramsar Site at Dalmore Inlet (known as the Inlets). To the north, the creeks have catchments that drain from the foothills of the Great Dividing Range (Yugovic and Mitchell 2006).

Tobin Yallock Swamp was mainly fed by the Lang Lang River, and consisted largely of *Melaleuca* scrub. Gum Scrub Creek, vegetated by *Leptospermum* Swamp Scrub, drained the outer Koo Wee Rup Swamp at Caldermeade and entered the Tobin Yallock Swamp, where it dissipated. Scrub from the two swamps was loosely connected.

Grazing of the swamp was facilitated by sand ridges which were used by stock to access the swamp. Two large sandy ridges occurred between Cora Lynn and Bayles. Many of the sand ridges once present through the swamp have been covered in peat deposits creating peaty loam soils. Other sandy ridges are still evident underlaying the present Cardinia and Rythdale townships. Emergent sand ridges are likely to have supported vegetation ranging from stunted Paperbark scrub to Swampy Woodland on higher sites. Monomeith supported extensive grassy plains, with Swamp Scrub and acacia woodlands forming a mosaic. On the western side, open grassy plains adjoined the swamp at Cardinia where Cardinia Creek entered the swamp, and north of Tooradin (Yugovic and Mitchell 2006).

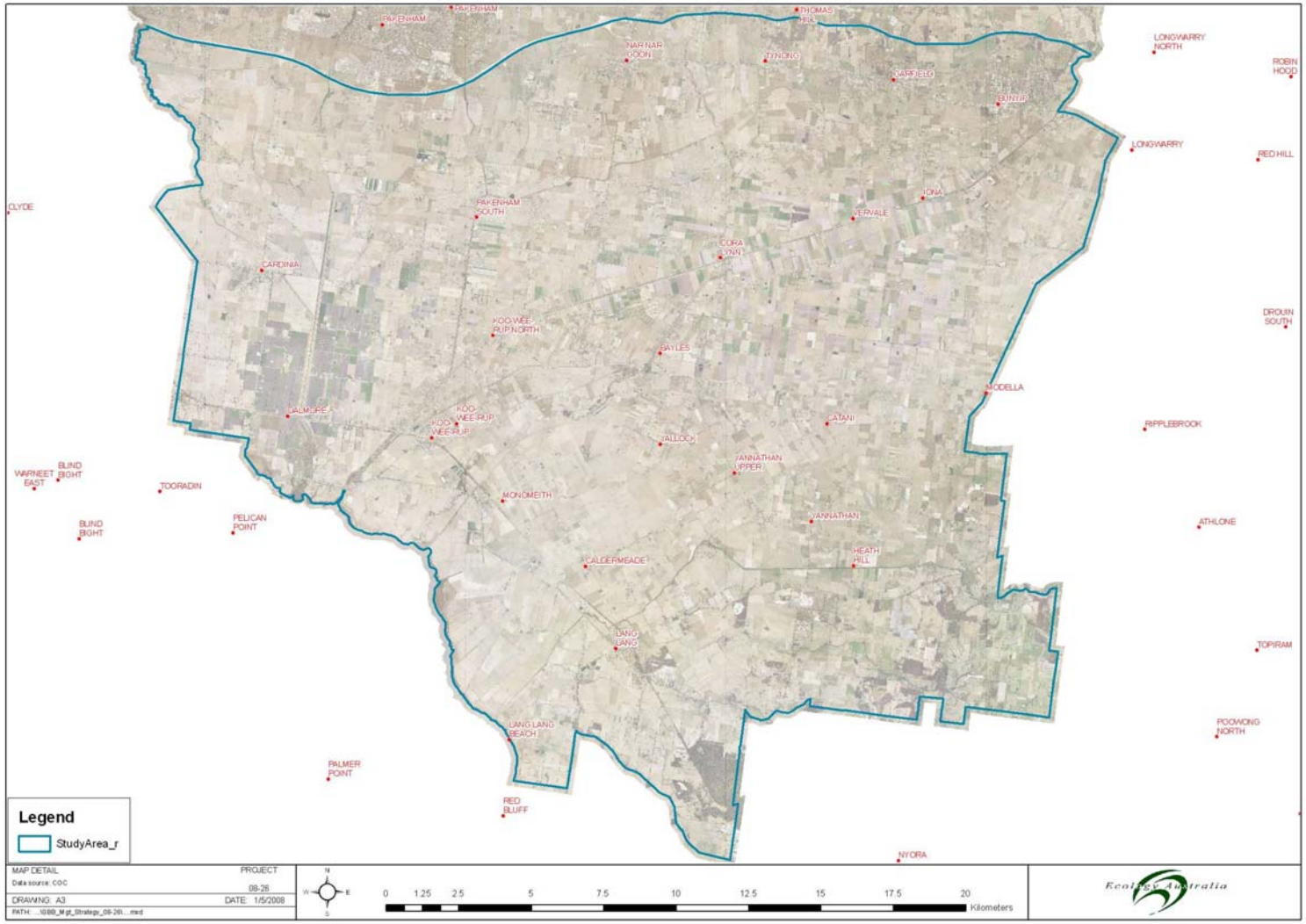


Figure 1 Southern Brown Bandicoot Strategic Management Plan: Former Koo Wee Rup Swamp Study Area

4 Bandicoots in the Former Koo Wee Rup Swamp Area

Southern Brown Bandicoots within the former Koo Wee Rup Swamp area form part of the south-central population in Victoria. The south-central population extends east from Melbourne to Drouin and south to Cape Liptrap. It includes the Mornington Peninsula, Western Port Bay, French Island, Phillip Island and extends along the Bass Coast from San Remo to Walkerville (Coates et al. 2008).

4.1 Historic distribution

At the time of European settlement, bandicoots were common throughout Melbourne and the Mornington Peninsula (Coates et al. 2008). Until the 1960's the species was still known to persist within greater Melbourne, in south-eastern suburbs including Clayton, Springvale, Glen Waverly, South Oakleigh, Mordialloc, Carrum Downs, Dingley and Rowville (Seebeck 1977). However, by this time, populations had been declining as a result of urban expansion, and scientists began to warn of their inevitable and continuing decline (Dixon 1966, Seebeck 1977, Coates et al. 2008). Today, these populations have disappeared (Coates et al. 2008). The pattern of local extinctions has been of a wave radiating outwards from Melbourne, as the city expands.

Historic records of Southern Brown Bandicoots in the Koo Wee Rup Swamp area indicate that the species was primarily distributed within the outer swamp region and the grassland areas of the Koo Wee Rup Swamp complex (Coates et al. 2008). Before 1900, the species was recorded from the South Gippsland Railway line in Tooradin and on Ballarto Road, Cardinia, and immediately north of the former swamp at Bunyip (Coates et al. 2008). During the 1970s, bandicoots were also recorded in Bayles (Coates et al. 2008), after drainage of the swamp had been completed.

4.2 Current distribution and population structure

The precise range and distribution of bandicoots in the former Koo Wee Rup Swamp area is not known, as no large-scale comprehensive surveys have been carried out. Current knowledge is based on the collation of records from State databases, smaller field surveys and incidental observations (see Appendix 5). Based on these records, four main population clusters of Southern Brown Bandicoots are considered to currently occur within the study area (Figures 3 to 6):

- Dalmore – Koo Wee Rup;
- Bayles;
- Cardinia - Rythdale; and
- Garfield – Longwarry.

Since little is known of the actual distribution or population structure, the term 'population cluster' is used in this management plan for a seemingly discrete concentration or 'cluster' of records.

The Cardinia cluster consists of a number of records centred over the creeks and drainage lines, which once entered the former Dalmore Swamp, and residential areas along Ballarto Road. Four creeks and numerous drainage lines converge at Cardinia and are channelled to flow south into Western Port Bay at Dalmore. The Dalmore – Koo Wee Rup cluster lies approximately 4.5 km south of the Cardinia cluster, spanning an area from Tooradin Station Road in the west, eastwards to the township of Koo Wee Rup. Many of these records are concentrated around the South Gippsland Railway line between Koo Wee Rup and Dalmore, with numerous records also scattered along the coastline from the Swamp lookout tower to Tooradin Station Road. It appears that since the drainage of the Koo Wee Rup Swamp, bandicoots have colonised areas within Bayles that would have once formed the inner swamp. Formerly, these areas of Reed Swamp may have been less suitable for the Southern Brown Bandicoot. In the north, Southern Brown Bandicoots have been recorded between Nar Nar Goon and Drouin, and are thought to span an arbitrary boundary between the Gippsland Plain and Highlands-Southern Fall Bioregions (Coates et al. 2008). However, most of these records are concentrated in an area between Garfield, Bunyip and Longwarry, south of the Princes Freeway (Figure 6). Until relatively recently, Southern Brown Bandicoots were thought to be locally extinct north of the freeway. The species had not been recorded north of the Princes Freeway since 1978 and 1981 in Bunyip State Park. However, between 2001 and 2004, eight individuals were captured in the north of Bunyip State Park (Clarke and White 2008). Nevertheless, the Princes Freeway is likely to represent a significant barrier for bandicoots north and south of the freeway. Nar Nar Goon and Tynong have isolated records. Between the Bayles and Garfield – Longwarry clusters, there are individual records at Cora Lynn and Iona.

The persistence of the Southern Brown Bandicoot in the former Koo Wee Rup Swamp area is unusual, given the absence of substantially large patches of remnant vegetation in a predominantly agricultural landscape. Bandicoots in the area appear to survive in narrow road and riparian corridors and small remnants on private land, also making use of anthropogenic resources, including houses and gardens. The use of these remnant strips of vegetation along riparian and roadside corridors may be the mechanism allowing bandicoots to move through and persist within the agricultural matrix. This is thought to be the case in Portland (Reese and Paull 2000), and also in Naringal, where Southern Brown Bandicoots were shown to move between forest patches by movement along roadsides as narrow as 5 m wide (Bennett 1990). It has been suggested that the persistence of bandicoots in this region may be primarily attributed to the extensive network of creeks and drainage lines providing vegetated linkages and provisions for dispersal throughout the landscape (David Nicholls and Terry Coates pers. comm.). Poor connectivity and isolation has been suggested as a factor contributing to the decline and disappearance of Southern Brown Bandicoots in the south-east of the region and in other outer eastern suburbs (David Nicholls pers. comm.). If dispersal occurs between patches of vegetation within the clusters, then parts of the Southern Brown Bandicoot population in the former Koo Wee Rup Swamp area may be acting as metapopulations, enhancing their viability in the area. However, this is as yet unclear.

Two of the largest and most suitable areas of remnant vegetation in the study area, from where Southern Brown Bandicoots have been recorded, are 'The Inlets' at Dalmore and the Koo Wee Rup Swamp Lookout tower. It has been suggested that these areas support important source populations of bandicoots, from which individuals seasonally disperse out of, into remnants at Cardinia, Koo Wee Rup and Bayles, through the arc of rivers and drains (David Nicholls pers. comm.). Bandicoot Corner and Bayles Fauna Reserve also probably sustain important populations. It seems plausible that the population clusters in the four main areas are linked by dispersal along riparian and roadside corridors, however, there is no evidence to confirm this. The Garfield-Longwarry cluster is considered by some authorities to be a self-sustaining population which has become fragmented and isolated with the drainage of the swamp (Rolf Willig pers. comm.).

4.3 Research

Only one population of Southern Brown Bandicoots has been studied in depth and for a considerable length of time in Victoria; the population within the Royal Botanic Gardens, Cranbourne. This population has been studied since the 1970s and has contributed much of the current knowledge concerning the ecology and biology of Southern Brown Bandicoots in Victoria (Braithwaite and Gullan 1978, Stoddart and Braithwaite 1979, Cockburn 1990, Lobert 1985 and Lobert and Lee 1990).

Very little research has been carried out on other bandicoot populations in Melbourne. In 2006 a Population Viability Analysis (PVA) was developed for bandicoots in the local government areas of Casey, Cardinia, Frankston and Mornington Peninsula Shires, to help inform management actions in greater Melbourne (Lechner 2006). The results indicated that the viability of Melbourne populations was dependent on landscape dynamics and demographic variables. Without management intervention, there was a 95 % predicted risk of decline of local populations. The greatest predicted increases in population abundance were achieved by at least halving the number of Red Foxes (*Vulpes vulpes*) and incorporating fire management techniques. However, many populations were predicted to become extinct because of isolation limiting the ability to recolonise following local declines (Lechner 2006). A follow-on study investigated the sensitivity of the PVA to habitat requirement uncertainty. The results of this investigation were similar. Management scenarios that substantially maximised the estimated minimum population (EMP) were those that included measures to reduce predation by Red Foxes. However, maintaining an appropriate fire regime and decreasing cat predation did not greatly improve the EMP. Habitat suitability maps were also developed to identify areas which should be prioritised for conservation (Southwell 2006, Southwell et al. 2008). The best habitat models indicated that the probability of bandicoot presence increased linearly with shrub cover, sandy soils and predator proof fencing (Southwell 2006). Habitat suitability maps developed from these models revealed the most suitable habitat to be located within Cranbourne Royal Botanic Gardens, as well as Bayles Fauna Park which are enclosed by a predator proof fence.

The research committee of the Mornington Peninsula and Western Port Biosphere Reserve Foundation, formed in 2002, has established a Southern Brown Bandicoot Recovery Team, in

collaboration with other organisations. The foundation held a public meeting in 2006, of researchers, land managers and locals to exchange knowledge and determine how to best conserve the species (MPWPBRF 2008). A recovery plan based on state recovery plans was developed specifically for the Mornington Peninsula and Western Port Region, which highlighted the need for immediate on ground actions and identified the need for further inventory and survey work on Southern Brown Bandicoots.

The historic distribution, current records and decline of Southern Brown Bandicoots across the south-central district, including the former Koo Wee Rup Swamp, has been mapped and documented by Coates et al. (2008) (see Sections 4.1 and 4.2).

Other relevant work in the former Swamp area

In addition to the above projects, there have been several other studies which have addressed the Southern Brown Bandicoot within the study area. These include:

- Surveys and preliminary impact assessment in regards to the Healesville - Koo Wee Rup Road upgrade (Ecology Australia 2005, 2008a);
- Preliminary habitat assessment of Manks Road bridges (Ecology Australia, draft 2008b)
- Surveys, Environmental Management Plan and EPBC documentation for the Bayles – Longwarry Road Bridge upgrade over Yallock Creek, Bayles (Ecology Australia 2002, 2005, 2006a);
- Surveys and Management Plan for the Inlets at Koo Wee Rup (Biosis 2008a)
- Flora and fauna assessments of the proposed desalination pipeline corridor (Biosis 2008b);
- Bayles oil spill into Yallock Creek (Ecology Australia 2006b).

4.4 Ability of the Southern Brown Bandicoot to recover in the former Koo Wee Rup Swamp area

The patchy but broad distribution of the Southern Brown Bandicoot throughout the former Koo Wee Rup Swamp area, and the potentially very small population sizes, has increased the vulnerability of populations in the area. It is not clear whether bandicoots in each of the clusters identified are isolated from each other, or if dispersal of individuals occurs between them, along the network of drainage lines and roads. However, the long term viability of bandicoots in this area is at risk from further habitat loss, fragmentation and isolation, and degradation. Habitat patches supporting some clusters and most probable habitat links are not necessarily managed for the conservation of the bandicoot due to conflicting management needs and land uses. Therefore, the risk of local population extinctions within the former Koo Wee Rup Swamp area is high due to on-going developments, systematic threats, and an increased vulnerability to stochastic events and the secondary pressures of predation, upon small and isolated populations.

Theoretically, the ability of the Southern Brown Bandicoot to persist or recover is high. The high level of fecundity and rate of juvenile dispersal is characteristic of a life history strategy favouring the colonisation of ephemeral and patchy environments (see Appendix 2). Since bandicoots are habitat generalists, capable of persisting in a variety of native and exotic vegetation types that provide dense cover, once threats are removed or reduced, it has the ability to rapidly increase in numbers. This increase would then be limited only by the extent of available habitat and its fragmentation. Therefore, this management plan is based on the abatement of threats, including habitat loss and fragmentation, degradation, predation and road mortality. The long-term viability of bandicoots in the former Koo Wee Rup Swamp area will also rely heavily upon the protection and enhancement of habitat and the restoration and enhancement of habitat connectivity throughout the former Koo Wee Rup Swamp area. The biology and ecology of Southern Brown Bandicoots and the threats to the species are detailed in Appendix 2.

5 Overview of Land Use in the former Koo Wee Rup Swamp area

The former Koo Wee Rup Swamp has been drained through the excavation of many drains and channels, and diversion of creeks and rivers, which have severely degraded the ecological values of the area (see Section 4). As a result of the development of the area, the former Swamp encompasses a range of land uses that include existing residential and agricultural land, proposed developments, resource extraction (e.g. sand), a disused railway line, and conservation/bushland reserves.

The following section outlines the different land uses within the study area

5.1 Conservation and recreation reserves

The former Koo Wee Rup Swamp area contains several areas of remnant vegetation primarily managed for conservation and/or recreation. These include:

Bushland Reserves in Cardinia Shire

There are several bushland reserves and recreational parks within the Cardinia Shire which occur in the former Koo Wee Rup Swamp area, these include:

- Bayles Fauna Reserve
- Bunyip Sanctuary;
- Bandicoot Corner; and
- small remnant roadside reserves.

Apart from Bunyip Sanctuary, these reserves are not managed directly by Cardinia Shire; more detail is provided below.

Bayles Fauna Reserve

The Bayles Fauna Reserve covers an area of 13.9 ha and is located on the Koo Wee Rup – Longwarry Road in Bayles and is zoned as Public Use. Yallock Creek is located immediately south of the reserve (Figure 4). It is Crown Land reserved for Public Recreation and managed by Bayles Fauna Park Committee of Management Inc. (CoM) in conjunction with DSE.

The reserve supports two Ecological Vegetation Classes: Swamp Scrub and Swampy Riparian Woodland. The Southern Brown Bandicoot has been recorded in the reserve. Priority management actions for the bandicoot as stated in the Bayles Fauna Reserve Management Plan (DSE 2006) include: maintaining areas of vegetation by fencing, fence maintenance (e.g. upgrade boundary predator-proof fence) and weed control (sensitive to the needs of bandicoots and Growling Grass Frogs *Litoria raniformis* which occur in the adjoining Yallock Creek); habitat enhancement along the southern section adjoining Yallock Creek (undertaken in conjunction with Melbourne Water); monitoring revegetation areas; pest animal control (monitor success of pest

plant and animal control; and monitoring vegetation to ensure areas are not over-grazed by macropods (e.g. Eastern Grey Kangaroos *Macropus giganteus*).

Bandicoot Corner, Bayles

Bandicoot Corner is a 3.6 ha reserve of remnant Swampy Riparian Woodland and Swamp Scrub, enclosed by electric predator-proof fencing. It is zoned as Public Use Zone, Services and Utility (PUZ1) comprised of parts of three parcels of Crown land. The reserve is managed by the Cardinia Environment Coalition, and a management plan has recently been produced (CEC 2008a). Key management actions identified for the Southern Brown Bandicoot in this plan include revegetation and weed control and pest animal control. Funding has recently been secured for habitat enhancement and restoration, a fox-baiting program and community engagement programs. The site is located between Yallock Creek and Number Four Drain (Figure 4).

Bunyip Sanctuary

Bunyip Sanctuary is a 50 ha reserve situated north of the Bunyip Township adjacent to the Princes Highway (Figure 7). It is managed by the Bunyip Sanctuary Committee of Management (Claessen 2007). Much of this area was cleared at the time of the drainage of the Koo Wee Rup Swamp. The north-eastern corner of this reserve is a 12 ha conservation zone, containing remnant and regenerating native vegetation, including: Lowland Forest, Swampy Woodland and Damp Heathy Woodland EVCs. The area is a public park and recreation zone and is subject to inundation. Management works to date have included tree planting and vegetation regeneration, weed control and fencing. The reserve is not predator proof, and foxes, feral cats (*Felis catus*) as well as European Rabbits (*Oryctolagus cuniculus*) are known to occur within the reserve (Claessen 2007). Bandicoots have not been recorded in this reserve, however, potential habitat is present, particularly in the conservation reserve in the north-east corner, off Doran Road. A carbon sink of 12 ha will be direct seeded by the end of 2009 in the north-west zone of the Sanctuary adjoining Tea-tree Creek, providing future core habitat opportunities.

Parks Victoria Reserves

Lang Lang Bushland Reserve

The Lang Lang Bushland Reserve is a small reserve managed by Parks Victoria, located off Range Road (Figure 7). It is adjacent to a rifle range and dog coursing-track. Remnant vegetation in the study area includes Grassy Woodland and Heathy Woodland (DSE 2008b). The reserve is zoned Public Conservation and Resource Zone (PCRZ) and is covered by an Environmental Significance Overlay (ESO3) and a Significant Landscape Overlay (SLO3). The reserve has been heavily degraded by the creation of tracks, weed invasion and dumping of rubbish. However, there is potential habitat for the bandicoot, within the northern section where there are areas of dense sedges (e.g. *Gahnia* spp.*)* adjoining pasture, and on the western side where the reserve adjoins remnant Swamp Scrub vegetation along the South Gippsland Railway Line. As with other reserves within the Lang Lang area, it is largely isolated from areas which support the bandicoot (i.e. Koo Wee Rup supports the closest cluster of recent records) and none have been recently recorded (see Section 8).

Lang Lang Nature Conservation Reserve

The Lang Lang Nature Conservation Reserve is part of a larger remnant and is located south-west of the Unimin mine, off McDonalds Track and Samuels Lane (Figure 7). The reserve is managed by Parks Victoria and is zoned as Public Conservation and Resource Zone (PCRZ) and surrounded by land zoned as Rural Conservation Zone (RCZ), which is under lease by Unimin. There is a Significant Landscape Overlay (SLO3) covering this reserve. While the site is largely isolated from other occupied areas, there is suitable habitat within this large patch of remnant vegetation (e.g. as well as the Unimin site). However, no bandicoots have been recorded here, despite recent survey efforts (Ecology Australia 2005, David Nicholls pers. comm.).

Other reserves

Royal Botanic Gardens Cranbourne

Royal Botanic Gardens Cranbourne (RBGC) is a division of the Royal Botanic Gardens Melbourne and comprises 363 ha of heathlands, wetlands and woodlands (Figure 7). The reserve supports remnant vegetation (e.g. Heathy Woodland and wetland areas), which is actively managed through ecological burns, weed control, habitat enhancement and predator control, and has predator-proof fencing. The RBGC is zoned Public Conservation and Resource Zone (PCRZ) and is covered by an ESO. The RBGC is not located within the former Koo Wee Rup Swamp area, however, it is a very important reserve for bandicoots in the south-central region of Victoria. It is one of the few remaining secure sites for bandicoots in Victoria, where the species still appears to occur in good numbers (Coates et al. 2008). There are currently several proposals to provide a habitat link, also known as a 'biolink', from the former swamp area (e.g. Cardinia Creek or Dalmore) to the RBGC (see Section 8). Providing a link between the RBGC and the former Koo Wee Rup Swamp area is likely to be critical for long-term population maintenance of the bandicoot in the south-central region (Lechner 2006, Southwell et al. 2008).

Wuchatsch Reserve - Trust for Nature

Wuchatsch Reserve is located in Nyora on Cherry Tree Road (it can also be accessed via Seaview Court or Forrest Drive), and is just outside the study area (Figure 7). It is zoned as Rural Living Zone (RLZ1). The reserve consists of two patches linked by a corridor, and covers 20 ha, of which 13 ha support remnant vegetation. The reserve supports Heathy Woodland EVC. This land is protected by a covenant and is managed by Trust for Nature. While the habitat is considered suitable, bandicoots have not been recorded from this reserve. However, there are records from within 2 km or the reserve, at Nyora (DSE 2007b).

5.2 Melbourne Water land

Since the drainage of the Swamp, many drains have been created and creeks and streams have been channelised (Figure 2). Vegetation along these creeks and drains now comprises a large and critical component of habitat occupied and utilised by bandicoots in the former Koo Wee Rup Swamp area (i.e. supports core populations and provide habitat links across the area) (see Section 8). The following table presents a summary of the drains, creeks and streams which are managed

by Melbourne Water and the current maintenance and/or land uses within these watercourses (Table 1).

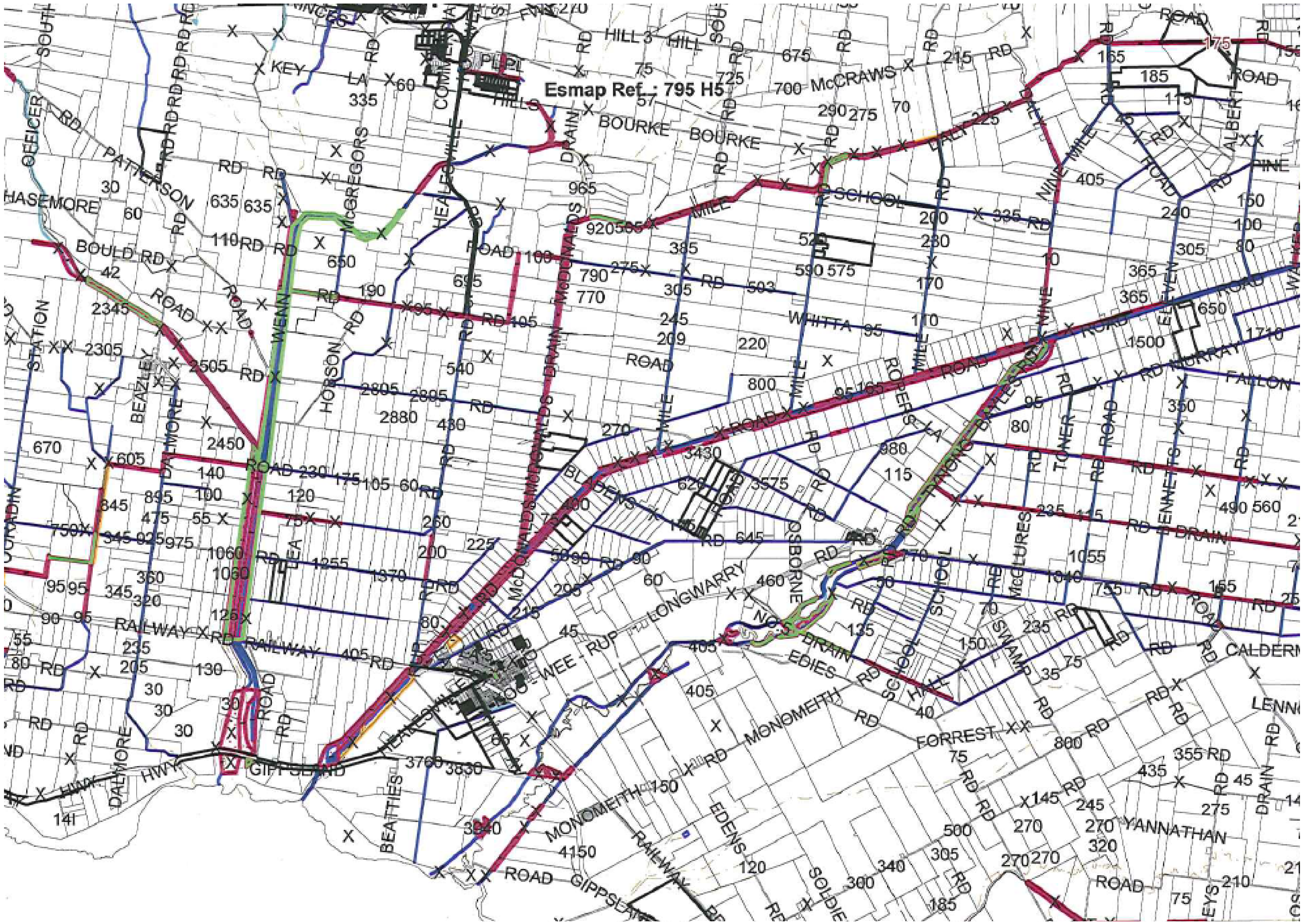
It is evident from the table below that none of the drains are zoned with a conservation focus. All of the watercourses are subject to either a Floodway Overlay or a Land Subject to Inundation Overlay (LSIO1), and are managed primarily for drainage and flood mitigation rather than environmental values. Melbourne Water also issues grazing leases along many of the waterways.

However, Melbourne Water's operational management practices are evolving with an increasing awareness of the need for management practices sympathetic to conservation values and requirements. This management plan has identified the need for Melbourne Water to develop an operational management strategy to address the conservation issues and conflicts associated with waterway and drain management identified throughout this plan.

Table 1 Southern Brown Bandicoot Strategic Management Plan: Melbourne Water land within the former Koo Wee Rup Swamp area

Melbourne Water managed land	Jurisdiction	Current maintenance (where known)	Zoning
The Inlets – covered by an Environmental Significance Overlay - Schedule 3 (ESO3)	Bed and banks with a 5-10 m setback from 'top of the bank'	Vegetation maintenance via slashing Dredging for flood mitigation	Public Conservation and Resource Zone (PCRZ) Public Use Zone 1 - Services and Utility (PUZ1) Rural Conservation Zone (RCZ1)
Drains around the Koo Wee Rup Swamp Lookout area	Bed and banks with a 5-10 m setback from 'top of the bank'	Vegetation maintenance via slashing	Public Conservation and Resource Zone (PCRZ)
Koo Wee Rup Drains (e.g. Bunyip River Drain)	Bed and banks with a 5-10 m setback from 'top of the bank'	Vegetation maintenance via slashing Dredging for flood mitigation	Public Use Zone 1 - Services and Utility (PUZ1)
Bunyip River (continue from Koo Wee Rup Drains)	Bed and banks with a 5-10 m setback from 'top of the bank'	Vegetation maintenance via slashing Dredging for flood mitigation	Special Use Zone 1 (SUZ1) Public Use Zone 1 - Services and Utility (PUZ1)
McDonalds Drain	Bed and banks with a 5-10 m setback from 'top of the bank'	Vegetation maintenance via slashing	Public Use Zone 1 - Services and Utility (PUZ1)
Healesville – Koo Wee Rup Road	Bed and banks only		Road Category 1 (RZ1)
Boundary Drain Road	Bed and banks only	Vegetation maintenance via slashing	Residential Zone 1 (RDZ1) Green Wedge Zone 1 (GWZ1)
Yallock Creek	Bed and banks with a 5-10 m setback from 'top of the bank' upstream and downstream of Bayles Bed and banks around Bayles township and south of No. 5 Drain Road to South Gippsland Highway	Vegetation maintenance via slashing Grazing leases	Public Use Zone 1 - Services and Utility (PUZ1)

Melbourne Water managed land	Jurisdiction	Current maintenance (where known)	Zoning
Number Four Drain	Bed and banks with a 5-10 m setback from 'top of the bank' upstream of Bayles	Vegetation maintenance via slashing Grazing leases	Public Use Zone 1 - Services and Utility (PUZ1)
Cardinia Creek Drains	Bed and banks with a 5-10 m setback from 'top of the bank' Part of the area is just bed and banks	Vegetation maintenance via slashing Grazing leases	Public Use Zone 1 - Services and Utility (PUZ1)
West Dalmore Road Drain	Bed and banks only	Vegetation maintenance via slashing	Public Use Zone 1 - Services and Utility (PUZ1) Special Use Zone 1 (SUZ1)
Ararat Creek and drain	Bed and banks with a 5-10 m setback from 'top of the bank'	Vegetation maintenance via slashing Grazing leases	Public Use Zone 1 - Services and Utility (PUZ1) Green Wedge Zone 1 (GWZ1)



Melbourne Water Land

Red – Melbourne Water land, bed and banks to 5-10 m from ‘top of the bank’

Green – Grazing lease

Orange – Other body

Blue – Melbourne Water land, but only bed and banks through private property

Figure 2 Southern Brown Bandicoot Strategic Management Plan: Melbourne Water owned and managed land

5.3 Residential, agricultural and commercial development

The existing and proposed land uses within the study area are having, or will potentially have, significant impacts on Southern Brown Bandicoot populations. The following section summarises land use practices in the study area, and outlines proposed developments (where known) and their relevance to habitat conservation for the bandicoot.

Residential

There are several townships within the study area, which are zoned Residential Zone 1 or Low Density Residential Zone, the largest being Koo Wee Rup, Lang Lang, Bayles, Cardinia, Bunyip and Garfield. These towns are likely to increase in density in the future. Other residences outside of these areas are on farmland within either Rural Conservation Zone or Green Wedge Zones.

In regards to the Urban Growth Zone, there was a recent amendment to the Cardinia Planning Scheme on 10 June 2008. This introduced an Urban Growth Zone (UGZ) to land previously designated as Farming Zone within the Urban Growth Area of Cardinia Shire. The Cardinia Urban Growth Area is divided into seven precincts, including four residential precincts (Beaconsfield, Officer, Cardinia Road and Pakenham), and three employment precincts (Officer Employment, Cardinia Road Employment and Pakenham Employment Precincts).

The southern section of the Urban Growth Boundary (which includes the Officer, Cardinia Road and Pakenham Employment Precincts) encompasses the north-western corner of the study area (see Figure 7).

Outside the current UGZ, there are also other upcoming residential developments and sub-divisions in the townships, such as Bunyip. As many of the bandicoot records in Bunyip (and Garfield) are from private properties. Further sub-division of land and the creation of smaller lots for residential development have the potential to threaten bandicoots in these areas. As these areas are zoned either Residential Zone or Low Density Residential Zone, they are not secure for conservation in perpetuity and are likely to be developed in the future. Therefore, it will be important to develop planning controls within a Southern Brown Bandicoot Overlay for the protection of habitat in areas such as Bunyip, and to alert developers for the need to consider bandicoots prior to development and planning applications. Relatively large areas of remnant bushland on private land, known to support bandicoots or strategically located in regards to habitat links to other occupied patches, could also be protected by conservation covenants (e.g. through Trust for Nature), in order to retain habitat for the species in these rural townships. The notion of a bandicoot overlay and conservation covenants are further discussed in Section 9.

Agricultural

Ongoing farming and agricultural activities may jeopardise conservation initiatives for bandicoots (generally zoned Special Use Zone, Farming Zone, Rural Conservation Zone or Green Wedge Zone). Grazing by cattle is a major concern along watercourse as cattle remove the understorey vegetation which provides shelter, rendering bandicoots more vulnerable to predation. Cropping

activities adjacent to reserves and/or watercourse have the potential to increase weed invasion via nutrient run-off from fertilisers and pesticides.

Vegetation management and/or maintenance is currently carried out through cattle grazing (i.e. Melbourne Water grazing leases) on Melbourne Water land, such as the 'Koo Wee Rup Drains' (e.g. Bunyip River Drain) and 'Dalmore Drains' (e.g. Cardinia Creek).

Extractive Industry

A number of quarries exist within the study area and surrounds. Quarry developments (sand extraction) are situated along McDonalds Track in Lang Lang and further east around the Heath Hill area. Quarrying activities have the potential to remove habitat for bandicoots and also have direct impacts on water quality and native vegetation degradation in Lang Lang River and Adams Creek in the south-east section of the study area.

5.4 Other proposed developments

Healesville - Koo Wee Rup Road upgrade

VicRoads are proposing to upgrade the Healesville – Koo Wee Rup Road, between the Pakenham Bypass and the South Gippsland Highway. Ecology Australia has undertaken several studies as part of a planning investigation to determine options for the future upgrade of the road along its current alignment

Two, possibly three, dead specimens of the Southern Brown Bandicoot have been found along the Healesville – Koo Wee Rup Road, during September 2008 (Rolf Willig pers. comm.). Many other Southern Brown Bandicoots have been recorded within proximity to the proposed connection alignment to the South Gippsland Highway. The final alignment has not yet been devised. However, given these recently found road kills, and the already high traffic load carried by the road, it appears that the upgrade of the Healesville – Koo Wee Rup Road may pose a major barrier to movement across it for the Southern Brown Bandicoot. Mitigation measures and management strategies will be implemented to reduce impacts to the Southern Brown Bandicoot as part of the road upgrade studies.

Desalination pipeline corridor

The Department of Sustainability and Environment, on behalf of the Victorian Minster for Water, proposes to develop a seawater desalination plant approximately 3 km west of Wonthaggi to treat and transfer water to Melbourne's water supply system, and other regional supply systems. An underground pipeline (c. 85 km) from Wonthaggi to Berwick, to transfer water to Melbourne's water supply system, and a power supply grid are required. Both of these alignments will traverse part of the former Koo Wee Rup Swamp area. Within the former Koo Wee Rup Swamp area, the northerly power connection is anticipated to be laid largely overhead.

Preliminary flora and fauna assessments for this project were conducted, which revealed potential habitat for the Southern Brown Bandicoot within the transfer pipeline corridor (Biosis 2008b, DSE 2008c). Subsequent to the information provided, the Minister for Planning decided that an

Environmental Effects Statement (EES) was required for the Desalination Project. As such, further assessments were carried out to assess the impacts and outline the strategies to minimise, manage and offset adverse effects on environmental values, and an EES was produced.

The proposed pipeline corridor runs:

- Parallel to Ballarto Road, Cardinia (in the road reserve), from Pound Road to McDonalds Drain Road. The pipeline corridor would impact on a known habitat link along Ballarto Road;
- Traverses Cardinia Creek, north of Ballarto Road (a habitat patch/habitat link);
- Crosses the northern section of Dalmore Drains, adjoining Wenn Road (a habitat patch/habitat link);
- Runs south, parallel to McDonalds Drain Road and crosses McDonalds Catch Drain to Fechner Road (limited habitat);
- Crosses over Bunyip River Road and Main Drain Road north (a potential habitat link between Koo wee Rup and Cora Lynn - limited habitat at present);
- Crosses Daley's Road (part of a potential habitat link between Koo Wee Rup and Bayles);
- Crosses farmland and Boundary Drain Road (strongest potential habitat link between Koo Wee Rup and Bayles);
- Crosses Yallock Creek (a potential habitat link between Bayles and South Gippsland Highway, Koo Wee Rup);
- Through to Monomeith Road and then adjoining the South Gippsland Railway Line (a potential habitat link to Lang Lang – Nyora areas); and
- Towards Wonthaggi crosses the Lang Lang River and Adams Creek (potential biolink).

Detailed assessments have so far not been carried out. Further survey work will be required along the proposed pipeline route, to help inform the detailed design phase.

South Gippsland Railway Line - Rail Trail

The South Gippsland Railway Line (also known as the Leongatha Railway Line) from Cranbourne to Leongatha was constructed by 1878, as part of the South Gippsland Regional Rail Network (DPI 2008). Passenger services from Cranbourne to Leongatha were withdrawn in 1993, and in 1994 a community lease for the line from Nyora to Leongatha was signed by South Gippsland Tourist Rail. Tourist services on this line are still in operation. The railway line from Cranbourne to Nyora has not carried rail traffic since 1999, and has had no maintenance since 1998 (TransNet 2007). The track is now largely overgrown by vegetation, growing between the sleepers in many places, and the general structure has deteriorated.

In 2005, an investigation into the feasibility of restoring rail services from Cranbourne to Leongatha commenced (TransNet 2007). The railway was found to be un-serviceable due to ballast

collapse, abnormal alignment, general formation failures and extremely poor sleeper condition. An ecological assessment found vegetation communities along the railway line that are significant at state and national levels, and much of the railway line falls within BioSites significant at Regional and National levels. The assessment also concluded that any vegetation clearance (native or exotic), particularly between Clyde and Koo Wee Rup would impact upon Southern Brown Bandicoots in the study area, and vegetation clearing to the prescribed widths for maintenance and fire prevention for the full length of the railway would result in significant impacts. The investigation concluded that restoration of rail services was economically unviable and would not go ahead (TransNet 2007). Instead, Public Transport Minister Lyn Kosky announced a funding package to improve bus and coach services to South Gippsland. There was also a proposal for a rail trail between Cranbourne and Nyora.

We strongly advocate that given the importance of vegetation along the disused railway line as habitat for bandicoots, the vegetation be retained and managed appropriately for conservation of bandicoots as a priority for any future use plan. Vegetation loss along the railway line could fragment the Dalmore - Koo Wee Rup population reducing its viability, and would have implications for connectivity to outside of the study area, increasing the threat of local extinctions.

Port of Hastings Land Use and Transport Strategy

With a predicted increase in national and international trade, the Port of Melbourne is anticipated to reach its full capacity by 2035, and the Port of Hastings is expected to take a greater share of the State's trade. The Port of Hastings is the Victorian Government's preferred site for the development of container trade to support the Port of Melbourne, because of its naturally deep water channel. This development requires substantial infrastructure, and so the Port of Hastings Corporation has developed the *Port of Hastings Land Use and Transport Strategy* (PoHC 2008). Some of this infrastructure requires the upgrade and construction of roads and railway lines through the former Koo Wee Rup Swamp area. The regional transport strategy proposes:

- A road connection from Baxter-Tooradin Road to Gippsland;
- A short bypass of Koo Wee Rup from the South Gippsland Highway to Pakenham Bypass;
- A new road corridor along the Melbourne-Sale Railway line between Officer and Pakenham; and
- A new freight railway from the Port of Hastings to Pakenham.

The freight railway line would follow the Baxter-Tooradin Road and the proceed north along Berwick Cranbourne Road, continue eastwards along Ballarto Road up to near Cardinia Creek, north to the Melbourne-Sale Railway line. The new freight line is expected to be used once the roads and other routes have reached capacity.

6 Ecological Vegetation Classes

The former Koo Wee Rup Swamp area encompasses a variety of remnant native vegetation patches within Conservation Reserves, drains, creeklines, roadsides and private property. Vegetation modelling by the Department of Sustainability and Environment (DSE 2008a) indicates that they are comprised of several different Ecological Vegetation Classes (EVCs) within the former Koo Wee Rup Swamp area.

The EVC maps produced by DSE are intended as a guide only. The scope of this project was not aimed to verify EVCs across the study area; however, vegetation structure and EVC can give an indication of habitat suitability for bandicoots. Each area known to be inhabited by the Southern Brown Bandicoot at some time, was assigned a habitat type based on EVC descriptions, dominant plant species identified in the field and DSE mapping (see Section 7).

The most commonly occurring EVCs and their conservation status for the Gippsland Plain Bioregion are listed below. Habitats occupied by bandicoots were generally dominated by one of the three EVCs, shown in bold. A brief description of these key habitat types is provided below. An asterisk is used to denote exotic species.

- **Swamp Scrub EVC 53 (Endangered)**
- **Swampy Riparian Woodland EVC 83 (Endangered)**
- **Lowland Forest EVC 16 (Vulnerable)**
- Estuarine Flats Grassland EVC 914 (Endangered)
- Swampy Woodland 937 (Endangered)
- Grassy Forest EVC 128 (Endangered)
- Damp Heathy Woodland EVC 793 (Vulnerable)
- Herb-rich Foothill Forest EVC 23 (Vulnerable)
- Coastal Saltmarsh EVC 9 (Least Concern)
- Mangrove Shrubland EVC 140 (Least Concern)

Swamp Scrub

This EVC was the most dominant vegetation type, scattered throughout the seasonally inundated areas known to support bandicoots, such as creeks and drains (Tables 4 to 7). Intact examples comprise a closed scrub dominated by Swamp Paperbark (*Melaleuca ericifolia*) and Scented Paperbark (*Melaleuca squarrosa*). Occasional large shrubs are also present, including Blackwood (*Acacia melanoxylon*), Prickly Moses (*Acacia verticillata*) and Snowy Daisy-bush (*Olearia lirata*). The understorey is dominated by Weft Moss (*Thuidium* sp.) with scattered sedge-like species and herbs such as Tassel Cord-rush (*Baloskion tetraphyllum* ssp. *tetraphyllum*), Square Twig-sedge

(*Baumea tetragona*), Pithy Sword-sedge (*Lepidosperma longitudinale*) and Ivy-leaf Violet (*Viola hederacea*).

Within the study area, however, most of the remnant Swamp Scrub is a drier and highly degraded form of the pre-European condition. It is generally characterised by an overstorey of Swamp Paperbark with an understorey dominated by *Blackberry (*Rubus fruticosus*), *Bridal Creeper *(Asparagus asparagoides*), *Flax-leaf Broome (*Genista linifolia*), *Gorse (*Ulex* spp.) and exotic grasses (e.g. *Canary Grass *Phalaris aquatic*, *Yorkshire Fog *Holcus lanatus* and *Panic Veldt Grass *Ehrharta erecta*). In some of the more 'intact' areas there may also be scattered sedges such as Spiny-headed Mat-rush (*Lomandra longifolia*), Red-fruit Saw-sedge (*Gahnia sieberiana*) and Thatch Saw-sedge (*Gahnia radula*).

Lowland Forest

Most of the areas identified as Lowland Forest are in the Garfield – Bunyip areas and parts of Lang Lang and Heath Hill. Lowland Forest is dominated by Narrow-leaf Peppermint (*Eucalyptus radiata ssp. radiata*) and Messmate Stringybark (*E. obliqua*), with occasional occurrences of Coast Manna Gum (*E. viminalis*) as the EVC grades into Heathy Woodland.

Shrubs and groundcover species commonly occurring include: Manuka (*Leptospermum scoparium*), Prickly Tea-tree (*L. continentale*), Thatch Saw-sedge (*Gahnia radula*), Wattle Mat-rush (*Lomandra filiformis* ssp. *coriacea*) and Weeping Grass (*Microlaena stipoides* var. *stipoides*).

Swampy Riparian Woodland

This EVC was most common in the Bayles area, particularly along Yallock Creek and in patches in the Koo Wee Rup – Dalmore area. Swampy Riparian Woodland is characterised by Swamp Gum (*Eucalyptus ovata*) and Narrow-leafed Peppermint (*E. radiata*), Blackwood (*Acacia melanoxylon*) and Swamp Paperbark, with a ground-layer of Common Reed (*Phragmites australis)* and Wattle Mat-rush *(Lomandra filiformis*).

Exotic vegetation

Within the former Koo Wee Rup swamp area, much of the habitat occupied by bandicoots is dominated by weeds. The dominant weed species encountered within bandicoot habitats include: *Blackberry, *Broome (*Genista spp.)*, *Gorse, *Bridal Creeper, *Spanish Heath (*Erica lusitanica*), *Sweet Pittosporum (*Pittosporum undlatum*), *African Boxthorn (*Lycium ferrocissimum*), *Hawthorn (*Crataegus monogyna*), *Cape Ivy (*Delairea odorata*), *Arum Lily (*Zantedeschis aethiopica*) and exotic grasses such as *Canary Grass, *Yorkshire Fog and *Panic Veldt Grass.

7 Habitat function for population clusters in the former Koo Wee Rup Swamp area

The distribution of bandicoots in the former Koo Wee Rup Swamp area has not been fully established. However, current knowledge of their distribution has been formed through the collation of past and recent records from various sources including state databases, public sightings, field researchers, and from field surveys undertaken for this management plan. Details of the sources of bandicoot records and of the field investigations undertaken for this management plan are provided in Appendix 5.

As discussed in Section 4.2, based current understanding of the distribution of bandicoots within the former Koo Wee Rup Swamp area, four population clusters are apparent:

- Dalmore – Koo Wee Rup cluster;
- Bayles cluster;
- Cardinia - Rythdale cluster; and
- Garfield – Longwarry cluster (Figures 3 to 6).

The following section describes the key habitat components and likely habitat functions within each cluster and classifies the habitat in regards to its importance for the long-term persistence of the species within the study area. It also outlines habitat security (e.g. land tenure and zoning) and key threats to bandicoots and constraints for management. This has been based on the known distribution of bandicoots and assessment of habitats undertaken during the field surveys.

Some of the areas classified as core habitat, habitat patches and/or habitat links are not secured for conservation, and land tenure and zoning allow for land uses and management practices not compatible with Southern Brown Bandicoot habitat and conservation requirements. For example, the Koo Wee Rup Drains support core habitat for bandicoots but are zoned as Pubic Use Zone (Services and Utility). As such the drains are managed for flood mitigation rather than conservation. This was evident throughout many of the population clusters (see Tables 3 to 6).

Table 2 outlines the terminology for the following section in regards to habitat function in the study area.

Table 2 Southern Brown Bandicoot Strategic Management Plan: Population cluster habitat function definitions

Habitat function	Definition
Core habitat	Large areas of habitat (e.g. >3 ha) which may support a large core or source population of bandicoots, and are well connected to other areas of known habitat. Core habitat is critical for the long-term persistence of clusters, and requires protection and security in perpetuity. Core habitat may also act as habitat links within a cluster.
Habitat Patch	A small habitat patch which is known to support bandicoots but may be poorly linked and is not considered critical for the long-term persistence of the cluster. These patches may also be constrained by their surroundings (e.g. within residential areas), but require protection and security in the long-term.
Habitat Link - within	Provides connectivity within a cluster – important for dispersal, movement between areas and population viability.

7.1 Dalmore – Koo Wee Rup population cluster

Within the Dalmore – Koo Wee Rup cluster, all areas known to support bandicoots are classified as core habitat. These include: the patch of vegetation adjoining the Koo Wee Rup Swamp Lookout Tower on the South Gippsland Highway; the Koo Wee Rup Drains (McGregors Drain, McDonalds Drain, North West Drain, Bunyip River Drain and Southern Boundary Drain) which extend upstream from the Lookout area (Appendix 3, Plates 1 and 2) and the Inlets (e.g. Deep, Cardinia and Tomuc Creeks) from the South Gippsland Highway to the Railway Line. The Inlets habitat also extends downstream of the South Gippsland Highway to the Ramsar site, also considered important habitat for the bandicoot (Figure 3).

The vegetation at the Koo Wee Rup Swamp Lookout is classified as Swamp Scrub. Extending upstream, from the South Gippsland Highway to the Healesville – Koo Wee Rup Road, the habitat along the Koo Wee Rup drains is mostly contiguous and is comprised of Swamp Scrub remnants, exotic vegetation (e.g. *Gorse, *Broome and *Genista* sp.*Blackberry *Rubus* sp.) and cleared grassy levees (e.g. from slashing for maintenance and flood mitigation). There is a Coastal Saltmarsh component within the downstream sections of the drains which support Beaded Glasswort (*Sarcocornia quinqueflora ssp. quinqueflora*), and there are also areas on slightly higher ground that support Saltbush (*Rhagodia* sp.) and Marsh Saltbush (*Atriplex paludosa* ssp. *paludosa*). Coast Tussock Grass (*Poa poiformis* ssp. *poiformis*), Sea Rush (*Juncus kraussii* ssp. *australiensis*) and Chaffy Saw-sedge (*Gahnia filum*) grow on the banks with young regenerating Swamp Paperbarks.

The Inlets support several vegetation communities. The flora of the study area has recently been mapped in detail by Biosis (2008a). Some of the main vegetation communities include: Estuarine Flats Grassland, Coastal Saltmarsh, remnants of Mangrove Shrubland and smaller areas of Swamp Scrub and Swampy Riparian Woodland. On the western and eastern side of Cardinia Creek, there is a large patch of Estuarine Flats Grassland. This vegetation is comprised of large tussocks of

Coast Tussock-grass, Chaffy Saw-sedge and Prickly Spear-grass (*Austrostipa stipoides*) (Appendix 3, Plate 4). North of the South Gippsland Highway, Grey Mangroves (*Avicennia marina* ssp. *australasica*) from the Mangrove Shrubland EVC (mangroves form extensive communities in Westernport Bay) have extended up the Creeks and border the channel and occur on mudflats within the tidal zone. A narrow strip of Coastal Saltmarsh occurs immediately above the marine and estuarine tidal flats and grades into Estuarine Flats Grassland. The Coastal Saltmarsh is dominated by Beaded Glasswort, Shrubby Glasswort (*Sclerostegia arbuscula*), with occurrences of Rounded Noon-flower (*Disphyma crassifolium* ssp. *clavellatum*), Saltbush (*Rhagodia* sp.) and Sea Rush.

The levees support scattered Blackwoods (*Acacia melanoxylon*), Black Wattles (*Acacia mearnsii*) Swamp Paperbark, *Blackberry, *Gorse and *Broom, over a grassy ground layer.

It is recommended that 'The Inlets', the Koo Wee Rup Swamp Lookout area and Koo Wee Rup Drains are provided with predator-proof fencing (see Figure 3). Biosis have also produced management recommendations for The Inlets, and recommend that the Inlet Waterway Reserve be extended northwards to the Railway line (Biosis 2008a).

Lyall's Inlet (including the West Dalmore Drain system) is located c. 700 m to the west of the Inlets (Figure 3). This area is classified as core habitat and supports similar vegetation to the Inlets, including Estuarine Flats Grasslands, Swamp Scrub, Coastal Saltmarsh and Mangrove Shrubland.

Habitat along the South Gippsland Railway Line from the Koo Wee Rup Township to the Cardinia Creek Drains is absent around the township and somewhat patchy along other areas (e.g. dissected by driveways), but generally supports suitable habitat attributes where there is a dense cover of midstorey vegetation. For example, along Railway Road (adjacent to the Railway Line), the habitat is classified as degraded Swamp Scrub with dense areas of *Blackberry and a sedgy/reed dominated understorey (e.g. *Lomandra* sp. and Common Reed *Phragmites australis*) (Appendix 3, Plate 5).

Table 3 Southern Brown Bandicoot Strategic Management Plan: Dalmore – Koo Wee Rup population cluster

Area/Location	Habitat function	EVC/Habitat	Tenure	Zoning	Overlays	Key Threats and Constraints
Koo Wee Rup Swamp Lookout	Core habitat	Estuarine Flats Grasslands Swamp Scrub Coastal Saltmarsh	Public	Public Conservation and Resource Zone (PCRZ)	Floodway Overlay	• Fox predation • Recreational and resource use • Proposed Healesville - Koo Wee Rup Road Upgrade
Koo Wee Rup Drains (e.g. Bunyip River Drain)	Core habitat	Estuarine Flats Grasslands Swamp Scrub Coastal Saltmarsh Exotic vegetation Cleared levees	Public (Melbourne Water)	Public Use Zone 1 - Service and Utility (PUZ1)	Floodway Overlay Significant Landscape Overlay SLO2 (south side of South Gippsland Highway)	• Not secure for conservation • Not protected by zoning • Fox predation • Vegetation clearing (e.g. drain maintenance) • Proposed Healesville - Koo Wee Rup Road Upgrade
The Inlets (between South Gippsland Highway and Railway Road)	Core habitat	Estuarine Flats Grasslands Swamp Scrub Coastal Saltmarsh Mangrove Shrubland Swamp Scrub Swampy Riparian Woodland	Public (Melbourne Water)	Public Conservation and Resource Zone (PCRZ) Public Use Zone 1 - Service and Utility (PUZ1) Rural Conservation Zone 1 (RCZ1)	Environmental Significance 2 (ESO2) Significant Landscape Overlay SLO2 (south side of South Gippsland Highway) Floodway Overlay	• Fox predation • Not protected by zoning in parts • Recreational and resource use • Farming practices (e.g. grazing and/or cropping) • Vegetation clearing (e.g. drain maintenance) • Proposed Healesville - Koo Wee Rup Road Upgrade

Area/Location	Habitat function	EVC/Habitat	Tenure	Zoning	Overlays	Key Threats and Constraints
Lyalls Inlet (includes south-east section of the West Dalmore Road Drain system)	Core habitat	Estuarine Flats Grasslands Swamp Scrub Coastal Saltmarsh Mangrove Shrubland	Public Private	Rural Conservation Zone 1 (RCZ1)	Land Subject to Inundation (LSIO1) Significant Landscape Overlay SLO2 (south side of South Gippsland Highway)	• Not secure for conservation • Not protected by zoning • Fox predation • Recreational and resource use • Farming practices (e.g. grazing and/or cropping) • Vegetation clearing (e.g. drain maintenance)
South Gippsland Railway Line (adjacent to Railway Road between Koo Wee Rup Township and Cardinia Creek Drains)	Core habitat	Swamp Scrub	Private	Public Use Zone - Transport (PUZ 4)	Land Subject to Inundation (LSIO1)	• Not secure for conservation • Not protected by zoning • Proposed Rail Trail • Proposed Healesville - Koo Wee Rup Road Upgrade • Fox predation • Predation by domestic pets • Vegetation clearing (e.g. roadside maintenance)

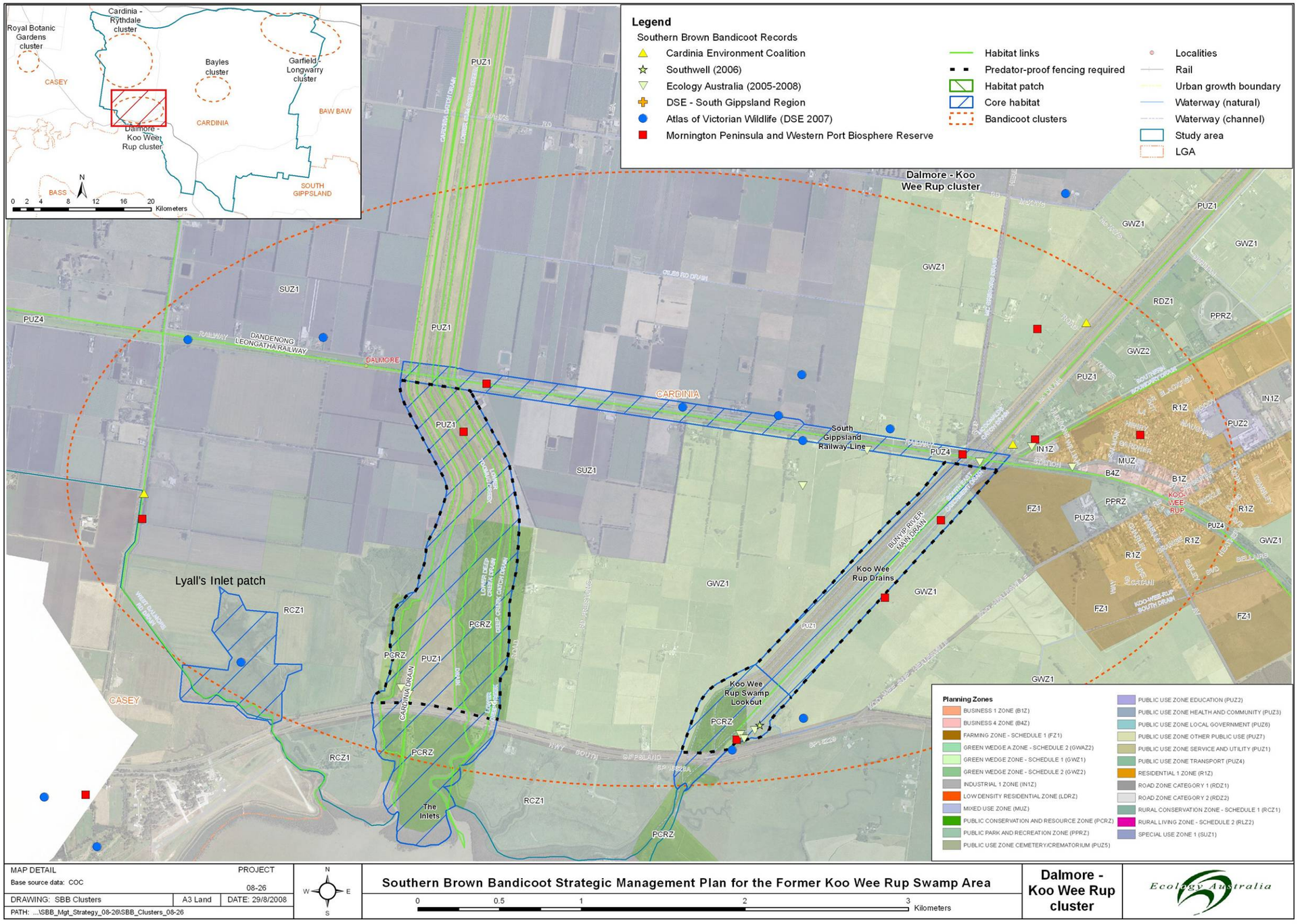


Figure 3 Southern Brown Bandicoot Strategic Management Plan: Dalmore – Koo Wee Rup population cluster

7.2 Bayles population cluster

Within the Bayles population cluster, the three areas known to support bandicoots are classified as core habitat. These are: the Bayles Fauna Reserve, Bandicoot Corner and Yallock Creek from Bayles to Cora Lynn.

The Bayles Fauna Reserve is 13.9 ha of remnant vegetation and is managed by the Bayles Fauna Park Committee Inc. (COM). The reserve is important in regards to remnant vegetation within the area, as most of the region was cleared during the drainage of the Swamp. The reserve now supports two EVCs: Swamp Scrub and Swampy Riparian Woodland. There is predator-proof fencing around the perimeter of the reserve, which adjoins Yallock Creek (Figure 4).

Bandicoot Corner is a 3.6 ha reserve consisting of Swampy Riparian Woodland and Swamp Scrub, enclosed with electric predator-proof fencing. There is PVC piping at the ground level, flush with the predator-proof fence, which is aimed to allow free movement of bandicoots, whist keeping large predators out. This reserve adjoins Number Four Drain. As these two reserves have predator-proof fencing and regular fox-control and are actively managed for bandicoots, they are very important patches for this cluster in regards to long-term habitat security, and are also likely to form the strongholds for the species within the cluster (Table 4).

Yallock Creek is likely to form part of the core habitat within the cluster and also provides a habitat link between Bayles and Cora Lynn (Table 4). Habitats within and adjoining Yallock Creek, which are known to support bandicoots, include beds of Common Reed and rushes within the stream channel; and scattered Swamp Scrub and Swampy Riparian Woodland remnants on the levees and in road reserves. The levees also support patches of Blackwood, *Flax-leaf Broome, *Blackberry and sedges (e.g. *Lomandra* and *Gahnia* spp.).

Grazing has been removed along Yallock Creek, immediately upstream of the Bayles-Longwarry Bridge to c. 500 m upstream (Appendix 3, Plate 6). This has resulted in the regeneration of in-stream vegetation and understorey cover on the levees. During the field survey, numerous bandicoot diggings and scats were recorded at the interface of the grazed and non-grazed areas, demonstrating the importance of the combination of dense areas interspersed with open areas for foraging (see Appendix 3, Plate 7).

Areas upstream and downstream of Bayles have been heavily grazed. This has resulted in loss of understorey vegetation which provides shelter for bandicoots, as well as loss of in-stream vegetation which has caused substantial degradation and modification of the habitat for other threatened fauna species known to occur within Yallock Creek (e.g. Growling Grass Frog and Dwarf Galaxias *Galaxiella pusilla*). However, there are patchy occurrences of *Broome and *Blackberry on the levees and rushes and sedges (e.g. *Juncus* sp. and *Carex* sp.) in the stream bed which are providing suitable habitat for the bandicoot (Appendix 3, Plates 16 and 17). Several diggings and one bandicoot carcass (probably predated by a cat) were found in this type of habitat along Yallock Creek, near Murray Road.

Table 4 Southern Brown Bandicoot Strategic Management Plan: Bayles population cluster

Area/Location	Habitat function	EVC/Habitat	Tenure	Zoning	Overlays	Key Threats and Constraints
Bayles Fauna Reserve	Core habitat	Swamp Scrub Swampy Riparian Woodland	Public	Public Use Zone 6 - Local Government (PUZ 6) Public Use Zone 7 - Other Public Use (PUZ 7)	Land Subject to Inundation (LSIO1)	• Fox predation • Rabbits • Recreational use • Weed infestation (e.g. Blackberry)
Bandicoot Corner	Core habitat	Swamp Scrub Swampy Riparian Woodland	Public	Public Use Zone 1 - Service and Utility (PUZ1)	Floodway Overlay	• Fox predation • Rabbits • Weed infestation (e.g. Blackberry)
Yallock Creek (between Bayles and Cora Lynn)	Core Habitat	Swampy Riparian Woodland Swamp Scrub Exotic vegetation Cleared levees	Public (Melbourne Water)	Public Use Zone 1 - Service and Utility (PUZ1)	Floodway Overlay	• Not secure for conservation • Not protected by zoning • Cattle grazing • Fox predation • Vegetation clearing (e.g. drain maintenance)

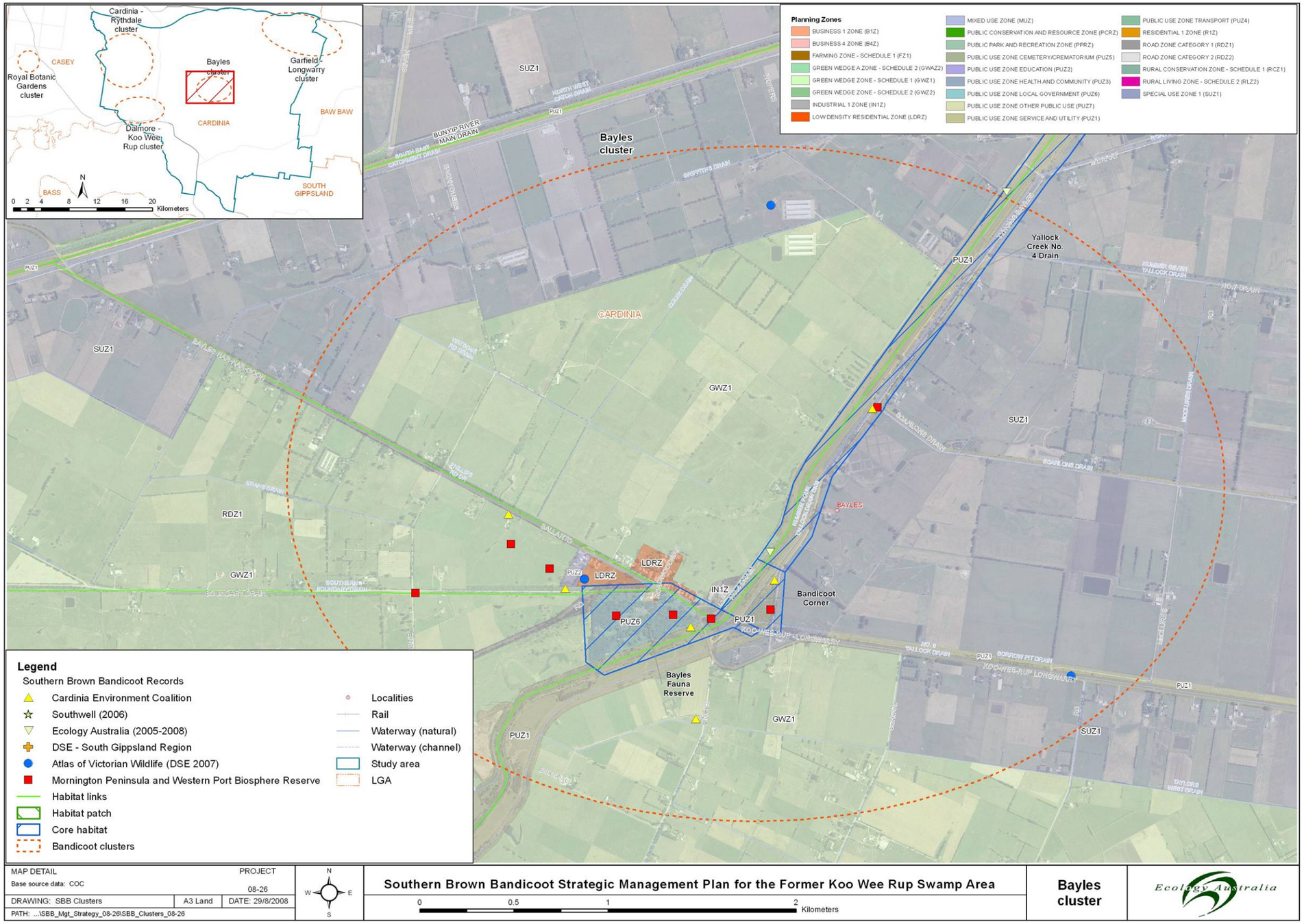


Figure 4 Southern Brown Bandicoot Strategic Management Plan: Bayles population cluster

7.3 Cardinia – Rythdale population cluster

Within the Cardinia-Rythdale cluster, there are several small patches of occupied habitat within private properties, roadside reserves and within the drains/creeks between Ballarto Road and Watsons Road in the north (e.g. Cardinia Creek, Lower Gum Scrub Creek and Haglethorns Drain).

Cardinia Creek is considered to be core habitat for the bandicoot in this cluster (Table 5, Figure 5). There is a small patch of degraded Swamp Scrub adjoining the creek. The creek itself supports scattered patches of Swamp Scrub and areas of dense *Blackberry, *Gorse and *Broome. The levees have been cleared either through cattle grazing or slashing for maintenance. The channel vegetation supports reed beds and rushes.

Other habitat patches within the Cardinia cluster are centred on Lower Gum Scrub Creek, Haglethorns Drain, Cardinia Officer Road and Healesville – Koo Wee Rup Road. Remnant vegetation along these road and riparian corridors consists of degraded Swamp Scrub, with a dense, weedy layer of exotic grasses.

Vegetation along the drains and watercourses is mostly continuous from approximately Island Road in the south to Watsons Road in the north. The vegetation is comprised of small scattered Swamp Scrub remnants with a largely exotic understorey (e.g. *Blackberry, exotic grasses), cleared levees and some instream vegetation (e.g. rushes and reed beds).

Two habitat links have been identified within the cluster: West Dalmore Road Drain and Ballarto Road (Figure 6). West Dalmore Road Drain provides a link between Ballarto Road and vegetation along the drain, further to the south. The roadside vegetation is a linear strip comprised of scattered patches of degraded Swamp Scrub, *Blackberry brambles and exotic grasses. This link also extends further south to the Dalmore - Koo Wee Rup cluster (see Section 9 and Figure 8).

Ballarto Road provides connectivity between Cardinia Creek and private properties at the intersection of Ballarto Road and Tooradin-Station Road. Ballarto Road supports small scattered patches of degraded Swamp Scrub and weeds (e.g. *Blackberry). The private properties at the intersection of Ballarto Road and Tooradin-Station Road comprise a habitat patch. Bandicoots have been observed under the houses, utilising old car bodies, gardens and other anthropogenic debris. One of the property owners has undertaken re-vegetation to increase available habitat for bandicoots (Appendix 3, Plate 8). A fox scat collected on this property during the field survey contained hair of the Southern Brown Bandicoot.

Table 5 Southern Brown Bandicoot Strategic Management Plan: Cardinia – Rythdale population cluster

Area/Location	Habitat function	EVC/Habitat	Tenure	Zoning	Overlays	Key Threats and Constraints
Cardinia Creek	Core habitat	Swamp Scrub Exotic vegetation Cleared levees	Public (Melbourne Water)	Public Use Zone 1 - Service and Utility (PUZ 1)	Floodway Overlay	• Not protected by zoning • Fox predation • Predation by domestic pets • Grazing • Vegetation clearance (e.g. drain maintenance) • Recreation/public use • Proposed desalination pipeline corridor • Farming practices (e.g. cropping in adjoining Green Wedge)
Lower Gum Scrub Creek	Habitat patch	Swamp Scrub Exotic vegetation Cleared levees	Public	Green Wedge Zone 1 (GWZ1)	Land Subject to Inundation (LSIO1)	• Not protected by zoning • Fox predation • Predation by domestic pets • Adjoining farming practices (e.g. cropping) • Proposed desalination pipeline corridor • Encroachment of Urban Growth Zone • Vegetation clearance (e.g. drain maintenance) • Isolation
Haglethorns Drain	Habitat patch	Swamp Scrub Cleared levees	Public (Melbourne Water)	Green Wedge Zone 1 (GWZ1) Special Use Zone 1 (SUZ1) Public Use Zone 1 - Service and Utility (PUZ1)	Land Subject to Inundation (LSIO1)	• Only partly protected by zoning • Fox predation • Predation by domestic pets • Adjoining farming practices (e.g. cropping) • Proposed desalination pipeline corridor • Adjoining special uses (e.g. animal husbandry, mineral exploration) • Vegetation clearance (e.g. drain maintenance)

Area/Location	Habitat function	EVC/Habitat	Tenure	Zoning	Overlays	Key Threats and Constraints
Private properties: intersection of Tooradin-Station Road and Ballarto Road	Habitat patch	Swamp Scrub Gardens Revegetation (young) Mown grass	Private	Road Category 2 (RDZ2) Green Wedge Zone 1 (GWZ1)	Land Subject to Inundation (LSIO1)	• Not secure for conservation in the long-term (private property) • Encroachment of residential development • Fox predation • Predation by domestic pets • Isolation • Road mortality • Proposed desalination pipeline corridor • Weed infestation (e.g. Blackberry) • Vegetation clearance (e.g. roadside/residential maintenance)
Cardinia - Officer Road	Habitat patch	Swamp Scrub	Public	Green Wedge Zone 1 (GWZ1)	Floodway Overlay Land Subject to Inundation (LSIO1)	• Road mortality • Fox predation • Predation by domestic pets • Proposed desalination pipeline corridor • Encroachment of Urban Growth Zone • Isolation • Adjoining farming practices (e.g. grazing/cropping) • Vegetation clearance (e.g. roadside maintenance)

Area/Location	Habitat function	EVC/Habitat	Tenure	Zoning	Overlays	Key Threats and Constraints
Healesville – Koo Wee Rup Road	Habitat patch	Swamp Scrub Exotic vegetation (rank grasses)	Public	Road Zone 1 (RDZ1) Green Wedge Zone (GWZ1)	Land Subject to Inundation	• Road mortality • Fox predation • Predation by domestic pets • Proposed road upgrade with connection alignment to South Gippsland Highway • Weed infestation • Vegetation clearance (e.g. roadside maintenance)
Ballarto Road (between Cardinia Creek and Tooradin Station Road) [part of a proposed biolink]	Habitat link-within	Swamp Scrub Exotic vegetation	Public Private	Road Zone 1 (RDZ1) Public Park and Recreation Zone (PPRZ) (off Dalmore Road) Green Wedge Zone 1 (GWZ1) Low Density Residential (LDRZ) (off Dixons and Beazley Road)	Land Subject to Inundation (LSIO1) Vegetation Protection - Schedule 1 (VPO1)	• Fox predation • Predation by domestic pets • Road mortality • Encroachment of residential development • Vegetation clearance (e.g. roadside maintenance) • Proposed desalination pipeline corridor • Weed infestation (e.g. Blackberry) • Adjoining farming practices (e.g. grazing/cropping in Green Wedge Zone)
West Dalmore Road Drain	Habitat link - within	Swamp Scrub Cleared levees	Public (Melbourne Water)	Special Use Zone 1 (SUZ1) Public Use Zone 1 - Service and Utility (PUZ1)	Land Subject to Inundation (LSIO1)	• Fox predation • Predation by domestic pets • Isolation • Vegetation clearance (e.g. roadside maintenance) • Adjoining farming practices/special use zone

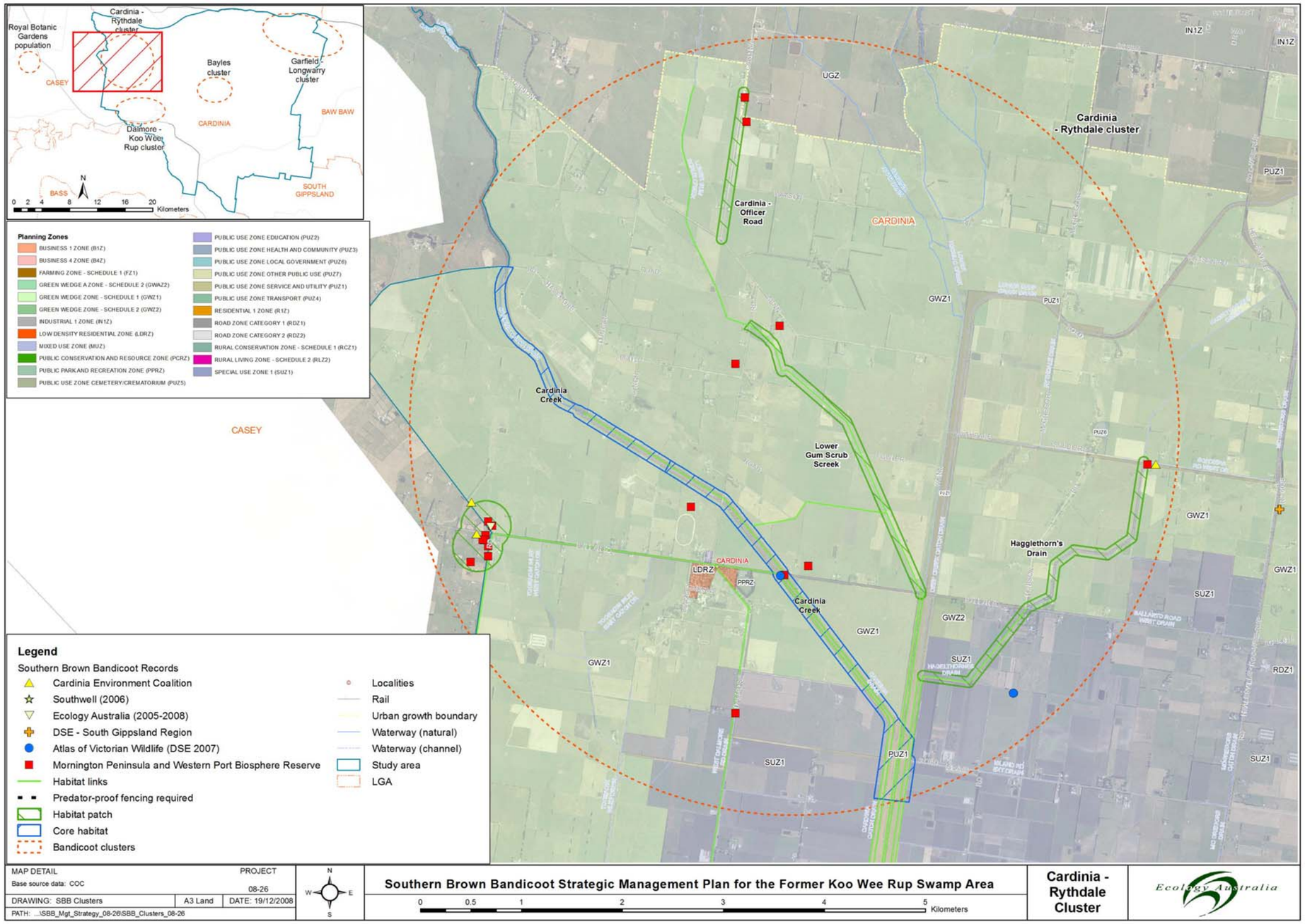


Figure 5 Southern Brown Bandicoot Strategic Management Plan: Cardinia – Rythdale population cluster

7.4 Garfield – Longwarry population cluster

Within the Garfield-Longwarry cluster, the vegetation associated with the Railway Line and road corridor on the Nar Nar Goon-Longwarry Road is classified as core habitat (Table 6, Figure 6). The other habitat patches are important to the maintenance of this core habitat, but are largely on private residential properties within the townships and therefore may not be secure in the long-term. These properties are centred on McNamara Road, Tonimbuk Road, A'Beckett Street, Doran Road, Chambers Road, Flett Road and Brownbill Road. There are also occupied habitat patches on these road reserves and some drainage-lines in the area (Figure 6).

Vegetation along the railway is mostly contiguous with small gaps (<100 m) around rail crossings and stations. Remnant vegetation along this corridor primarily consists of Swampy Woodland, Grassy Woodland and small areas of Swamp Scrub. Swathes of Bracken or sedges provide a dense understorey. In some areas dense vegetation is provided by thickets of *Broom and *Blackberry.

The other area considered core habitat within this cluster is the old Pine Plantation, adjoining the Bunyip Primary School on Nar Nar Goon – Longwarry Road.

The semi-rural township of Bunyip supports considerable areas of remnant Lowland Forest. However, much of this vegetation is located on private properties. Some of the largest patches occur on A'Beckett Road and Doran Road.

Bandicoots also occupy artificial habitat within and adjoining private properties. These consist of residential gardens, plantings along roadsides (e.g. Columba Primary Catholic School) and at the nursing home in Bunyip. They have also been observed under houses and utilising anthropogenic debris in gardens.

Small, narrow and discontinuous patches of habitat also extend along roadsides within and outside of the townships of Bunyip, Garfield and Longwarry (e.g. small disconnected patches of Damp Heathy Woodland and Lowland Forest). The understorey is often dominated by weeds such as *Blackberry and *Broome.

Table 6 Southern Brown Bandicoot Strategic Management Plan: Garfield – Longwarry population cluster

Area/Location	Habitat function	EVC/Habitat	Tenure	Zoning	Overlays	Key Threats and Constraints
Railway line between McNamara Road, Bunyip and Ti-tree Road, Garfield	Core habitat	Swamp Scrub Grassy Woodland Swampy Woodland Exotic vegetation	Public	Public Use Zone – Transport (PUZ4) Green Wedge Zone 1 (GWZ1) Road Category 1 (RDZ1) Low Density Residential Zone (LDRZ)	Environmental Significance, Schedule 3 (ESO3) Land Subject to Inundation (LSIO1)	• Not secure for conservation • Fox predation • Predation by domestic pets • Vegetation clearance (e.g. railway and roadside maintenance) • Weed infestation (e.g. Blackberry) • Road mortality
Railway line between Jefferson Road and Thirteen Mile Road, Garfield	Core Habitat	Grassy Woodland Herb-rich Foothill Forest Exotic vegetation	Public	Public Use Zone – Transport (PUZ4) Road Category 1 (RDZ1) Residential 1 (R1Z) Business 1 (B1Z)	Land Subject to Inundation (LSIO1)	• Not secure for conservation • Road mortality • Fox predation • Predation by domestic pets • Vegetation clearance (e.g. railway and roadside maintenance) • Weed infestation (e.g. Blackberry) • Road mortality

Area/Location	Habitat function	EVC/Habitat	Tenure	Zoning	Overlays	Key Threats and Constraints
Railway Line between McNamara Road and Henry Road, Bunyip	Core Habitat	Lowland Forest Exotic vegetation	Public	Public Use Zone- Transport Road Category 1 (RDZ1) Public Use Zone – Other Public Use (PUZ7) Public Use Zone – Education (PUZ2) Low Density Residential Zone (LDRZ) Residential 1 (R1Z) Business 1 (B1Z)	Land Subject to Inundation (LSIO1) Vegetation Protection Overlay (VPO1)	• Not secure for conservation • Fox predation • Predation by domestic pets • Vegetation clearance (e.g. railway and roadside maintenance) • Road mortality • Weed infestation (e.g. Blackberry)
Pine Plantation (immediately west of the Bunyip Primary School on Nar Nar Goon – Longwarry Road)	Core habitat	Pine overstorey Dense understorey (e.g. sedges) Exotic vegetation	Public	Public Use Zone – Other Public Use (PUZ7)	Land Subject to Inundation (LSIO1)	• Not secure for conservation • Not protected by zoning • Fox predation • Predation by domestic pets • Vegetation clearance (e.g. residential and roadside maintenance) • Road mortality • Encroachment of residential development

Area/Location	Habitat function	EVC/Habitat	Tenure	Zoning	Overlays	Key Threats and Constraints
McNamara Road between Wattletree Road and Railway Avenue, Bunyip	Habitat patch	Lowland Forest	Private	Farming Zone (FZ) Low Density Residential Zone (LDRZ) Residential 1 (R1Z)	Environmental Significance (ESO1)	• Not secure for conservation in the long-term (private property) • Road mortality • Fox predation • Predation by domestic pets • Vegetation clearance (e.g. roadside and residential maintenance) • Encroachment of residential development
Tonimbuk Road, between Wattletree Road and Railway Avenue, Bunyip	Habitat patch	Lowland Forest	Public	Residential 1 (R1Z) Industrial 1 (IN1Z) Public Park and Recreation (PPRZ)		• Road mortality • Fox predation • Predation by domestic pets • Vegetation clearance (e.g. roadside and residential maintenance) • Encroachment of residential development
Corner of A'Beckett and Mary Street	Habitat patch	Lowland Forest	Private	Public Use - Health Community (PUZ3) Residential 1 (R1Z)		• Not secure for conservation in the long-term (private property) • Road mortality • Fox predation • Predation by domestic pets • Vegetation clearance (e.g. roadside and residential maintenance) • Encroachment of ongoing residential development
Corner of A'Beckett and Doran Road	Habitat patch	Lowland Forest	Private	Low Density Residential Zone (LDRZ)	Vegetation Protection (VPO1)	• Not secure for conservation in the long-term (private property) • Road mortality • Fox predation • Predation by domestic pets • Vegetation clearance (e.g.

Area/Location	Habitat function	EVC/Habitat	Tenure	Zoning	Overlays	Key Threats and Constraints
						roadside and residential maintenance) • Encroachment of residential development
Chambers Road and Flett Street	Habitat patch	Lowland Forest	Private	Low Density Residential Zone (LDRZ) Residential 1 (R1Z)	Vegetation Protection (VPO1)	• Not secure for conservation in the long-term (private property) • Fox predation • Road mortality • Predation by domestic pets • Vegetation clearance (e.g. roadside and residential maintenance) • Encroachment of residential development
Brownbill Road, Garfield	Habitat patch	Swamp Scrub	Private	Green Wedge (GWZ)	Land Subject to Inundation (LSIO1)	• Not secure for conservation in the long-term (private property) • Farming practices (e.g. grazing) • Predation by domestic pets • Vegetation clearance (e.g. roadside and residential maintenance) • Road mortality • Fox predation • Encroachment of residential development
Patch adjoining Railway at Sixteen Mile Drain	Habitat patch	Swamp Scrub	Public	Public Use Zone - Local Government (PUZ6) Public Use Zone – Other Public Use (PUZ7)		• Not secure for conservation • Fox predation • Vegetation clearance (e.g. roadside and residential maintenance) • Encroachment of residential development

Area/Location	Habitat function	EVC/Habitat	Tenure	Zoning	Overlays	Key Threats and Constraints
A'Beckett Road	Habitat link - within	Lowland Forest Riparian Forest	Private	Low Density Residential Zone (LDRZ) Residential 1 (R1Z)	Vegetation Protection (VPO1)	• Not secure for conservation in the long-term (private property) • Fox predation • Predation by domestic pets • Road mortality • Vegetation clearance (e.g. roadside and residential maintenance) • Encroachment of residential development

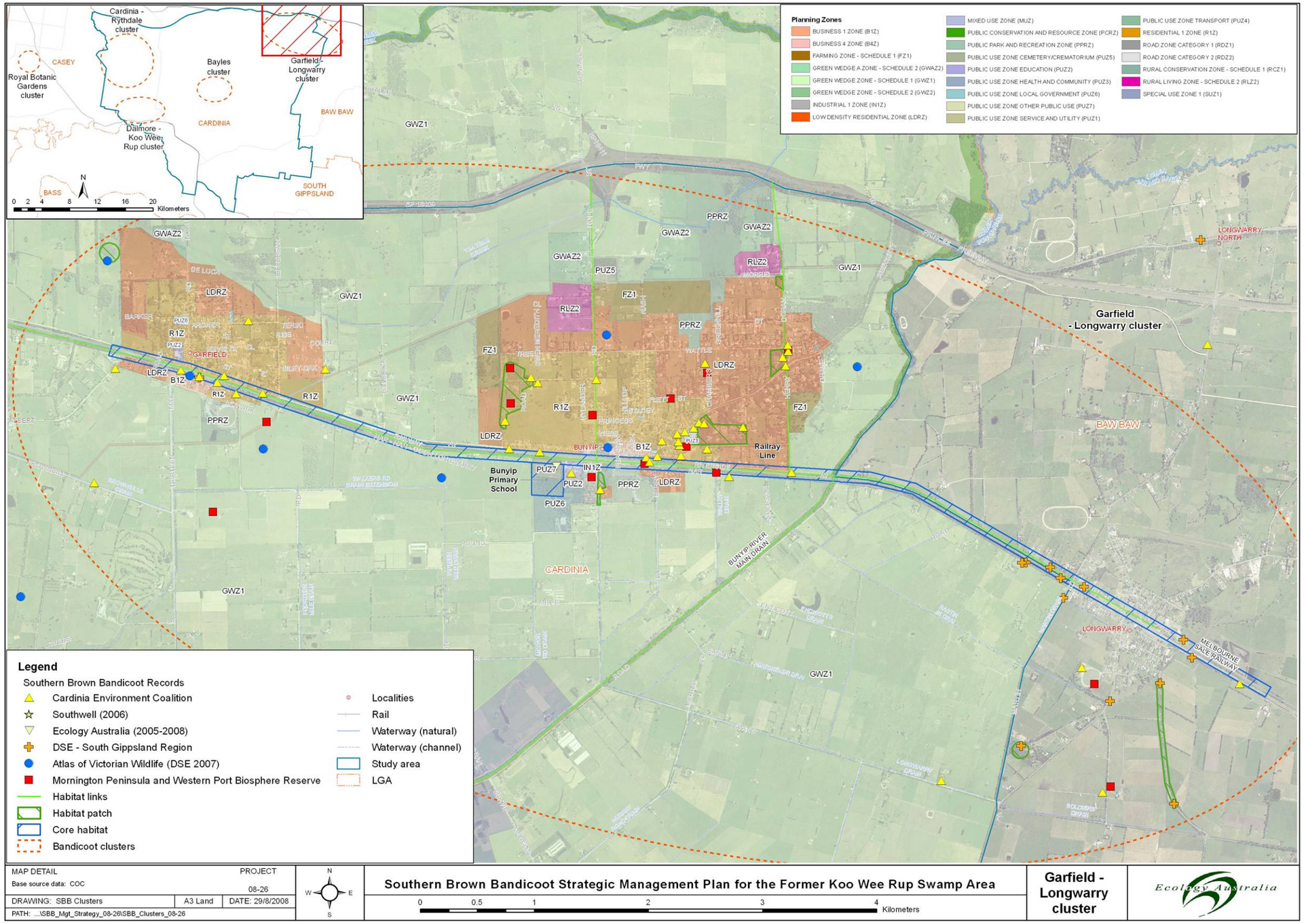


Figure 6 Southern Brown Bandicoot Strategic Management Plan: Garfield - Longwarry population cluster

8 Potential habitat and habitat links within the former Koo Wee Rup Swamp area

8.1 Potential habitat

During the field investigation and review of recent and past bandicoot records, several areas were identified as potential habitat for the bandicoot. Much of this habitat is in the Lang Lang - Nyora area in the south-eastern section of the study area. There are also several patches identified in Koo Wee Rup, Monomeith, Cardinia, and Bunyip.

Lang Lang and Heath Hill areas

Southern Brown Bandicoots have not been recorded around Lang Lang and Heath Hill since the early 1970s, despite the presence of several relatively large areas of suitable habitat. In 1970, the species was recorded just east of Gippsland Road outside the Lang Lang township and from along Burt Road, south of the Lang Lang River in 1971. More recently, in 1995, the bandicoot was recorded in Nyora, within 2 km of Wuchatsch Reserve and just north of the railway (DSE 2007b).

Recent surveys in this area (e.g. Unimin Sand Mine, McGregor Sands, Lang Lang Nature Conservation Reserve, Lang Lang Bushland Reserve and along the South Gippsland Railway Line) have failed to detect bandicoots (Ecology Australia 2005, present study, David Nicholls pers. comm.). The apparent disappearance of bandicoots in this area may be due to the extinction of local populations, which have not been recolonised due to their isolation. Alternatively, given the large size of the area to be surveyed, the absence of recent records may simply be attributed to a low survey effort or that bandicoots are in such low abundance they are difficult to detect. Bandicoots are notoriously cryptic and trap shy and are often not detected by some survey methods in areas where they are known to occur. Some anecdotal evidence and unconfirmed reports suggest that the species may still be present around Lang Lang, at the Golf Course, Educational Area, and The Gurdies (Coates et al. 2008, Rolf Willig pers. comm.). Unconfirmed reports of bandicoots have also been made by security guards at the GMH Proving Grounds (Terry Coates pers. comm.).

The vegetation at the Unimin mine and adjoining Lang Lang Nature Conservation Reserve comprises a large patch of high quality habitat for bandicoots, and consists of several suitable EVCs (Appendix 3, Plate 9) (Figure 7). These include: Sand Heath, Lowland Forest, Herb-rich Foothill Forest, Heathy Woodland, Swamp Scrub, Riparian Scrub and Shrubby Gully Forest.

The Lang Lang Bushland Reserve on Range Road, just outside of the Lang Lang Township, is approximately 12 ha (Figure 7). This reserve supports patches of Swamp Scrub. There are also scatterings of Eucalypts (e.g. Narrow-leafed Peppermint *Eucalyptus radiata* and Manna Gum *E. viminalis*), Scented Paperbark (*Melaleuca squarosa*), Cherry Ballart (*Exocarpus cupressiformis*), Banksia (*Banksia* sp.) and Blackwoods (*Acacia melanoxylyn*) (Appendix 3, Plates 10). The reserve in some areas is devoid of an understorey due to rubbish dumping, trail bike riding, soil dumping and there are several vehicle tracks throughout the reserve. The reserve adjoins paddocks to the

north, a dog coursing track to the west and the South Gippsland Railway Line to the east and south. The railway line supports similar vegetation and suitable habitat. However, no bandicoots were recorded in these areas during the field survey.

It is possible that bandicoots may be able to colonise these areas via the South Gippsland Railway Line, and disperse throughout the landscape via Lang Lang River, Adams Creek, their tributaries and patches of vegetation on roadsides, small bushland reserves and vegetation on private property (Figure 7). There may be an opportunity to re-introduce bandicoots into these areas in the future (see Section 9).

Extending further to the east near Heath Hill, many of the areas which support remnant vegetation (e.g. Lowland Forest) are on private land. There is extensive grazing of vegetation remnants in this area which has either completely removed or severely degraded the understorey vegetation.

Koo Wee Rup, Monomeith and Cardinia area

Along the South Gippsland Highway, there is a patch of vegetation along Yallock Creek which adjoins an open space area used for recreation (e.g. playground, truck parking and picnic tables) (Figure 7). This patch (c. 9 ha) is a Swampy Riparian Woodland remnant (Appendix 3, Plate 11). It has been severely degraded by weed invasion, considerable amounts of rubbish, track creation from 4WD and trail bikes and lack of management. No bandicoots were recorded in this patch during the field survey. There are opportunities to improve this patch (e.g. through fencing, revegetation and active management), which could provide habitat for bandicoots within the southern section of Yallock Creek (see Section 9). There is another small patch further along the South Gippsland Highway, adjoining Number Four Drain in Monomeith. This is a small linear patch of heavily degraded Swamp Scrub. Similarly, this patch could be rehabilitated to provide habitat for bandicoots in the southern section of this catchment.

Within the Dalmore-Koo Wee Rup cluster, there is a potential habitat link along the South Gippsland Highway. The northern section of the Highway comprises small patches of revegetation/regeneration with little understorey, and is largely unsuitable for Bandicoots. However, the reserve south of the Highway supports a linear patch of Swamp Scrub, which is contiguous with the series of Koo Wee Rup Drains. It is not known whether there would be movement of animals from the north-west side of the highway (where they have been recorded around Deep Creek), to the south (i.e. movement under bridges). However, considering the proximity of recent records, this area is still considered to be potential habitat.

The Cardinia Creek Drains, from approximately Watson Road in the north to Island Road in the south, support potential habitat for bandicoots (Appendix 3, Plate 12 and Figure 7). The vegetation comprises linear Swamp Scrub remnants, with patches of *Broome and *Blackberry and mown and/or grazed exotic grasses on the levees.

Also in the Cardinia area, there is a potential habitat link between Gum Scrub Creek and Cardinia Creek, via vegetation on roadsides and private property. The link would involve retaining and enhancing existing vegetation along Officer Road near Gum Scrub Creek, heading west through private property (north of Bould Road) along what appears to be a drainage-line, over Duncan

Road, and continue west along Chasemore Road until Cardinia Creek (Figure 7). This would require negotiations with landowners and possibly provision of funding from Cardinia Shire to revegetate areas on private land (see Section 9).

Garfield - Bunyip area

There are two notable patches of potential habitat within the Bunyip Township: Tonimbuk Road patch and Bunyip Sanctuary (Table 7, Figure 7). There is a small patch (c. 3 ha), immediately south of the Princes Highway, located on the west side of Tonimbuk-Bunyip Road. No bandicoots were recorded in this patch during the field survey, however, the habitat is considered to be suitable. The patch is floristically diverse and is mapped as Damp Heathy Woodland and Swamp Scrub (Appendix 3, Plate 13). Outside the area of Swamp Scrub, which dominates the drainage-line running along the southern corner of the reserve, there is a patch of Blackwoods with an understorey of Austral Bracken (*Pteridium exculentum)* and sedges (e.g. *Gahnia* sp., *Lomandra* sp.). The western section of the reserve supports scatterings of Green Scentbark (*Eucalyptus fulgens*), a shrub layer of Prickly Tea-tree (*Leptospermum continentale)*, Manuka (*Leptospermum scorparium*), Pale-fruit Ballart (*Exocarpus strictus*) and She-oak (*Allocasuarina* sp.), with a ground-layer of Common Heath (*Epacris impressa*), Small Grass-tree (*Xanthorea minor* ssp. *lutea*), Spreading Rope-rush (*Empodisma minus*), Slender Dodder-laurel (*Cassytha glabella*) and *Spanish Heath (*Erica lusitanica*). This patch may be connected to other areas known to support the Bandicoot in the Bunyip Township, via patches of linear roadside remnants along Tonimbuk-Bunyip Road (Figure 7).

Bunyip Sanctuary (c. 50 ha) is located north of the Bunyip Township and is bordered by the Princes Freeway in the north (Figure 7). The northern corner supports remnant vegetation which is classified as a 'Conservation Zone'. Remnants of three EVCs have been identified within the sanctuary: Lowland Forest, Damp Heathy Woodland and Swampy Woodland (Classaen 2007). The northern section is somewhat contiguous with remnant vegetation on private property along Doran Road. Outside the Bunyip Township, these areas provide the best potential habitat for bandicoots in this northern section of the Garfield-Longwarry cluster.

The balance of the property was cleared when the Bunyip Township was settled. The land is subject to flooding, and was therefore established as 'Open Space' which is now surrounded by existing and proposed residential development. A Melbourne Water Retarding basin is located in the centre of the reserve. There are extensive rehabilitation works (e.g. revegetation) carried out in the reserve by Landcare and the management committee (Tamara Griffiths and Alan Cole pers. comm.).

Table 7 Southern Brown Bandicoot Strategic Management Plan: Summary of potential habitat/habitat links for Southern Brown Bandicoots within the former Koo Wee Rup Swamp area

Area/Location	Habitat function	EVC/Habitat	Tenure	Zoning	Overlays	Key Threats and Constraints
Lang Lang -Nyora area						
Lang Lang Nature Conservation Reserve	Potential habitat (former bandicoot habitat)	Heathy Woodland Swamp Scrub Sand Heath	Public	Public Park and Recreation Zone (PPRZ)	Significant Landscape (SLO3) Wildfire Management (WPO)	• Fox predation • Isolation • Weed infestation (e.g. Blackberry) • Recreational use
Lang Lang Bushland Reserve	Potential habitat	Swamp Scrub Damp Heathy Woodland	Public	Public Park and Recreation Zone (PPRZ)	Environmental Significance– Schedule 3 (ESO3) Significant Landscape (SLO3)	• Fox predation • Weed infestation (e.g. Blackberry) • Isolation • Recreational use (e.g. track creation from trail bikes) • Rubbish dumping
Unimin Site (sand mine)	Potential habitat (former bandicoot habitat)	Sand Heath Lowland Forest Herb-rich Foothill Forest Heathy Woodland Swamp Scrub Wetland Formation Riparian Scrub Shrubby Gully Forest (EVCs determined by Ecology Australia 2005)	Private	Farming Zone Rural Conservation Zone (RCZ1)	Land Subject to Inundation Overlay (LSIO1) Wildfire Management Overlay (WPO)	• Not secure for conservation • Mining activities and quarry expansion • Fox predation • Weed control (e.g. Blackberry) • Vegetation clearance (e.g. quarry maintenance)
Remnant vegetation on private property	Potential habitat	Lowland Forest	Private	Farming Zone	Some areas have an Environmental Significance Overlay – Schedule 5 (ESO5)	• Not secure for conservation • Farming practices (e.g. grazing) • Isolation • Fox predation • Predation by domestic pets • Weed infestation (e.g. Blackberry)
Wuchatsch Reserve (outside of study area)	Potential habitat	Heathy Woodland	Public	Rural Living Zone (RLZ)		• Fox predation • Predation by domestic pets • Isolation • Weed infestation (e.g. Blackberry)
Koo Wee Rup/ Monomeith / Bayles / Cardinia area						
Yallock Creek (upstream of the South Gippsland Highway, Koo Wee Rup)	Potential habitat	Swampy Riparian Woodland Exotic vegetation	Public (Melbourne Water)	Public Conservation and Resource Zone (PCRZ)	Floodway Overlay	• Not protected by zoning • Isolation • Fox predation • Grazing • Vegetation clearance (e.g. roadside maintenance) • Recreation/public use • Rubbish dumping

Area/Location	Habitat function	EVC/Habitat	Tenure	Zoning	Overlays	Key Threats and Constraints
						• Track creation (e.g. by illegal 4WD and trail bikes)
Patch adjoining Number Four Drain and Number Four Drain (upstream of South Gippsland, Monomeith through to Bayles)	Potential habitat/habitat link	Swamp Scrub Exotic vegetation	Private	Green Wedge Zone (GWZ)	Land Subject to Inundation (LSIO1)	• Not secure for conservation • Isolation • Fox predation • Vegetation clearance (e.g. drain maintenance)
South Gippsland Highway (south side between Koo Wee Rup Swamp Lookout and Inlets at Dalmore)	Potential habitat/link within	Swamp Scrub Exotic vegetation	Public	Road Category 1 Zone (RDZ1)	Land Subject to Inundation (LSIO1)	• Not secure for conservation • Vegetation is patchy on the north side of road reserve (little understorey vegetation) • Fox predation • Road mortality • Little provision for road crossing to the south side • Vegetation clearing (e.g. roadside maintenance) • Proposed Healesville - Koo Wee Rup Road Upgrade
Cardinia Creek Drains (approximately from Watson Road in the north to Island Road in the south, Cardinia)	Potential habitat/link within	Swamp Scrub Exotic vegetation	Public (Melbourne Water)	Public Use Zone 1 - Service and Utility Zone (PUZ 1)	Floodway Overlay	• Not protected by zoning • Fox predation • Recreation/public use • Grazing • Vegetation clearance (e.g. drain maintenance) • Desalination pipeline corridor • Farming practices (e.g. cropping in adjoining Green Wedge and Special Use Zone)
Officer Road, private property (north of Bould Road) and Chasemore Road Between Gum Scrub Creek and Cardinia Creek	Potential habitat link - within	Swamp Scrub Roadside remnants Exotic vegetation	Public (Roads) Private	Green Wedge Zone (GWZ1)	Land Subject to Inundation (LSIO1)	• Not secure for conservation • Would require extensive revegetation works • Private landowners may not want habitat corridor on their property • Fox predation • Predation by domestic pets • Grazing • Vegetation clearance (e.g. roadside and property maintenance) • Farming practices (e.g. cropping in adjoining Green Wedge and Special Use Zone)
Rythdale Road	Potential link - within	Swamp Scrub	Public (Melbourne Water)	Public Use Zone 1 - Service and Utility	Land Subject to Inundation (LSIO1)	• Not secure for conservation • Cattle grazing • Fox predation • Predation by domestic pets • Vegetation clearance (e.g. roadside maintenance) • Road mortality
Bunyip Area						
Patch on Tonimbuk Road, immediately south of the Princess Highway	Potential habitat	Damp Heathy Woodland Swamp Scrub	Public	Road Zone Category 1 (RDZ1) (possibly part of road reserve) adjoins Green Wedge Zone (GWZ)		• Not secure for conservation • Fox predation • Vegetation clearance (e.g. roadside maintenance, grazing in adjoining property)
Bunyip Sanctuary	Potential habitat	Lowland Forest Damp Heathy Woodland Swampy Woodland	Public	Public Park and Recreation (PPRZ)	Land Subject to Inundation (LSIO1)	• Fox predation • Predation by domestic pets • Weed infestation (e.g. Blackberry) • Encroachment of residential development • Recreation

8.2 Habitat links between population clusters

At a landscape scale, there are several habitat links between population clusters within the study area that currently do, or have the potential to, support bandicoots. These links are likely to be used for dispersal and movement of individuals between clusters. All links between population clusters identified within the study area require long-term security and enhancement and/or rehabilitation.

Several existing and/or potential habitat links are located between the Dalmore-Koo Wee Rup and Cardinia-Rythdale clusters (Figure 7). The Cardinia Creek Drains form the most important habitat link between these clusters (extending northwards from The Inlets) (Appendix 2, Plate 12). The drains and levees support remnant Swamp Scrub, Coastal Saltmarsh and exotic vegetation, as well as instream vegetation (e.g. dense reed beds). There are three other possible habitat links: Tooradin - Station Road; South Gippsland Railway Line and Tooradin-Station Road; and South Gippsland Railway Line and Dalmore Road (Table 7, Figure 7). Habitat on the South Gippsland Railway Line is patchy and is mostly comprised of exotic vegetation (e.g. *Blackberry, Broome and exotic grasses) (Appendix 3, Plate 14). The roads support patchy, linear Swamp Scrub remnants with a largely exotic understorey.

Between the Dalmore- Koo Wee Rup and Bayles clusters, there are two potential habitat links: Boundary Drain Road (Appendix 3, Plate 15) and Yallock Creek. The most likely link is provided by the vegetation along Boundary Drain Road. The Swamp Scrub vegetation is largely contiguous, although the understorey is sparse in patches and consists of Common Reed, sections of dense *Blackberry, *Bridal Creeper and exotic grasses with scatterings of *Broome. The main gaps (between 100-200 m wide) within this link are associated with driveways and road intersections.

Yallock Creek may provide a potential corridor for movement between the Koo Wee Rup area (railway line) and Bayles. However, much of the vegetation along Yallock Creek has been cleared and is subject to intense cattle grazing (Appendix 3, Plates 6, 16 and 17). This has caused the loss of understorey vegetation, as well as loss and/or severe degradation of the in-stream vegetation. This is particularly noticeable downstream of the Bayles - Longwarry Road Bridge and around the crossing of Number 5 Drain Road. This area requires the cessation of grazing leases and rehabilitation of the creek corridor or at least a significant reduction in grazing frequency and intensity (see Section 9 and Figure 8). Number Four Drain is also another potential link which runs parallel to Yallock Creek from the South Gippsland Railway Line to Bayles. The vegetation is patchy, mostly exotic and narrow in parts, but with rehabilitation may become more suitable.

Two potential habitat links exist between Dalmore – Koo Wee Rup and Garfield – Longwarry: the Bunyip River (adjacent to Fechner Road - Bunyip River Road - Main Drain Road) and McDonalds Drain to Ararat Creek/Drain and Daly Road (Figure 7). The Bunyip River has been identified as a 'Biolink' (MPWPB 2008). It has been channelled, and at Koo Wee Rup, there are large cleared areas as a result of vegetation removal for maintenance and flood mitigation. Further north/upstream at Cora Lynn, Vervale and Iona, there are degraded patches of Swamp Scrub and

Swampy Riparian Woodland with a largely exotic understorey of *Blackberry, *Cape Ivy, *Bridal Creeper and exotic grasses. The banks are heavily incised and eroded. McDonalds Drain is largely devoid of vegetation due to regular slashing for maintenance. This link would begin at the Koo Wee Rup Drains, continue north up McDonalds Drain and north-east along Ararat Creek to the Nar Nar Goon - Longwarry Road. This corridor would require extensive rehabilitation works (see Figure 8).

From the Dalmore - Koo Wee Rup cluster to the Lang Lang – Nyora area, the South Gippsland Railway Line provides the best opportunity to provide a habitat link between these two areas. While the vegetation cover is patchy (e.g. open around road crossings), there are scatterings of Swamp Paperbark, Swamp Gum, *Acacia* sp. and Sweet Pittosporum, and large patches of *Blackberry, *Broome and exotic grasses (see Figures 7 and 8) .

Between Dalmore-Koo Wee Rup and the Nar Nar Goon/Tynong area (to Garfield – Longwarry), a potential habitat link has been identified, via Bunyip River, McDonalds Drain/Seven Mile Road, Daly Road, Ararat Creek to the Nar Nar Goon-Longwarry Road (Table 7, Figure 7). This is an area proposed as a secondary priority biolink or 'bionode' (MPWPB 2008). As stated, the vegetation along the first section of the Bunyip River in Koo Wee Rup has been mostly cleared along the levees. Heading north up McDonalds Drain, vegetation cover is sparse, and along Seven Mile Road, there is little vegetation until Convent School Road which comprises a linear strip of degraded Swamp Scrub. Heading north between Daly Road and a tributary of Ararat Creek (i.e. a channelised drain), there are scatterings of Swamp Paperbark, with a high cover of *Spiny Broom, *Blackberry and exotic grasses (Appendix 3, Plate 18). The deeply incised drain appears to be regularly slashed for maintenance. This drain then converges with Ararat Creek, which extends north towards Nar Nar Goon - Longwarry Road. Ararat Creek supports small scattered remnants of Swampy Riparian Woodland. Revegetation works were evident at the junction of McGraws Road and Ararat Creek.

8.3 Habitat links beyond the former Koo Wee Rup Swamp study area

There are eight major opportunities to create habitat links to areas/populations beyond the former Koo Wee Rup Swamp area, leading west, east and south-east. These habitat links, particularly west to the Royal Botanic Gardens Cranbourne (RBGC) will be important for maintaining the viability of populations within the former Koo Wee Rup Swamp area in the future (Lechner 2006, Southwell 2006). Some of the potential links highlighted in this plan have already been proposed as 'biolinks' by the CEC, as part of an initiative to link remnant bandicoot populations in Melbourne's outer south-east and to provide connectivity across the landscape (CEC 2008b), a concept which is supported by DSE (Clare White pers. comm.). The CEC has proposed a width of 70 m for these biolinks.

The alignments of the eight different proposed links have been summarised below and are represented in Figure 7.

Dalmore-Koo Wee Rup to RBGC:

- Along the disused South Gippsland Railway line; and
- Along the coastline to Cannons Creek, continuing north to the RBGC via Cannons Creek and Wylies Drain

Cardinia to RBGC:

- Ballarto Road

Garfield-Longwarry to Drouin:

- Along the Melbourne- Sale Railway Line

Lang Lang to Gurdies

- From the Unimin Site along the creekline to the coast, following the Bass Coastline to the Gurdies; and
- From the Unimin Site to the Gurdies via the Adams Creek Nature Conservation Reserve and the GMH proving ground

Lang Lang to Wonthaggi:

- Along the Bass coastline

Tooradin to Quail Island

- Along Cannons Creek to Quail Island via a land bridge

Depending on the nature of each link, including its position in the landscape, spatial alignment and surrounding land tenures and land uses, the creation of some proposed links may be more feasible than others.

Links to Royal Botanic Gardens Cranbourne (RBGC)

The proposed biolink to RBGC is considered by many to be one of the most important for the Southern Brown Bandicoot, and has the backing of several agencies. A biolink to RBGC was included in the porposed Cranbourne East Precinct Structure Plan, prepared by David Lock and Associates (GAA 2008). Following this, DSE provided written advice to the GAA, explaining the importance of biolinks for the preservation of biodiversity. The proposed Precinct Structure Plan was independently reviewed by Biosis, which also endorsed the notion of including a biolink (Biosis 2008c), and is strongly advocated within this management plan also.

This management plan recognises three options for linking the RBGC to the former Koo Wee Rup Swamp area.

The disused South Gippsland Railway line, as stated in Sections 5 and 7, is not secured for conservation, and there are proposals for a 'Rail Trail' along the corridor from Cranbourne to Nyora. However, this corridor presents an excellent opportunity to link bandicoot populations in the Dalmore-Koo Wee Rup (and Cardinia) areas to RBGC, by making use of an existing, partially vegetated, landscape corridor leading directly north-east to Cranbourne. Vegetation along the railway line, consisting mainly of patches of degraded Swamp Scrub, already forms a discontinuous link to Cranbourne, and is of a suitable vegetation type and structure for bandicoots. If this link were to be protected and enhanced, there is good reason to expect that the link will be utilized by bandicoots as vegetation along the railway line is already known to support bandicoots at Clyde, and Cranbourne. Conserving this corridor for use as a habitat link also provides a good opportunity to conserve and enhance substantial remnants of vegetation in a depleted landscape, including BioSites of National and Regional significance, at Manks Road, Clyde and between Dalmore and Koo Wee Rup. Biosis has assessed this corridor and also regards it to be a critical link for the Southern Brown Bandicoot (Biosis 2008c). Although this option makes use of an existing corridor, this link may require the inclusion of some roadside vegetation along Ballarto Road, to create the most direct link to Cranbourne. Despite this, we consider that this is probably one of the best and most important options.

The other possibility linking the Dalmore-Koo Wee Rup areas to RBGC incorporates the western coastline of Western Port Bay and the Western Port Nature Conservation Reserve, from The Inlets to Cannons Creek. The link would then proceed north via Cannon's Creek and Wylies Drain to the RBGC. Making substantial use of the coastline, this link may have minor implications for land tenure and planning, although it is likely that it would still have to traverse a residential area near Cranbourne. This link is also substantially longer, which may reduce the likelihood of it being utilized by bandicoots, although it would incorporate habitat known to support bandicoots at Tooradin.

The most direct link west to the RBGC from Cardinia Creek follows Ballarto Road. This alignment is the biolink which has been proposed by the CEC, and DSE has requested its consideration by the Growth Areas Authority (GAA) when preparing the Cranbourne East Precinct Structure Plan. However, this corridor is constrained by adjoining private land, the new growth area of Cranbourne East, as well developments such as the desalination pipeline (which is proposed along the northern side of Ballarto Road) and the Port of Hastings Transport Strategy. There is currently little support for this link from private landholders along Ballarto Road (Sarah McClagan pers. comm.) and from the GAA (GAA 2008). The 70 m wide corridor has implications for adjoining private land, and also for growth area planning and open space allocations. Other issues have also been identified including a disparity between the former vegetation type along Ballarto Road, and the habitat requirements of the Southern Brown Bandicoot (Biosis 2008c). This link would require further research and design to be effective.

While this management plan strongly emphasizes the importance of such a habitat link, we cannot at this stage specify a particular alignment which should be followed as there are various issues which require further consideration and investigation, due to the urbanized nature of the Cranbourne area and other developments which would restrict some options.

Links to Drouin

The best possible link eastwards from the Garfield-Longwarry area to Drouin is via the Melbourne-Sale Railway line. Although this railway line is currently in use, enhancing and expanding vegetation along either side of this railway corridor provides a good opportunity to provide a link within existing planning infrastructure. Vegetation along this corridor is patchy, but is already used by bandicoots at Longwarry and Red Hill. Thus, it has the potential to become a viable link. This alignment has also been proposed as a biolink by the CEC.

Links to The Gurdies and Wonthaggi

Some habitat links may be of a higher priority than others, depending on the spatial distribution of bandicoots and their alignment. In particular, corridors that link known habitat and/or extant populations of bandicoots may be of a higher priority than corridors linking areas of potential habitat or where the status of bandicoots is uncertain. Although bandicoots were recorded in Lang Lang during the 1970s, their current status in Lang Lang is unclear (see Section 8.1).

There may be an opportunity in future to create links from Lang Lang (starting at Koo Wee Rup) to The Gurdies, and to Wonthaggi, from where they are known. Small numbers have been recorded at the Wonthaggi Coastal Heathland Reserve (Rolf Willig pers. comm.). Prior to linking habitat at Lang Lang to other areas outside of the former Koo Wee Rup Swamp area, a habitat link from Koo Wee Rup, following the coastline to Lang Lang, should be investigated.

A link to Wonthaggi could continue to follow the strip of public land along Bass coastline, which is an important area to conserve for bandicoot populations further east, and for the overall protection of biodiversity values (Rolf Willig, Terry Coates and David Nicholls pers. comm.). Improved land management along this coastline is urgently required and conserving and enhancing this coastline as a habitat link may help to achieve this (Ian Stevenson pers. comm.).

A link from Lang Lang to The Gurdies may be achieved from the Unimin site, via the creekline to the Bass coastline, following the coast down towards The Gurdies. Alternatively, another link from the Unimin site to The Gurdies may be possible by making use of discontinuous remnant vegetation which can be easily enhanced. This link would proceed directly southwards from the Unimin site, via the Adams Creek Nature Conservation Reserve, Lang Lang Golf Course and Educational Area to the GMH Proving Ground, to The Gurdies. There have been andecdotal reports of bandicoots at the GMH Proving Ground by security staff (Terry Coates pers. comm.), and some evidence in the form of diggings at the Lang Lang Golf Course and Educational Area.

Link to Quail Island

A habitat link to Quail Island, following Cannons Creek, is also likely to be very important for the conservation of Southern Brown Bandicoots in the south central region. A land bridge currently exists between Cannons Creek and Quail Island, which can facilitate the movement of bandicoots. The land bridge is covered by mangroves, however, Quail Island supports a substantial amount of Swamp Scrub, Heathy Woodland and Sandy and Wet Heathland communities. Bandicoots were captured on Quail Island opposite the Warneet Pier over October - November 2008. Two females were caught with very small pouch young, and it was thought that they may be in their second

breeding phase (Malcolm Legg pers. comm.). Numerous diggings were observed at Quail Island, prior to trapping. The land bridge also facilitates the passage of foxes and cats to the island, although, this land bridge is the only point of access. Permanent baiting stations are being set up as part of a pest control program currently underway (Malcolm Legg pers. comm.). There is a good chance that foxes can be controlled or near eliminated on this island if fox control focuses on the land bridge. If this can be achieved, then Quail Island may become an important breeding refuge for Southern Brown Bandicoots.

The implementation of these proposed links will require co-ordination and thorough consultation with landholders, environmental organizations (e.g. CEC, Mornington Peninsula and Western Port Biosphere Reserve Foundation), independent researchers, local governments, planning departments (e.g. GAA), state authorities (DSE) and the RBGC. More than one habitat link may be required to maintain population viability, and all options should be investigated further. Habitat links between the Pines Flora and Fauna Reserve, Langwarrin Reserve, the RBGC and the former Koo Wee Rup Swamp area should also be considered and thoroughly investigated by the relevant management authorities and stakeholders, as they have also been identified as critical for the viability of the South Central populations of Southern Brown Bandicoots (Lechner 2006, Southwell 2006).

Table 8 Southern Brown Bandicoot Strategic Management Plan: Summary of habitat links for Southern Brown Bandicoots between population clusters and beyond the former Koo Wee Rup Swamp area

	EVC/Habitat	Tenure	Zoning	Overlays	Key Threats and Constraints
Habitat link cluster TO cluster					
Dalmore - Koo Wee Rup TO Cardinia-Rythdale cluster					
Cardinia Creek Drains	Swamp Scrub Exotic vegetation Cleared levees In-stream vegetation	Public (Melbourne Water)	Public Use Zone 1 - Service and Utility (PUZ1)	Floodway Overlay (FO)	• Not secured for conservation • Vegetation clearing (e.g. drain maintenance) • Fox predation • Cattle grazing • Proposed desalination pipeline corridor
Tooradin - Station Road	Small Swamp Scrub patches Exotic vegetation Cleared roadsides	Public	Green Wedge Schedule 1 and 6 (GWZ1/6) Road Category 1 (RDZ 1)	Land Subject to Inundation Overlay (LSIO1)	• Not secured for conservation • Vegetation clearing (e.g. roadside maintenance) • Fox predation • Predation by domestic pets • Proposed desalination pipeline corridor
South Gippsland Railway Line and Tooradin-Station Road	Swamp Scrub Exotic vegetation	Public	Public Use Zone 1 - Service and Utility (PUZ1) Road Category 1 (RDZ 1)	Land Subject to Inundation Overlay (LSIO1)	• Not secured for conservation • Proposed rail trail • Vegetation clearing (e.g. road maintenance) • Fox predation
South Gippsland Railway Line and Dalmore Road	Swamp Scrub Exotic vegetation	Public	Special Use Zone (SUZ1) Green Wedge Schedule 1 (GWZ1)	Land Subject to Inundation Overlay (LSIO1)	• Not secured for conservation • Proposed Rail Trail • Vegetation clearing (e.g. roadside maintenance) • Fox predation
Dalmore - Koo Wee Rup TO Bayles					
Boundary Drain, on Boundary Drain Road	Roadside vegetation Swamp Scrub Exotic vegetation	Public (Melbourne Water (adjoins private)	Residential Zone 1 (RDZ 1) Green Wedge Zone 1 (GWZ 1)	Land Subject to Inundation Overlay (LSIO1)	• Not secure for conservation • Fox predation • Predation by domestic pets • Cattle grazing (in adjoining properties) • Vegetation clearing (e.g. roadside maintenance)
Yallock Creek and **Number Four Drain**	Swamp Scrub Swampy Riparian Woodland In-stream vegetation Exotic vegetation Cleared levees	Public (Melbourne Water)	Public Use Zone 1 - Service and Utility (PUZ1) Green Wedge Zone 1 (GWZ 1) Public Conservation and Resource Zone (PCRZ)	Floodway Overlay	• Not secure for conservation • Cattle grazing • Fox predation • Vegetation clearing (e.g. drain maintenance) • Recreational use
Habitat link cluster TO cluster					

	EVC/Habitat	Tenure	Zoning	Overlays	Key Threats and Constraints
Dalmore – Koo Wee Rup TO Garfield - Longwarry					
Bunyip River (McKays Road in Koo Wee Rup to Nar Nar Goon-Longwarry Road) Part of a proposed priority biolink	Swamp Scrub In-stream vegetation Exotic vegetation Cleared levees Swampy Riparian Woodland	Public (Melbourne Water)	Special Use Zone 1 (SUZ 1) Public Use Zone 1 - Services and Utility (PUZ1)	Floodway Overlay Land Subject to Inundation Overlay (LSIO1)	• Not secure for conservation • Proposed desalination pipeline corridor • Fox predation • Cattle grazing • Vegetation clearing (e.g. drain and roadside maintenance)
McDonalds Drain, Ararat Creek/drain and Daly Road	Roadside and creek side vegetation Swamp Scrub Swampy Riparian Woodland Exotic vegetation Cleared areas In-stream vegetation	Public (Melbourne Water)	Public Use Zone 1 - Services and Utility (PUZ1)	Floodway Overlay Land Subject to Inundation Overlay (LSIO1)	• Not secure for conservation • Proposed desalination pipeline corridor • Fox predation • Predation by domestic pets • Cattle grazing • Vegetation clearing (e.g. drain and roadside maintenance)
Dalmore - Koo Wee Rup TO Lang Lang- Nyora					
South Gippsland Railway Line	Swamp Scrub Exotic vegetation Cleared areas	Public	Public Use Zone 4 - Transport (PUZ4)	Land Subject to Inundation Overlay (LSIO1)	• Not secure for conservation • Proposed Rail Trail • Fox predation • Proposed desalination pipeline corridor
Cardinia - Rythdale TO Garfield - Longwarry					
Rythdale Road to McDonalds Drain to Ararat Creek and Daly Road Part of a proposed secondary biolink (‘bionode’)	Roadside and creek side vegetation Swamp Scrub Swampy Riparian Woodland Exotic vegetation Cleared areas In-stream vegetation	Public (Melbourne Water)	Public Use Zone 1 - Services and Utility (PUZ1) Green Wedge Zone 1 (GWZ1)	Floodway Overlay (FO)	• Not secure for conservation • Fox predation • Vegetation clearing (e.g. drain and roadside maintenance) • May require extensive rehabilitation works
Habitat links beyond the former Koo Wee Rup Swamp study area					
Dalmore - Koo Wee Rup TO Cranbourne RBGC					
South Gippsland Railway Line and Ballarto Road	Swamp Scrub Exotic vegetation Cleared areas	Public	Public Use Zone 4 - Transport (PUZ4) Green Wedge Zone 1 (GWZ1)	RBGC (Environmental Significance Overlay ESO1)	• Not secure for conservation • Proposed Rail Trail • Predation by domestic pets • Encroachment of Urban Growth Zone (i.e. Camborne East growth area) • Fox predation • Vegetation clearing (e.g. maintenance)

	EVC/Habitat	Tenure	Zoning	Overlays	Key Threats and Constraints
Coastline from the Inlets at Dalmore, incorporating the North Western Port Nature Conservation Reserve and via Cannons Creek and Wylies Drain (and through a residential area)	Estuarine Flats Grassland Coastal Saltmarsh Mangrove Shrubland Cleared areas (in RCZ) Mangrove Shrubland	Public (Melbourne Water) Private	Public Park and Conservation Resource Zone (PCRZ) Rural Conservation Zone (RCZ) Green Wedge A Zone 1 (GWAZ1) Green Wedge Zone 5 (GWZ5) Urban Growth Zone (UGZ) Township Zone (TZ)	Environmental Significance Overlay (ESO1, ESO2, ESO3) Significant Landscape Overlay (SLO2) Land Subject to Inundation Overlay (LSIO1)	• Not secure for conservation in parts • Encroachment of Urban Growth Zone (particularly in the Cranbourne East growth area) • Fox predation • Predation by domestic pets • Vegetation clearing (e.g. property and drain maintenance)
Cardinia (& Dalmore - Koo Wee Rup) TO Cranbourne RBGC					
Ballarto Road Part of a proposed biolink	Swamp Scrub Exotic vegetation Cleared areas	Public (adjoins public land) Private	Green Wedge Zone 1 (GWZ1) Road Category 1 (RDZ1)	Land Subject to Inundation Overlay (LSIO1) RBGC (Environmental Significance Overlay ESO1)	• Landowners and the GAA do not currently support the link • Not secure for conservation • Proposed desalination pipeline route • Proposed freight railway route • Encroachment of Urban Growth Zone (particularly in the Cranbourne East growth area) • Fox predation • Predation by domestic pets • Vegetation clearing (e.g. roadside maintenance)
Garfield – Longwarry TO Drouin					
Melbourne – Sale Railway Line between Longwarry and Drouin Part of a proposed priority biolink	Swamp Scrub Exotic vegetation Cleared areas	Public	Public Use Zone 4 - Transport (PUZ 4) Low density Residential Zone (LDRZ)	Land Subject to Inundation Overlay (LSIO1) Vegetation Protection Overlay - Schedule 1 (VPO1)	• Not secure for conservation • Encroachment of residential areas • Fox predation • Predation by domestic pets • Vegetation clearing (e.g. railway and roadside maintenance)
(Koo Wee Rup Drains to) Lang Lang TO The Gurdies					
Follow the coastline from the Koo Wee Rup drains to Lang Lang **From the Lang Lang Unimin site, via the adjacent Adam's Creek Nature Conservation Reserve, through the GMH Proving Ground to The Gurdies**	Heathy Woodland Riparian Scrub Herb-rich Foothill Forest Swampy Riparian Woodland Lowland Forest Wet Heathland	Public Private	Farming Zone (FZ) Public Conservation and Resource Zone (PCRZ) Green Wedge Zone (GWZ) Rural Conservation Zone (RCZ) Public Park and Recreation Zone (PPRZ) Public Use Zone (PCRZ)	Land Subject to Inundation Overlay (LSIO1) Wildfire Management Overlay (WMO) Significant Landscape Overlay (SLO3)	• Priority may depend on whether bandicoots are still in the Lang Lang and the Gurdies areas • Needs further investigation and collaboration with landowners • Predation by domestic pets • Not secure for conservation • Fox predation • Road mortality • Vegetation clearing (e.g. property maintenance)

	EVC/Habitat	Tenure	Zoning	Overlays	Key Threats and Constraints
(Koo Wee Rup drains to) Lang Lang TO Wonthaggi Heathland Conservation Reserve					
Follow the coastline from the Koo Wee Rup drains to Lang Lang **From Lang Lang Unimin site along creeklines and Bass Coastline**	Swampy Riparian Woodland Mangrove Shrubland Berm Grassy Shrubland Swamp Scrub Coastal Saltmarsh Heathy Woodland Lowland Forest Grassy Woodland	Public Private	Farming Zone (FZ) Public Conservation and Resource Zone (PCRZ) Green Wedge Zone (GWZ) Rural Conservation Zone (RCZ) Road Category 1 (RDZ1) Residential Zone (RZ1) Low Density Residential (LDRZ) Special Use Zone (SUZ2)	Environmental Significance Overlay (ESO1, ESO2) Significant Landscape Overlay (SLO1) Erosion Management Overlay (EMO1)	• Priority may depend on whether bandicoots are still in the Lang Lang area • Needs further investigation and thorough consultation with landowners • Not secure for conservation • Encroachment of residential areas • Fox predation • Road mortality • Vegetation clearing (e.g. roadside maintenance)
Tooradin to Quail Island					
Follow Cannons Creek	Coastal Saltmarsh Heathy Woodland Mangrove Shrubland Damp Sands Herb-rich Woodland Swamp Scrub Sand Heathland/ Wet Heathland Mosaic Grassy Woodland	Public Private	Rural Conservation Zone (RCZ) Public Conservation and Resource Zone (PCRZ) Township Zone (TZ)	Environmental Significance Overlay (ESO1) Land Subject to Inundation (LSIO1) Significant Landscape Overlay (SLO2)	• Encroachment of Township along Cannons Creek • Fox predation • Feral Cat predation • Vegetation clearing (drainage maintenance)

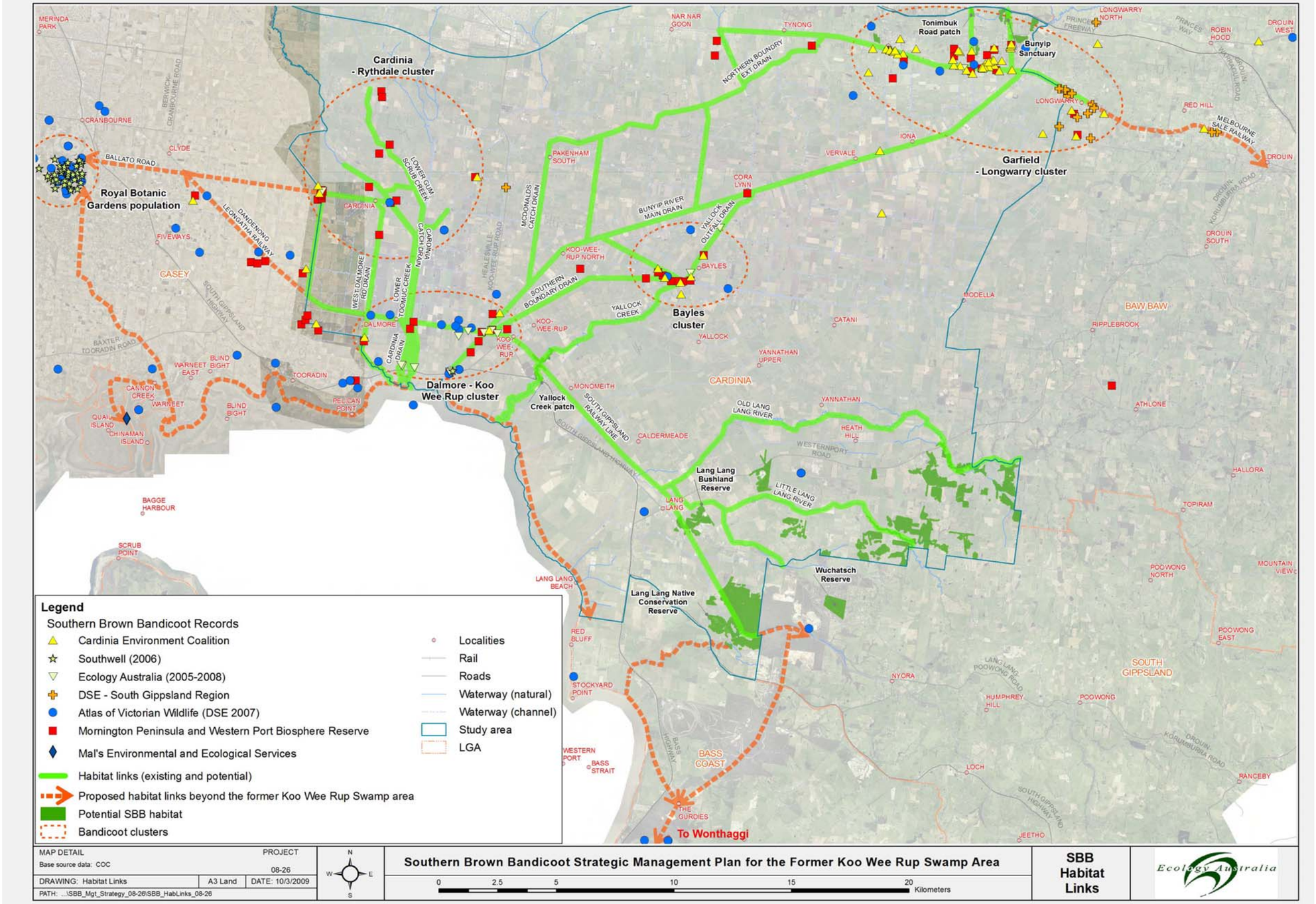


Figure 7 Southern Brown Bandicoot Strategic Management Plan: Potential habitat and habitat links (existing and potential) within the former Koo Wee Rup Swamp area

9 Strategic Management Plan: Objectives and Actions

The overall objective of this strategic management plan is to maximise the long term viability of the Southern Brown Bandicoot in the former Koo Wee Rup Swamp area. To achieve this objective, a number of actions, to be carried out by various stakeholders, are required. These actions are described below.

The success of these actions relies heavily upon the co-operation between stakeholders and management agencies. It is imperative that a Southern Brown Bandicoot management committee for the former Koo Wee Rup Swamp area is established, with representatives from all stakeholders identified in this plan, to oversee the implementation of this management plan. The committee will be the ultimate body responsible for sourcing and allocating funds, co-ordinating actions between stakeholders, ensuring the implementation of actions and monitoring the outcomes of the management actions.

9.1 Threat Abatement: Habitat loss, fragmentation and isolation

Since the drainage of the Koo Wee Rup Swamp, vast tracts of native vegetation have been cleared, leaving a predominantly agricultural landscape dominated by introduced pasture and crops. Bandicoots in the former Koo Wee Rup Swamp area are now restricted to small, spatially isolated or loosely connected, patches of remnant vegetation in reserves or private land and along road corridors and waterways. In some areas this vegetation is protected by Vegetation Protection Overlays. However, there are a number of factors that threaten what remains of this vegetation from being lost or further fragmented, including land tenure, management practices and future developments. The primary focus of this management plan should be to protect and enhance existing habitats and halt further habitat loss.

9.1.1 Objective 1: Secure known habitat and habitat links for conservation

Action 1.1: Revise local planning schemes to ensure core habitats and links identified in Sections 7 & 8 (see Figure 8) are secured and protected for conservation

The conservation of the Southern Brown Bandicoot in the former Koo Wee Rup Swamp area is compromised by the lack of security of core and other known habitats, and requires foremost, the long-term protection of habitat on public land. It is evident from the local planning schemes that many areas known to support bandicoots are not protected against vegetation loss or degradation. The primary objective of zoning in many of these areas, including core habitats, reflects land use and management needs, other than conservation, and allows actions which conflict with the conservation requirements of the Southern Brown Bandicoot.

For example, much of the habitat utilised by bandicoots in the former Koo Wee Rup Swamp area exists along riparian corridors and drains. This includes Yallock Creek at Bayles, and Cardinia Creek, sections of which are considered core habitat. A review of the management of riparian land

in Victoria recommended that all riparian parcels on Crown land be zoned as Public Conservation and Resource Zone (PCRZ), and that all riparian land (Crown or freehold) within 20 m of a waterway be included within an Environmental Significance Overlay (ESO) (PLC 2008). However most waterways within the former Koo Wee Rup Swamp area are managed primarily for drainage function and flood mitigation, reflected in their zoning as Public Use - Services and Utilities (PUZ1). These objectives do not necessarily promote management compatible with bandicoots.

Two core habitats, the Koo Wee Rup Swamp Lookout Tower and parts of The Inlets are protected under the zoning of PCRZ. While one of the intended purposes of this zoning is to conserve the natural environment and processes for their scientific and habitat values, this zoning also allows for resource based uses which may not be consistent with conservation initiatives for the Southern Brown Bandicoot (e.g. apiculture, boat launching facilities, mineral exploration). Despite these limitations, this is currently the most appropriate zoning for conservation areas. However, even within these areas, the western half of the Inlets and the feeder creeks are zoned PUZ1, and are not protected. Biosis has recommended to Melbourne Water that the entire Inlets site be reserved, with the reserve extended north to the railway line (Biosis 2008a). This recommendation is supported by this plan. Other areas of core habitat such as Bandicoot Corner and Bayles Fauna Reserve are currently managed for conservation, but are not secured in perpetuity, due to their zoning as PUZ1. Similarly, other known habitats and habitat links are not secured or protected.

It is essential that habitat known to support bandicoots is protected in a manner that is consistent with the conservation requirements of this species. Under current zoning, bandicoot habitat is not protected or secure, as there are allowances for land use and management practices which may threaten the bandicoot. The best mechanism to ensure the protection of bandicoot habitat, whilst accommodating other land management uses is to revise the local planning schemes covering public lands. A revision and amendment to the planning schemes should occur to increase the overall security and protection of bandicoot habitat in the former Koo Wee Rup Swamp area.

A specific Southern Brown Bandicoot Overlay, as a schedule of an ESO should be implemented, which reflects the conservation objectives for the bandicoot. The primary purpose of this overlay should be to protect these areas from developments or land uses that involve the further loss or fragmentation of vegetation. Processes that can potentially degrade habitat and waterways such as agricultural and pastoral land uses should also be prohibited. Protected areas (particularly core habitats) should be promoted for passive rather than active recreation to limit impacts of recreational use.

The first priority in this regard is to ensure the protection of core habitats and habitat links. Wherever possible, public land adjoining core habitat (e.g. at ‘The Inlets’), other known habitats and potential habitats should also be covered by the overlay.

9.1.2 Objective 2: Avoid future habitat loss and fragmentation

Action 2.1: Avoid slashing and the removal of roadside vegetation when not essential and prevent vegetation slashing along important roads identified in Figure 9

In highly disturbed or urbanised landscapes, such as the former Koo Wee Rup Swamp area, roadside remnants often contribute some of the few strips of vegetation remaining, providing important habitat refuges for displaced fauna. Distribution records indicate that Southern Brown Bandicoots in the former Koo Wee Rup Swamp area frequently utilise roadside remnants. Given the general scarcity of native vegetation in the area, it is clear that roadside habitats are valuable. Furthermore, roadside vegetation that provides links between remnant patches of vegetation is important in facilitating dispersal, gene flow, and range expansion (Bennett 1990). However, many roadsides within the former Koo Wee Rup Swamp area are currently slashed periodically for maintenance by council and private landholders. These activities can potentially threaten the viability of Southern Brown Bandicoots in the former Koo Wee Rup Swamp area by removing valuable habitats, and impeding movement, dispersal and potentially blocking gene flow.

It is widely recognised that roadside remnants should be managed for conservation so that the disturbance to roadside vegetation from clearing, slashing and grazing is minimised (Bennett 1988). Roadside vegetation is most valuable to bandicoots and other fauna when it comprises remnant vegetation, however, weedy vegetation such as Blackberry along roadsides can also provide habitat. Therefore, property owners and councils should be aware that the removal of any vegetation may constitute habitat loss for bandicoots. Thus, despite threats posed by traffic on roads, we recommend that the conservation values and continuity of roadside vegetation should be maintained and enhanced whenever possible. Cardinia's Roadside Management Plan should be reviewed to ensure that this occurs, and council should liaise with VicRoads, DSE and landholders.

Action 2.2: Cease vegetation slashing and clearance along waterways (Figure 9)

The drainage of the Koo Wee Rup Swamp required the construction of numerous drainage channels and diversion of creeks and rivers, resulting in a broad network of inter-connected watercourses throughout the area. As with road reserves, vegetation retained along these watercourses provides valuable habitat and a network of connectivity, which may allow bandicoots to persist within this altered environment, by facilitating movement into and within the agricultural matrix. Bandicoots appear to make extensive use of riparian corridors, and it is believed that in at least some instances they may provide habitat in which bandicoots can subsist (Terry Coates pers. comm.).

The waterways in the former Koo Wee Rup Swamp area are managed primarily for drainage and flood mitigation, rather than for conservation and natural values. Vegetation along creeks and drains is often slashed by water authorities to aid with maintenance for drainage and fire protection. Riparian vegetation not only holds significant habitat value for Southern Brown Bandicoots in the former Koo Wee Rup Swamp area, but also provides an opportunity for maintaining biodiversity and providing connectivity for other species in an agricultural landscape. Management practices along waterways should be reviewed to ensure that riparian vegetation is

protected from loss or degradation. Narrow, cleared maintenance strips may still be retained as it is clear that in many cases, this provides good foraging space close to dense vegetation, minimising exposure when foraging. The presence of foxes often exaggerates a species requirement for cover and the need for food to be nearby (May and Norton 1996). Foraging activities in these areas has been observed along Yallock Creek. However, it is likely that clearing large amounts of vegetation along parts or along the entire length of waterways will threaten the viability of Southern Brown Bandicoots within the former Koo Wee Rup Swamp area. Melbourne Water is currently aiming to reduce slashing and increase revegetation efforts. An operational management plan for waterways should be developed by Melbourne Water to address this issue and other issues relating to Melbourne Water's management practices, which are discussed in this plan.

Action 2.3: Ensure that informed planning decisions and environmental assessments are made where proposed developments have the potential to impact upon Southern Brown Bandicoot habitat

Proposed developments for infrastructure and residential growth, as outlined in section 5, have the potential to create further habitat loss and fragmentation for Southern Brown Bandicoots in the former Koo Wee Rup Swamp area. All future developments or activities in the former Koo Wee Rup Swamp area should consider whether bandicoot habitat will be affected, under the requirements of the EPBC Act. Council planners must ensure that procedures for appropriate environmental assessments are followed and that planning and design instruments are developed to avoid or minimise impacts to the species in potential habitat. To this effect, council planners should follow the decision guidelines set out in Section 11. These guidelines outline the steps required to make an informed environmental assessment regarding proposed developments or activities and explain how and when matters should be referred to the Federal Minister. Council authorities should also assess all given information with reference to this management plan when making decisions about developments. Local government authorities also need to make sure that developers comply with the minimum survey requirements and standards set out in Section 14, and apply appropriate measures to minimise potential impacts. As a priority, the loss of remnant vegetation should be avoided through appropriate design and planning. Where vegetation loss is unavoidable, this should be minimised and adequately offset. Habitat links, fauna underpasses and land bridges should be implemented when required, to mitigate fragmentation and isolation, following advice from qualified experts.

9.1.3 Objective 3: Increase protection of remnant vegetation on private land

Suburban expansion and agricultural and pastoral land uses constitute some of the largest threats facing the Southern Brown Bandicoot in the south-central region. The south-central area of Victoria is the most human-populated region of Victoria, and most areas of suitable habitat have been lost to housing and agriculture (Coates et al. 2008). Remnants of vegetation on private land in the Koo Wee Rup Swamp area are likely to continue to be further fragmented with increasing urbanisation and development.

This area is particularly vulnerable because of the rate of urban development. By 2030, Melbourne is expected to grow by one million people, with much of this growth expected to take place in the Casey and Cardinia growth areas (DOI 2002, Lechner 2006). In Cardinia Shire the population is expected to rise to 118,000 by 2021 (Cardinia Shire 2008). Thus, it is believed that the south-central population of Southern Brown Bandicoots may be at higher risk of decline than in other regions of Victoria (Coates et al. 2008). Areas outside of the urban growth zone are also likely to be affected by increasing urbanisation and residential development. Bunyip, which supports core habitat for Southern Brown Bandicoots, has been identified as a major area for future development and expansion. Relatively large parcels of loosely connected remnant vegetation remain in Bunyip, mostly on private land, which are likely to be threatened with urban development and the subdivision of land.

Action 3.1: Implement a specific Southern Brown Bandicoot Overlay over suitable habitat on private land

The greatest opportunities to protect and manage remnant habitat on private land arise from amendments to local planning schemes. A Southern Brown Bandicoot Overlay as a schedule of an Environmental Significance Overlay should be implemented across suitable habitat that exists on private land. The purposes of this overlay should be to protect Southern Brown Bandicoot habitat on private land from being lost and fragmented, wherever possible, through the use of planning controls. The implementation of this overlay into the planning scheme will also serve as a trigger for the *Decision Guidelines for Council planners* (Section 11) and *Survey Protocols* (Section 12) to ensure that before the removal of any vegetation suitable for bandicoots, the correct processes are followed to minimise habitat loss whenever possible.

Action 3.2: Extend the coverage of Vegetation Protection Overlays on private land

Where Southern Brown Bandicoots are known to occur, Vegetation Protection Overlays are currently implemented along: Ballarto Road, Cardinia; sections of the railway line in Bunyip; and along parts of A'beckett Road, Chambers Road and Flett Street in Bunyip. Vegetation Protection Overlays should be extended to cover all Residential and Green Wedge Zones, within the Koo Wee Rup Swamp area, which have significant areas of natural habitat. It is also important that these are implemented into land adjoining the railway lines from Tooradin to Cranbourne and from Bunyip to Longwarry. The continued loss of vegetation on private land, particularly in the Bunyip area may result in local extinctions of bandicoots.

Action 3.3: Continue to provide incentives for landholders to retain and manage remnant vegetation on private property

Financial and non-financial incentives are widely used to encourage and assist landholders to retain and manage remnant vegetation on their land. This management plan advocates the continuation of the Cardinia *Biodiversity Incentives Scheme*, administered with the CEC, which provides financial rebates to landholders with a Trust for Nature covenant, training subsidies for accredited courses on land management, and native vegetation protection on private property. Council should consider expanding this scheme to include rate rebates for property owners who retain and manage remnant

vegetation on their land, with informal landholder agreements. Incentive schemes are important motivational tools to encourage landholders to preserve remnant vegetation, and increasing current incentives for the community can greatly assist in halting the loss of habitat on private land. Grants from council for native vegetation protection may be another means of doing this, and grants can be linked to landholder management agreements. Non-financial incentives may include a local awards scheme for the recognition of efforts to conserve or rehabilitate remnant vegetation. Training and technical support provided through Landcare groups or other organisations can also assist property owners to retain small remnant strips of vegetation and aid them in integrating conservation measures with farming practices. The promotion of Land for Wildlife is also recommended. Owners of Land for Wildlife properties receive support from local extension officers who provide advice regarding management of the land.

In particular, landholders with freehold riparian land should be encouraged to rehabilitate and manage remnant vegetation along riparian corridors, given the likely role that these corridors play in providing connectivity for bandicoots throughout the landscape. Melbourne Water's Stream Frontage program, which provides incentives for such activities along designated waterways, could be expanded to include 'drains' which are currently exempt from the program. The *Biodiversity Incentives Scheme* could also be used to assist landholders with freehold riparian land.

Action 3.4: Continue to promote schemes to secure private land parcels for conservation

Land purchase, landholder agreements, covenants and revolving funds are some of the most effective and enduring means of securing private parcels for conservation. Organisations such as Trust for Nature and Bush Heritage are non-profit organisations that purchase land to be managed for conservation and as part of revolving fund schemes, where land is resold with a conservation covenant. Landholders who establish and maintain conservation covenants and landholder agreements with Trust for Nature or Bush Heritage receive support with management and monitoring through stewardship programs. Alternately, land purchased can be transferred to public estate. The Australian Government also provides tax concessions for landholders placing conservation covenants on their land or for donating land to environmental bodies. Council should promote covenanting programs and schemes, particularly in areas such as Bunyip and Lang Lang where remnant vegetation is threatened by future development. Landholder agreements will be particularly valuable where landholders with adjoining parcels of land agree to maintain covenants so that a larger parcel of un-fragmented vegetation can be retained. If in the future, potential habitat or habitat supporting bandicoots is found near or adjacent to other known or suitable habitats, relevant landholders should be notified of the significance of the habitat and encouraged to undertake conservation management and participate in covenant schemes.

Other similar schemes include the Victorian Government's ecoMarkets initiatives which include BushTender, BushBroker and EcoTender. These schemes create the opportunity for landholders to generate regular and reliable income from native vegetation management, making conservation management on their land economically viable.

Council should also investigate 'development concession' schemes as a means of securing important parcels of land with significant habitat value, for conservation on private land proposed

for development. This would involve negotiations with developers where concessions are provided if developers agree to forgo development of a particular parcel of land. This may be in the form of concessions elsewhere within the development or on land elsewhere, and may require rezoning. Under this scheme, councils can impose strict conditions of ongoing management of land. As recommended in the Cardinia Environment Strategy (Cardinia Shire 2004), council could also consider the concept of landscape bonds as planning conditions for native vegetation loss and offsets in applications for housing developments on bushland blocks.

9.2 Threat Abatement: Habitat degradation

A number of land uses and management practices on public and private land degrades remnant vegetation that supports or potentially supports habitat for the Southern Brown Bandicoot, by impacting upon the understorey vegetation. Grazing has depleted the understorey vegetation in a number of remnants on privately owned agricultural land and along various riparian corridors, throughout the former Koo Wee Rup Swamp area. In numerous cases, this has facilitated the invasion of environmental weeds, which has displaced native vegetation and impeded regeneration. Most native vegetation remnants and bushland reserves within the former Koo Wee Rup Swamp area are degraded by weeds to some degree. Further evidence of degradation is apparent in numerous bushland reserves and remnants, stemming from the dumping of rubbish, garden and chemical waste and trail bike riding which destroys vegetation and disturbs the soil. The gradual attrition of remaining fragments from increased edge effects could pose a threat to bandicoots. Protection and management of remnants and understorey vegetation is essential for the survival of Southern Brown Bandicoots in the former Koo Wee Rup Swamp area. A dense understorey of ground and shrub cover is an essential habitat resource for the Southern Brown Bandicoot, providing shelter and protection from predators.

9.2.1 Objective 4: Protect and enhance the integrity of remnant vegetation

Action 4.1: Cease livestock grazing in riparian Crown land parcels and prohibit stock access to riparian remnant vegetation (Figures 2 and 9)

Grazing by cattle poses a serious threat to understorey vegetation in the former Koo Wee Rup Swamp area. Where sustained grazing occurs along drainage lines and in vegetation remnants in private property, the understorey of native vegetation has greatly diminished or disappeared, and is often dominated by an exotic, grassy ground layer. This lack of understorey shelter exposes bandicoots to predation.

Grazing along riparian corridors poses a particular threat because of the role these corridors play in providing habitat connectivity throughout the landscape. Several important riparian corridors, including some of the Cardinia drains, a section of Cardinia Creek and sections of Yallock Creek are currently under licence (Figure 2). Yallock Creek is considered to provide core habitat, and the Cardinia drains potentially function as an important habitat link, central to sustaining the Cardinia cluster (see Section 7). The loss of understorey vegetation along these corridors can severely diminish their ability to function as habitat links, and therefore, threaten the viability of populations

and contribute to local extinctions. The damage to riparian habitats caused by grazing is best illustrated by impacts upon Yallock Creek (see Section 7, Appendix 3, Plate 6).

This management plan strongly advocates the removal of grazing from all riparian Crown land parcels, as soon as possible, as well as the prohibition of grazing on all freehold riparian land through changes to planning and local laws. The Public Land Consultancy has emphasised that a landholder's right to obtain water from the creeks should in no way be confused with a right to allow livestock access to waterways (PLC 2008). Fencing should be erected to prevent access.

The removal of grazing will allow the regeneration of native vegetation, including an understorey and will also decrease the effects of soil compaction. Regeneration of habitat along waterways will increase the amount of suitable habitat and enhance dispersal corridors. Removing grazing from waterways will also have positive effects on a number of other fauna and natural values including reduced pugging, erosion of banks and sedimentation (see also Section 10). Melbourne Water is currently reviewing this issue which should be incorporated in an operational management plan.

Action 4.2: Discourage livestock grazing in vegetation remnants on private property and encourage landholders to fence vegetation remnants from livestock

Many of the vegetation remnants that are known to support bandicoots and some relatively large areas of potential bandicoot habitat occur on private land. Pastoral land uses in these areas also have the potential to severely degrade the understorey vegetation and cause soil compaction. Encouraging private landholders to fence off remnant vegetation from livestock will increase the quality of remnant vegetation and bandicoot habitat across the former Koo Wee Rup Swamp area, particularly around Lang Lang and Heath Hill. While the Cardinia *Biodiversity Incentives Scheme* provides financial support for the fencing of remnants to landholders maintaining a Trust for Nature covenant, rebate incentives could be extended to all landholders with remnant vegetation on their property. Many of these properties may contain smaller patches of native vegetation which provide habitat for the Southern Brown Bandicoot and require protection, but can not meet the criteria for a Trust for Nature property. Broadening the scheme will encourage wider participation, and enable more landholders to support and contribute to conservation efforts for the Southern Brown Bandicoot. In this depleted landscape, it is important to protect as much remaining native vegetation as possible; fencing provides one of the most effective means.

Action 4.3: Continue to implement the Shire of Cardinia Weed Management Strategy and integrate actions for staged weed control

Environmental weeds pose serious threats to the productivity of agricultural land and natural biodiversity values. Therefore, weed control is important for economic and conservation reasons. However, it is important that this is done in a manner that does not adversely impact upon habitat of the Southern Brown Bandicoot. Many weed management techniques, particularly broad scale clearance of weeds, have the potential to remove or reduce habitat for Southern Brown Bandicoots by removing the dense cover and protection provided by the weeds. The Cardinia Weed Management Strategy (Cardinia Shire 2007) recommends that sites are rehabilitated following the clearance of weeds. Yet, it is typically three to five years before native vegetation regeneration

reaches a stage in which the level of cover is replaced and habitat is once again suitable for bandicoots. In the interim, an important habitat element has been removed and bandicoots effectively experience temporary habitat loss.

It is important that the Cardinia Weed Management Strategy (Cardinia Shire 2007) continues to be developed and implemented with protocols for staged weed removal in accordance with minimum disturbance techniques. This means that revegetation must occur before weed removal, so that the layer of cover removed is replaced without adversely impacting upon habitat structure and suitability. These weed control protocols must apply to roadsides and railway lines as well as other public lands. Council must liaise with VicRoads, VicTrack, and private landholders to ensure that weed management along roadsides and along the railway is managed correctly.

Action 4.4: Provide funding and other incentives for strategic revegetation and follow up weed control on private property

This action is designed to provide two benefits, addressing aspects of habitat degradation through weed control and habitat enhancement, through prior revegetation. As stated above, it is essential to carry out revegetation before weed removal to retain a level of cover for bandicoots, and it is important that landholders are aware of this.

The Cardinia Shire Council currently offers weed control grants, for the purchase of herbicide, open to landholders who are members of a Landcare group, are qualified in the use of agricultural chemicals, or who will control weeds in or near an area of high conservation value. The weed control grant scheme requires amendments, to stipulate the need for revegetation prior to weed removal, and to provide support for revegetation efforts. This may constitute an increase in the amount of funding, the provision of tube-stocks for revegetation, or technical support for the management and monitoring of revegetation. Recommendations made in the Cardinia Weed Management Strategy (Cardinia Shire 2007) for improving the grant scheme, which are supported by this management plan include: (i) allowing the grant to be used for labour and/or herbicide (and possibly tube-stocks); (ii) providing funding in proportion to the area of remnant vegetation; (iii) prioritising applications that target established weeds (or weeds which impact most upon understorey vegetation); and (iv) providing services for mulching woody weeds.

The Department of Primary Industries also administers grants through the Land Protection Incentives Scheme for works to address degradation issues on private property.

Private landholders also need to be informed of the ways in which weeds impact on the economic and conservation values of land and of their legal obligation to manage regionally controlled and prohibited weeds on their land under the CaLP Act (see Appendix 1). They should also be made aware that weed invasion is often symptomatic of other management practices which cause disturbance to native vegetation such as grazing, vegetation removal and erosion, to provide them with tools for the prevention rather than control of weed invasion.

Actions 4.5: Fence off reserves and remnant vegetation in known and potential habitat to prevent access by trail bikes and other vehicles

The formation of informal tracks by trail bikes through reserves, and their continued use can seriously degrade the understorey vegetation, damaging vegetation, creating soil disturbance and promoting weeds, as well as creating noise disturbance. Fencing reserves to prevent their access is an effective means of reducing this type of disturbance. Priority areas which require fencing include the reserve along Yallock Creek, particularly between the railway line and South Gippsland Highway, Land Lang Bushland reserve and the adjoining patch of remnant vegetation south of the railway line, and the remnant patch along Tonimbuk Road. There are numerous other remnants of vegetation within Lang Lang and Nyora. Further investigations may reveal that these would also benefit from fencing.

Action 4.6: Develop a community education program to promote public stewardship of reserves, waterways and remnant vegetation in the former Koo Wee Rup Swamp area

Within many reserves in the study area, there is evidence of rubbish dumping, four-wheel driving and trail bike riding which has resulted in soil disturbance, weed invasion, vegetation loss and degradation, indicating a general disregard by some, for the natural values of public reserves. Increasing public awareness of the values within reserves and promoting public involvement in conservation activities in reserves and community days will encourage the community to place more value in nature reserves. Interpretive signage and provision of educational material will be important in conveying a conservation message for these reserves. Education should also be provided regarding the management of watercourses and drains, and balancing the needs of management for flood mitigation and conservation.

9.3 Threat Abatement: Predation and pest animal control

The importance of predator, particularly fox, control is best illustrated by the failure of many recovery programs due to inadequate control (Short et al. 2002, Winnard and Coulson 2008). Small and isolated populations of bandicoots in fragmented remnants, such as in the former Koo Wee Rup Swamp area, are at increased risk of local extinction due to secondary pressures of Red Fox predation (Menkhorst and Seebeck 1990, Menkhorst 1995, Coates and Wright 2003). In addition, the preferential predation of female bandicoots by foxes is considered to pose a significant threat to the viability of isolated populations (Maxwell et al. 1996).

The DSE, in conjunction with the Mornington Peninsula and Westernport Biosphere Reserve Foundation (MPWBRF) and the Royal Botanic Gardens Cranbourne (RBGC) has recently implemented a fox control program for parts of the Port Phillip and Westernport region from Cranbourne to the Mornington Peninsula. As part of this program, RBGC, in addition to ongoing fox control within the gardens, is responsible for fox control on surrounding private land, and along Westernport Bay, north of Quail Island. Parks Victoria will be responsible for fox control at Quail Island (John Hick pers. comm.). Mornington Peninsula Shire is undertaking some control near Yaringa, and the MPWBRF is managing and monitoring fox baiting at around 20 properties in

the former Koo Wee Rup Swamp area, although this is likely to be inadequate for the former Koo Wee Rup Swamp area (David Nicholls pers. comm.). Melbourne Water is also due to undertake fox control at The Inlets.

If fox control is to succeed, a more intensive, co-ordinated, regional approach is essential. This will require collaboration between a number of agencies, stakeholders and cooperation from private landholders, as well as an integrated approach. Greater participation, particularly in the former Koo Wee Rup Swamp area is required for an effective fox control program. Guiding principles for the development of a pest control program, and common techniques are provided below.

9.3.1 Objective 5: Reduce the predation pressures of Red Foxes

Action 5.1: Determine the abundance and density of the Red Fox in the former Koo Wee Rup Swamp area

While the current density of foxes in the region is unknown, hair analysis of fox scats collected in Koo Wee Rup, during a survey in February 2008, revealed that 50% of scats collected contained the hair of Southern Brown Bandicoots (Ecology Australia 2008), indicating that predation rates in the region are potentially high. However, for any attempt at fox control to be effective, an estimate of the density and abundance of foxes in the region must be ascertained first. This will instruct the effort and intensity of control required such as helping to determine baiting rates (i.e. the number of baits required and frequency of baiting), and target areas. This information will also provide baseline data on fox abundances which will be required to make baseline comparisons when monitoring the effectiveness of fox control programs. Estimates of fox abundance should be undertaken by spotlight counts in the very early hours of the morning. There is a caution issued when estimating fox numbers: research suggests that for every fox observed, another four remain undetected (Bloomfield 2001). Locating den sites during the breeding season can also give an indication of presence.

Action 5.2: Develop a broad-scale integrated Red Fox control program around core areas

A broad-scale integrated control program, focusing on key target areas in the Koo Wee Rup Swamp area, is required to reduce predation pressure on Southern Brown Bandicoots. If possible, this should be co-ordinated with other programs in the south-central region. Small, localised attempts at fox control carried out in isolation are rarely effective. Such attempts simply create a vacuum that is quickly filled by foxes from surrounding areas (Kinnear et al. 1988). The larger the area of fox control, the longer it takes for foxes to re-colonise target areas. Thus, control should be executed on a broad regional scale with co-operation from land holders and land managers.

While poison baiting is often the most effective means of control, no single technique can provide effective long-term control (Bloomfield 2001). Therefore, we recommend an integrated program that includes more than one technique. Development of the control program should consider the different techniques currently available in fox control. Rabbit and feral cat control should also be integrated into the fox control program, and this is discussed further below.

Poison baiting

Poison baiting is undertaken with meat based baits laced with a standard dose of 3 mg of sodium monofluoroacetate (1080). Users should comply with the *Directions for the Use of 1080 Pest Animal Bait Products in Victoria* (Victorian Government 2007). As discussed in Appendix 2, the risk of poisoning to Southern Brown Bandicoots is considered to be negligible because of an inherently high tolerance to 1080. Furthermore, meat based baits are not highly attractive to bandicoots and because baits are buried, access is reduced. For these reason, the threat of 1080 baits to other non-target native species is also minimal, when administered in accordance with specified guidelines. The burying of baits is a safeguard which protects most non-target species from ingesting 1080, significantly reducing risk. The use of 1080 in control programs across the mainland have demonstrated that bait uptake by non-target species is almost negligible (Dexter et al. 2007). In the unlikely event that bait is taken by non-target species, most birds show a high tolerance to 1080 (carnivorous birds often vomit) and reptiles and amphibians show the highest tolerance of any animal group. Therefore, unusually large amounts of bait would need to be ingested before a lethal dose is consumed.

Domestic cats and dogs however, are susceptible to 1080. Therefore, it is imperative that local pet owners be made well aware of the timing, duration and areas of baiting through print media and letter drops, and baited areas should be clearly signed and designated as 'No Pet Zones'. The risk to domestic animals is minimal when this is carried out correctly. There are a number of other ways to reduce this risk, briefly outlined below. We advocate that land managers administering poison baits, complete the *Course in minimising the Risks in the Use of 1080 Pest Animal Bait Products for Vertebrate Pest Control.* Furthermore, it is a legal requirement to undertake a risk assessment for the use of 1080.

Nonetheless, the minimal risk associated with non-target animal uptake of poison is greatly outweighed by the benefits. Fox control programs throughout Australia have been shown to be highly effective in increasing numbers of critical weight range mammals (Dexter et al. 2007), including Southern Brown Bandicoots (Rees and Paull 2000, Coates 2008), and in the recovery of declining populations of numerous other mammals including Rock Wallabies (*Petrogale lateralis* and *P. rothschildi*) (Kinnear et al. 1988), Numbats (*Myrmecobius fasciatus*) (Friend 1990b), Woylies (*Bettongia penicillata*) and Chuditch (*Dasyurus geoffroii*) (Bailey 1996). Even when foxes are not completely eliminated, the abundance of mammals, including the Southern Brown Bandicoot has been shown to increase dramatically (Rees and Paull 2000, Dexter et al. 2007, Coates 2008). It is thought that species such as bandicoots, with a high reproductive rate may be able to recover and co-exist if predation pressures are kept sufficiently low (May and Norton 1996, Smith and Quin 1996). Furthermore, the Red Fox is declared vermin under the CaLP Act and all land owners and land managers have a legal obligation to control foxes on their property. Fox control on private land can not only benefit fauna in adjacent remnants but also protect stock (Saunders et al. 1995). Before fox baiting begins, a public awareness campaign should be implemented to inform the public of the need for and benefits of fox control, the reasons for using 1080, and to correct misconceptions surrounding the use and risks associated with 1080 (McPhee and Bloomfield 2004). Cooperation with landholders is vital.

A control program should include an appropriate baiting regime based on the abundance of foxes estimated previously, and the density of baits should always be higher than the density of foxes (McPhee and Bloomfield 2004). Bait stations should be established, as approximately 1 m diameter raised sand mounds or hillocks within which baits are be buried at depths of around 10-12 cm. In urban areas, baits should be laid at least 500 m away from residences (McPhee and Bloomfield 2004). Using fresh meat baits over processed baits in urban areas also reduces the risks to domestic animals. Fresh meat baits are less likely to be cashed by foxes as they are more palatable. In rural and semi-urban areas, baits can be alternated to avoid any development of bait aversion (McPhee and Bloomfield 2004).

Free feeding with non-toxic baits for a period of approximately three weeks, with regular bait replacement, will establish a regular feeding pattern, and ensure maximum success of toxic bait uptake (McPhee and Bloomfield 2004). Free feed baiting can be followed by two or three weeks of toxic baiting (McPhee and Bloomfield 2004). Sand mounds should be monitored to determine bait uptake by foxes and also to monitor possible bait uptake by non-target species (by tracks or scats) during free feeding. Once taken, poison baits should not be replaced until a follow up spotlight count of fox numbers has been undertaken to monitor success. In the incidence of moderate rainfall, baits should be replaced within two weeks (McPhee and Bloomfield 2004).

Den fumigation and destruction

Den fumigation is an effective technique in conjunction with baiting. The effectiveness of this technique is due to the high fidelity foxes show to dens year after year. Vixens typically begin excavating dens between April and May. Den fumigation is best undertaken in between August and October, while cubs are confined to the den, using carbon monoxide or phosphine gas. Where possible, dens should be destroyed following fumigation, by ripping with machinery. Dens should be revisited each year in May to June and August to September to measure and monitor fox activity (Bloomfield 2001). Mapping dens will greatly assist in monitoring the effectiveness of this activity (see Action 5.1).

Soft-jaw Trapping

Soft-jaw trapping has been effective when used in conjunction with baiting programs. This method employs the use of rubber jaw leg-hold traps, which allows non-target species to be released. It is particularly useful in areas were methods such as baiting pose too much of a risk or to remove animals that will not take baits. Set traps must be monitored daily.

Shooting

Shooting is the most target specific method aimed at reducing fox numbers, but does not offer long-term, broad scale control. Shooting at night with a spotlight is commonly undertaken by recreational hunters and farmers, with tin whistles used to imitate the sound of a distressed rabbit, to attract foxes. However, this practice is often not encouraged, particularly in semi-rural areas, due to potential injury of livestock and pets, and damage to property. It can sometimes also lead to indiscriminate shooting. Daylight drives by recognised fox hunting clubs can be effective but requires a large number of participants. Shooting tends to quickly educate foxes which appear in

progressively lesser numbers. Typically, young inexperienced foxes are shot. Still in late summer and early autumn, large numbers of young inexperienced foxes can be eliminated using this method (Bloomfield 2001).

Action 5.3: Implement the Red Fox control program developed in Action 5.2

Fox control should be focused on important habitats and areas known to support bandicoots, and areas of high risk as determined in the initial survey of foxes, across the former Koo Wee Rup Swamp area. Fox control programs should ideally commence in March to early April, and continue throughout autumn. Young foxes disperse during autumn and may rapidly settle into vacated territories from surrounding areas, during this time. For this reason it is necessary to carry out fox control over an extended period. Additional rounds of fox control should be carried out in spring (November), during the fox breeding season to reduce rapid re-colonisation by foxes (McPhee and Bloomfield 2004). This also reduces the reproductive capacity of foxes by removing potential offspring. Baiting should take place twice per season (i.e. four times per year) for the first two years. If bait uptake reduces significantly after this, baiting frequency can be reduced (McPhee and Bloomfield 2004). The program should continue for the duration of this plan.

An effective process of establishing and maintaining relationships with Landcare and other community groups, private landholders and government agencies is required. The ability to demonstrate good working relationships is essential to secure and attract funding (McPhee and Bloomfield 2004). Australian Government funds may be available to implement fox control programs in priority areas or for actions identified in regional plans (Commonwealth of Australia 2008). Programs such as *Caring for Our Country* will likely secure regular funding for fox control.

Action 5.4: Protect important areas with predator-proof fences and the creation of small mammal refuges

Predator-proof fencing is currently installed at Bayles Fauna Reserve and Bandicoot corner in Bayles, but not all areas of important habitat, such as The Inlets and Koo Wee Rup Swamp Lookout are protected from predators (see Section 7 and Figure 3). Whilst a predator control program will reduce predation pressures in general, this threat can not be entirely eliminated, and bandicoots are still vulnerable to predation. This plan recommends that core habitat areas identified, are protected by predator-proof fences to create a small mammal refuge. These should be constructed around The Inlets and around the Koo Wee Rup Swamp Lookout and associated drains, as shown in Figure 3. If other un-fragmented habitats, of at least 5 ha are found to support bandicoots in the future (e.g. at Lang Lang), these should also be fenced from predators.

Small mammal refuges (SMRs) have been shown to be highly effective in conserving small mammal populations on mainland Australia (Smith and Quin 1996). They are currently in place in the Mount Lofty Ranges, and have recently been implemented at Bandicoot Corner, Bayles. SMRs are simply standard predator-proof enclosures, of several hectares in size, which exclude foxes, cats and dogs but allow the passage of small mammals in and out of the enclosure. This has several benefits. By allowing the free dispersal of bandicoots, genetic exchange is maintained, reducing the effects of isolation inherent in standard predator-proof fencing. Furthermore, when these

enclosures encompass the range of at least a few breeding females, the protected population is allowed to increase in size, and juveniles dispersing into surrounding environments can recharge external populations that may be depleted by predation. The control of rabbits is also much easier within SMRs. SMRs are also a cost effective means of population protection. By fencing a smaller area, populations are protected without the cost of construction and maintenance of fences around large areas of habitat. Within the former Koo Wee Rup Swamp area, bandicoots are expected to occur along the entire coastal area from Yallock Creek to Tooradin (David Nicholls pers. comm.). This population can be protected without having to fence the whole area, by fencing smaller areas of core habitat at the Inlets and the Koo Wee Rup Swamp Lookout tower.

An appropriate design for the predator-proof fencing should be investigated, including designs of structures that allow the passage of small mammals. The design should also incorporate a means of appropriately crossing creeks and drainage lines, without retarding the flow of water or aquatic fauna.

9.3.2 Objective 6: Reduce the degradation impacts and control populations of the European Rabbit

A rabbit control program is required to: minimise the rabbit-induced degradation to native vegetation remnants; prevent eruptions in rabbit numbers following fox control; and prevent consequent increases in fox numbers characteristic of predator - prey relationships. As with fox control the adoption of a combination of control techniques is advocated for the control of rabbits.

Action 6.1: Determine the density of the European Rabbit in the former Koo Wee Rup Swamp area

The abundance of European Rabbits in the former Koo Wee Rup Swamp area is expected to be high, although an estimate of their density is not currently available. Before a control program for European Rabbits can be developed this needs to be determined, for use as baseline data and to inform baiting requirements. Estimates of rabbit numbers, densities and their impacts can be made in several ways. Night time counts of rabbit numbers can be undertaken with spotlights, which will also provide an indication of the areas in which rabbits are feeding, important for determining the placement of baits. The judicious placement of baits will determine their effectiveness. Daytime estimates can also be made from scat counts, using the Gibb Index for estimating rabbit abundance. A sample of this index is provided in Appendix 6. Searches should also be carried out to locate warrens. These should be mapped to identify where baits can be placed and for the destruction and monitoring of warrens. Daytime inspections should also be carried out to assess the vegetation condition in areas where rabbits are abundant, so that this can be used as baseline data for assessing vegetation condition as a performance indicator of the effectiveness of rabbit control.

Action 6.2: Develop a control program for the European Rabbit to be integrated with the Red Fox control program

The benefits of rabbit control programs are two-fold. It has been demonstrated that reducing rabbit numbers, and hence grazing pressure, in an attempt to extend and enhance habitat for bandicoot

species can be successful, in conjunction with predator control (Winnard and Coulson 2008). Rabbits are important prey items for Red Foxes (and cats). Therefore, large rabbit populations are also capable of sustaining large populations of Red Foxes and feral cats, increasing the predation pressure on native mammals such as bandicoots. For this reason, rabbits have been implicated in the decline of numerous native small mammals (Smith and Quin 1996). A decline in fox numbers should follow a decline in rabbit numbers. Because these two are intricately linked, a rabbit control program should be integrated into fox control efforts.

Poison baiting

There are two commonly used poisons that are effective in controlling rabbits. However, there are constraints associated with each of them, which should be considered in the development of the control program. Sodium monofluoroacetate can be used to lace diced carrots and oat grains, which are laid in trails near warrens or feeding areas. Theoretically, it is possible for Southern Brown Bandicoots to consume enough of these baits to receive a lethal dose, despite their elevated tolerance. However, this would depend on the palatability of the bait used (McIlroy 1983). It has been considered unlikely that bandicoots would consume enough oat grains required to ingest a lethal dose (DEH 2005). Oat baits can also be dyed to further reduce their attractiveness to bandicoots (McPhee and Bloomfield 2004). There is also a risk of secondary poisoning to domestic pets, with the use of 1080, stemming from the possible consumption of poisoned rabbit carcasses. Measures to minimise this risk should be carefully considered, particularly in semi-rural or urban areas. These risks are minimised when Pindone is used instead, because of the availability of an antidote. However, bandicoots have been killed by Pindone in Western Australia (Twigg et al. 1999), and its use is generally not recommended in close proximity to bandicoots. To reduce this risk, baits should be laid away from vegetation edges. The risk to birds of prey from secondary poisoning due to consumption of rabbit carcasses is generally low. Wedge-tailed Eagles would have to consume twice their body weight, at a time, in rabbit carcasses to receive a lethal dose (Platt 1999). However, care should be taken to remove rabbit carcasses following poisoning campaigns.

Baiting is most effective during late summer and autumn, when rabbit breeding is minimal and populations are at their base levels. This reduces rabbit numbers before the peak breeding season, reducing the number of breeding females. Regardless of the poison used, livestock should be prevented from potentially accessing baits. Baiting rates should be in accordance with rabbit numbers as determined beforehand.

Fumigation and destruction of warrens

Warrens can be fumigated with a variety of toxins. These include: Gastoxin and Phostoxin tablets, placed deep inside each entrance to the warren before being filled and sealed with soil; chloropicrin gas pumped through warrens with a pressure fumigator; and carbon monoxide. It is advisable to destroy warrens by ripping with machinery, approximately two to three days after fumigation. Revegetation of destroyed warrens will minimise the potential for weed invasion.

Before the fumigation or destruction of any rabbit warrens, it is vital to ensure that burrows are not occupied by bandicoots or other native fauna.

Fumigation is typically carried out in autumn and winter. Monitoring should be conducted to detect new warrens, and re-opened warrens should be fumigated. This follow up work is important for the success of this method.

Shooting

Shooting has been shown to be a successful and cost effective technique for controlling remaining rabbits, when other methods have been used beforehand.

Action 6.3: Implement the European Rabbit control program developed in Action 6.2 concurrently with the Red Fox control program

This management plan recommends the simultaneous control of Red Fox and European Rabbit populations, to prevent a population explosion of rabbits induced by lower densities of the Red Fox. Fox control can lower predation pressures on European Rabbits, allowing a rapid amplification of rabbit numbers. This not only increases habitat degradation but can also seriously set back revegetation efforts. It can also facilitate an increase in fox numbers, once fox control is reduced, increasing the secondary predation pressure on bandicoots. Even when only the 'doomed population surplus' of rabbits is removed, rabbits are able to maintain fox densities well above levels sustainable by native mammals, due to their exceptionally high and potentially continuous reproductive rate.

Equally, rabbit control should not be undertaken independent of fox control. Foxes are opportunistic predators, and low rabbit numbers can lead to prey-switching by foxes, where bandicoots are consumed in greater numbers as their preferred prey, European Rabbits, decline. This can cause a decline in bandicoots as it is unlikely that rabbit numbers will fall below bandicoot numbers. However, in the long term, smaller rabbit populations should lead to a reduction in fox numbers.

9.3.3 Objective 7: Reduce predation pressures by domestic and feral cats and dogs

Feral or wild dogs are probably uncommon in the Koo Wee Rup Swamp area, however, domestic dogs as well as domestic stray and feral cats, can pose a threat to bandicoots, particularly if rabbit numbers are high. Due to the urbanised nature of portions of the study area, the numbers of domestic or stray cats and dogs are potentially high. A bandicoot most likely killed by a cat was recently found at Yallock Creek, Bayles (see Appendix 5).

Action 7.1: Determine the presence and abundance of feral cats in the former Koo Wee Rup Swamp area

The level of threat currently posed by feral cats to the Southern Brown Bandicoot in the former Koo Wee Rup Swamp area can only be determined once their abundance is clarified. However, a predator control program should take into account predation pressures of feral cats as their numbers can be potentially high when there is an abundance of rabbits. They can show the same

predator-prey interactions with rabbits as foxes, and their numbers can increase when fox populations decline. If there is a concurrent decline in rabbits, this can increase the predation pressure of cats on native mammals (Smith and Quin 1996). Although the impacts of predation by feral cats on native mammals is thought by many to be less than that of Red Foxes (May and Norton 1996, Smith and Quin 1996, Lechner 2006), it has been demonstrated that they can contribute significantly to local extinctions of native fauna (Smith and Quin 1996). Feral cats are most likely to prey upon juvenile bandicoots, and this has been cited as one of the factors responsible for the decline of the Eastern Barred Bandicoot. We recommend that the abundance of feral cats be determined so that their potential effects can be clarified.

Action 7.2: Undertake targeted control of feral cats if they are identified as a threat in the former Koo Wee Rup Swamp area

If feral cats are considered to constitute a threat to Southern Brown Bandicoots in the former Koo Wee Rup Swamp area, methods for their control should be integrated into the predator control program. Cage trapping is a commonly used method of feral cat control and has recently been undertaken at Point Nepean in 2006 (MPWBRF 2008). Pre-feed baiting without traps maximises trapping success. Tagged cats that are trapped can be returned to their owners, and untagged cats impounded. If they are determined to be feral, they are humanely destroyed.

Action 7.3: Enforce responsible pet ownership laws and implement curfews

Free roaming domestic cats and dogs, particularly during dawn and dusk, pose a threat to bandicoots in urban and semi-rural areas. Under the Domestic Animals Act, cats are required to be confined to the property of their owner at all times and dogs must be confined and secured to the backyard, unless walked on a leash. Failure to do this is an infringement of local laws and will incur a fine. Councils should develop and adopt further methods of enforcing these laws and consider implementing curfews between dawn and dusk.

Action 7.4: Devise an education program to raise awareness of responsible cat and dog ownership and the threats of domestic pets to Southern Brown Bandicoots

Many pet owners are unaware of the impacts of domestic animals on native wildlife, particularly bandicoots. An educational program promoting responsible pet ownership and the ways in which this can assist the conservation of Southern Brown Bandicoots is essential to change attitudes towards the management of cats and dogs. Suitable avenues for the dissemination of information, such as pamphlets and flyers, radio, and local print media should be investigated. Educational material should clearly state the impacts of dogs and cats (even well fed pets) on native wildlife, and simple measures to reduce this threat including de-sexing, keeping pets indoors at night and building cat enclosures. Furthermore, the material should emphasise that confinement of pets is not cruel, and highlight the benefits of confining dogs and cats, such as reduced risk of road mortality, injury and infection through fighting.

9.4 Threat Abatement: Road mortality

The level of mortality to Southern Brown Bandicoots, caused by traffic in the former Koo Wee Rup Swamp area is not currently known, although in recent years, there have been several reports of bandicoot road kills, reported by locals in the Koo Wee Rup Swamp area. Road kills have been reported on major roads in Bunyip, Garfield, Cora Lynn and Pakenham South (David Nicholls and Rolf Willig pers. comm.). The urbanised nature of this area means that bandicoots are at a relatively high risk of road mortality. Adult males which typically move over larger distances and have larger home ranges, and dispersing juveniles are likely to be the demographics most affected by road mortality (DEH 2005).

9.4.1 Objective 8: Reduce road mortality

Action 8.1: Establish a mortality register for roads in the former Koo Wee Rup Swamp area to assess current impacts and mortality patterns

It appears that Southern Brown Bandicoots in the former Koo Wee Rup Swamp area make extensive use of roadside vegetation, so it is likely that measures to address road mortality are necessary. Recent road kills have been reported to the CEC by some interested locals, but this information is not currently kept in any official or centrally maintained database. Hence, it is difficult to determine where management efforts should be focused. More information is required on road mortality rates and high risk areas, before mitigation measures can be put into place. A road mortality register can be used to identify sites of frequent road mortality or mortality patterns which may be related to speed limits or seasons (e.g. breeding season or when juveniles disperse). The data may also yield additional information such as possible movement patterns of Southern Brown Bandicoots or important roadside habitats that require management. The register should include data on specimens such as age class, sex, and the presence of pouch young, whenever possible, to collect additional demographic data. This register should be maintained for the duration of this plan.

Action 8.2: Investigate need for road kill mitigation measures and implement where necessary

Data compiled in the road mortality register over the course of a year should be analysed to identify roads with a high mortality rate, which are in need of mitigation measures. The register may also identify trends in the data such as seasonal peaks in road mortality, reflecting greater movement by individuals during the breeding season or juvenile dispersal. Mitigation measures that could be considered include, low mesh fencing and underpasses to redirect bandicoots and other fauna away from roads, or speed limit reductions on major roads and identified trouble spots. Road mortality rates have been shown to be positively correlated with traffic volume and speed (Bennett 1991).

Action 8.3: Erect bandicoot warning signs on roads within and adjoining core habitats and on roads identified to be high risk in Action 8.2

Highly visible road signs should be installed along major roads and roads that have been identified from the mortality register as carrying a high risk, warning motorists of the presence of bandicoots. Road signs will hopefully make drivers more aware of bandicoots in the area and therefore, reduce the possibility of collision with bandicoots. We recommend that these signs also display a 'Help for Wildlife' number, so that assistance can be sought for injured bandicoots, with a view to their possible rehabilitation and release.

9.5 Habitat Enhancement and Revegetation: Habitat fragments and habitat links

Most native vegetation within habitat fragments or along habitat links in the former Koo Wee Rup Swamp area have been degraded (see Section 3 and 7) by weed invasion, rabbits and grazing by livestock. Areas which currently support suitable habitat for the Southern Brown Bandicoot can be improved with strategic weed removal together with supplementary plantings (following the removal of livestock grazing (Actions 4.1 and 4.2), as well as a reduction in rabbits (Action 6.2). Potential habitat links, which may currently support little bandicoot habitat can also be rehabilitated through plantings for bandicoot habitat restoration. Habitat enhancement and restoration projects should be developed and initiated in partnership with community groups which will help to increase community support and participation in on-ground works. Revegetation efforts should be carried out in accordance with the basic guidelines and by planting appropriate species, detailed in Section 13.

9.5.1 Objective 9: Increase habitat connectivity within the former Koo Wee Rup Swamp area through vegetation enhancement and rehabilitation

Action 9.1: Enhance vegetation along suitable habitat links identified in Figure 9

By assessing the current distribution records of the Southern Brown Bandicoot in the former Koo Wee Rup Swamp area, and assessing the suitability of vegetation along surrounding roads and watercourses, roads and riparian corridors with suitable vegetation that could feasibly provide a link between isolated patches of remnant vegetation were identified (Figure 9). Most of these links identified in Figure 9, support suitable habitat along most of their length, sufficient for providing some level of connectivity. Nonetheless, they require some habitat enhancement through supplementary plantings to improve the continuity, quality and density of the understorey vegetation, to improve their functionality as a habitat link. Therefore, revegetation efforts should be focussed where there are gaps in vegetation and where the understorey is sparse.

Action 9.2: Revegetate potential habitat links along watercourses identified in Figure 9

Several opportunities exist to increase habitat connectivity within the former Koo Wee Rup Swamp area by rehabilitating watercourses through targeted revegetation and habitat restoration. Some of the watercourses in the extensive network of creeks and drainage channels can provide direct links between clusters and patches of habitat. Riparian corridors that could provide feasible

links are also identified in Figure 9. Increasing the number of habitat links within the former Koo Wee Rup Swamp area can not only provide additional habitat but also increase the dispersal capabilities of the Southern Brown Bandicoot, facilitating genetic exchange and thereby increasing the viability of the clusters. Priority is given to the rehabilitation of natural (albeit modified) landscape corridors such as the creeks and drainage channels, as this not only increases the biodiversity values of the watercourses and habitat values for other species, but watercourses do not carry the same risk of mortality as roads. Creeks and drains also experience less human disturbances, such as traffic noise and rubbish. Preference should also be given to rehabilitating links that connect patches that are relatively close together over those that are farther apart. The effectiveness of linear corridors for dispersal depends on the distance the animal needs to traverse (Bennett 1990).

Melbourne Water is aiming to increase revegetation efforts along waterways, and the revegetation of Bunyip main drain has been identified as an action in the Melbourne Water River Health Strategy. The revegetation of other waterways in the region can be implemented in the operational management plan recommended for development by Melbourne Water.

Action 9.3: Revegetate potential habitat links along roads identified in Figure 9

Roadsides should be revegetated as a second priority due to inherent risks of road mortality, and the increases in disturbance due to traffic noise and rubbish. However, the continuity and extensive network structure of roads has been recognised as providing significant opportunities for retaining, expanding and enhancing wildlife habitats in disturbed environments (Bennett 1991). Furthermore, it appears that Southern Brown Bandicoots within the former Koo Wee Rup Swamp area already make extensive use of roadside vegetation. Road corridors identified in Figure 9 provide opportunities for a short or direct link between habitats and clusters and can provide a further opportunity for expanding the dispersal capabilities of bandicoots. Additional roadsides which may be identified as suitable in the future can be progressively revegetated as considered appropriate.

Action 9.4: Enhance vegetation along the South Gippsland Railway Line from Tooradin Station Road to Monomeith

The disused South Gippsland Railway Line provides core habitat and a likely a movement corridor for bandicoots in the Dalmore and Koo Wee Rup areas (and Tooradin, David Nicholls pers.comm.). Dense vegetation is fairly contiguous between Dalmore and Koo Wee Rup. However, there are various gaps in the understorey and informal paths created by trail bikes which would benefit from enhancement with supplementary plantings, followed by weed removal. Further to this, council should liaise with VicTrack, Pacific National and the Transport Minister to determine the railway's future use. The rail track can no longer feasibly function as a railway line. The best use for this habitat would be to secure and manage it for conservation, as a significant habitat corridor. We strongly recommend against the use of this corridor as a Rail Trail because of the further habitat loss and fragmentation this is likely to incur, and the significant impacts this and other human disturbances are likely to have on Southern Brown Bandicoots in the former Koo Wee Rup Swamp area (TransNet 2007). Loss of vegetation along the railway line, particularly between Dalmore and Koo Wee Rup would fragment the population and greatly reduce its viability. If

possible, the track should be dismantled and the area revegetated, to enhance and protect this area of core habitat for the Southern Brown Bandicoot. This could be promoted as a major community project and used as a public education tool.

9.5.2 Objective 10: Enhance known and potential habitats

Action 10.1: Enhance existing core habitat and other habitat patches through targeted revegetation and restoration

Areas of core habitat and other habitat patches identified in Figures 7 and 9 can be enhanced to reduce the impacts of degradation, with supplementary plantings followed by staged weed removal. These actions are intended to improve the overall habitat quality of these areas through improving the habitat structure and increasing the density of understorey vegetation to provide protection and shelter for the Southern Brown Bandicoot.

Action 10.2: Revegetate disused and informal tracks in remnants of known and potential habitat

Several areas of potential habitat such as Lang Lang Bushland Reserve and remnant vegetation patches at Yallock Creek have many informal tracks created by four wheel drive vehicles and trail bikes (Appendix 3, Plate 11). There are also many wider tracks which have fragmented the habitats, facilitated access by vehicles and promoted weed invasion. The rehabilitation of these tracks with plantings of native vegetation would increase the quality of habitat and decrease further weed invasion.

9.5.3 Objective 11: Enhance habitat connectivity to outside of the former Koo Wee Rup Swamp area

Action 11.1: Collaborate with stakeholders and government agencies outside the former Koo Wee Rup Swamp area to develop bio-links to Cranbourne, Drouin, Quail Island and Wonthaggi (Table 8) to increase connectivity between populations in these areas and the former Koo Wee Rup Swamp area

A recent population viability analysis of Southern Brown Bandicoots within Casey, Cardinia, Frankston and Mornington Peninsula local government areas suggested that creating vegetated habitat links between bandicoots in the outer south-eastern suburbs and larger populations such as at the Royal Botanic Gardens Cranbourne, are necessary to increase the long-term viability of local populations of Southern Brown Bandicoots (Southwell 2006, Southwell et al.2008).

Various biolinks have been proposed to connect habitat at the Cranbourne Royal Botanic Gardens (RBGC) with the former Koo Wee Rup Swamp area (Section 8.3). A habitat link to RBGC is considered the most important habitat link for Southern Brown Bandicoots beyond the former Koo Wee Rup Swamp area (Figure 7). Such a link would provide opportunities for genetic exchange to increase the viability of populations and reduce the risks inherent with small populations (see Appendix 2), as well as providing additional habitats and an opportunity for range expansion.

Casey City Council, Cardinia Shire Council and DSE should make efforts to provide their support and co-operation for a biolink by making amendments to planning schemes so that areas within the proposed corridors are protected. Planning controls should reflect the objectives of retaining remnant vegetation along the proposed biolinks. Efforts should also be made to consult private landholders in areas where links are proposed and consultation with the RBGC and planning authorities such as the GAA is essential. The disused South Gippsland Railway Line between Cranbourne and Koo Wee Rup provides an excellent opportunity for a biolink as it already supports relatively continuous remnant vegetation along much of its length, is already used by bandicoots, and can no longer carry rail traffic. If the rail track was removed and the area rehabilitated, this could be managed as a significant bio-link for the conservation of a variety of native species as well as the bandicoot. However, all options require further investigation.

The Garfield - Longwarry population cluster is presently thought to be a self-sustaining population (Rolf Willig pers. comm.). However, with increasing urbanisation and development expansion, this area is likely to undergo habitat loss and fragmentation which will significantly threaten the continued viability of this population. Therefore, measures to increase habitat connectivity between this area and Drouin may be important as a means of retaining the viability of the cluster by allowing dispersal and range expansion (also see Section 8.3, Table 8 and Figure 7). A habitat link between the Garfield- Longwarry population and Drouin would possibly follow the Melbourne – Sale Railway line. Habitat loss has recently occurred along this corridor for the installation of fast train signalling however, vegetation along the railway line is currently known to support bandicoots. Cardinia and Baw Baw Shire Councils must collaborate to ensure that vegetation loss and fragmentation along this corridor are limited and that initiatives can be set in place to protect, enhance and revegetate vegetation along this link.

A link from Tooradin to Quail Island should also be investigated by Casey City Council. Quail Island supports a significant amount of suitable habitat for bandicoots and in time, may function as an important breeding refuge for the species. Consideration of biolinks to Wonthaggi could be made once the status of bandicoots in Lang Lang has been clarified (Table 8).

9.6 Further research

There is an evident lack of knowledge concerning the specific ecology and biology of Southern Brown Bandicoots in the former Koo Wee Rup Swamp area. Very little work has been done to date investigating bandicoots in outer Melbourne, and of the research that has been previously carried out in the forme Koo Wee Rup Swamp area, there have been no comprehensive, field based surveys. As a result, little is known of specific distribution, population ecology, demographics, genetics, habitat use and the effects of land use changes on bandicoots in this region. Furthermore, the mechanisms facilitating persistence of bandicoots in the area is not clear and is currently only the subject of speculation.

Most research concerning bandicoots in Victoria has been conducted at Cranbourne, however, the applicability of this situation to other areas of south-east Melbourne is limited, considering the differences in habitat, land use and urbanisation.

9.6.1 Objective 12: increase knowledge of the distribution, abundance and ecology of Southern Brown Bandicoots in the former Koo Wee Rup Swamp area

Action 12.1: Develop research partnerships with higher education or research institutions to carry out research projects on bandicoots in the former Koo Wee Rup Swamp area

To increase the knowledge of Southern Brown Bandicoots in the former Koo Wee Rup Swamp area, intensive field based research needs to be carried out. These studies would be suitable for post graduate or undergraduate research projects undertaken in educational institutions. Support can be provided to these institutions through funding or the provision of logistical or technical support. Inclusion of these projects into research partnerships with Parks Victoria and Department of Sustainability and Environment is also advocated. Key aspects that need to be addressed are outlined below.

Action 12.2: Conduct surveys to determine the distribution, extent and abundance of Southern Brown Bandicoots in the former Koo Wee Rup Swamp area

No comprehensive, broad-scale surveys of Southern Brown Bandicoots have been carried out in the former Koo Wee Rup Swamp area. Understanding of the current distribution of bandicoots in this region has been derived primarily from incidental observations by public and through targeted surveys in various small parts of the region. As a result, knowledge of distribution, range and status of populations in this area is patchy and poorly known. Current distributional data provide no indication of overall abundance, population size, density or extent of range. Broad-scale comprehensive surveys of the former Koo Wee Rup Swamp area will help to clarify this and may identify further populations which require management. In particular, intensive survey effort is required in Lang Lang, where there is a lack of recent records despite much suitable habitat remaining. The results of this study in addition to current observational records will help to better manage existing populations, and can provide further direction on which populations or areas may require more intensive management. Results of this survey should be entered into the database of records in the south-central district, maintained by Gippsland Office DSE.

Action 12.3: Carry out research to determine population demographics, dynamics and life history characteristics of Southern Brown Bandicoots in the former Koo Wee Rup Swamp area

A broader understanding of the ecology and critical mechanisms allowing bandicoots to persist in an altered landscape is required to better manage populations in the former Koo Wee Rup Swamp area. Information is required on current life history characteristics of bandicoots in the region including reproduction, fecundity, breeding success, juvenile dispersal, population demographics and mortality. This information is currently lacking. Levels of dispersal are also unknown. It is not clear if Southern Brown Bandicoots in the region are a metapopulation or if population clusters are discrete. However, connectivity between population clusters is possibly a critical element of bandicoot persistence in the former Koo Wee Rup Swamp area and further scientific direction is required in this area.

Action 12.4: Carry out research to determine habitat use and micro-habitat preference by Southern Brown Bandicoots in the former Koo Wee Rup Swamp area

While there is some knowledge of habitats known to support bandicoots in the area, there is currently no understanding of habitat use patterns and the extent and way in which anthropogenic environments are utilised by bandicoots in urban and semi-rural areas. The habitat use and function of roadside remnants and riparian corridors is also unknown. It is unclear as to whether these environments are used as breeding habitat or dispersal and foraging habitat. A better understanding of the way in which these habitats are used would provide scientific direction as to the different ways in which various habitats should be managed. Information on home ranges should also be acquired to promote an understanding of how fragmented habitats are used and the minimum area of habitat required to sustain an individual.

Action 12.5: Conduct a study to investigate the genetic diversity and genetic structure of Southern Brown Bandicoot populations in the former Koo Wee Rup Swamp area

This research should determine the genetic diversity and structure of bandicoots within the former Koo Wee Rup Swamp area and should be carried out in a way that enables results of this study to be compared to genetic diversity elsewhere, including the population at Cranbourne. This study may also determine whether there is currently any movement between individuals at Cranbourne and the former Koo Wee Rup Swamp area. Fragmentation and isolation may have altered the genetics of this population. Their level of genetic similarity should be determined to investigate possible dispersal and genetic exchange between clusters. To maximise the amount of genetic data available for this study, genetic material should be collected as standard from all animals live trapped in the above studies, or from collected dead specimens with detailed records of these animals kept, and the materials appropriately stored.

Action 12.6: Support research into the possible effects of drought and climate change on Southern Brown Bandicoot habitat and survivorship in the former Koo Wee Rup Swamp area

The possible effect of drought and climate change on bandicoots is purely speculative at present. However, predicted impacts may severely affect the survivorship of the species. Research into these impacts should be supported and more information may help to manage habitats for future changes.

Action 12.7: Evaluate the feasibility of creating artificial dens for Southern Brown Bandicoots and investigate their likely effectiveness and use by bandicoots in urbanised areas

The extent to which Southern Brown Bandicoots use anthropogenic environments and structures is currently unknown, though it appears that these environments play an important role in allowing bandicoots to persist in altered environments. In the former Koo Wee Rup Swamp area, many records of the Southern Brown Bandicoots are centred within townships, and residents have reported bandicoots living in car bodies, sheds and under scrap woodpiles in backyards and under houses. Artificial den structures, similar in principle to nest boxes for arboreal mammals may help to ameliorate the effects of habitat loss from urbanisation and may provide a degree of protection

against predators. Investigations into the effectiveness of such structures should consider designs that prevent pest animals from utilising them.

9.7 Community Awareness and Education

Community involvement and support are essential for the conservation of the Southern Brown Bandicoot to be successful in the former Koo Wee Rup Swamp area. Members of the community share a responsibility to manage the protection of bandicoots and their habitat, with many bandicoots occurring on private residential and agricultural land. The persistence of the bandicoot in these areas relies on the community's co-operation in retaining, managing and revegetating suitable habitats, controlling predators and pests and reducing threats of domestic animals. Informing the community on ways to do this and the benefits of these actions is fundamental. The level of support for the conservation of bandicoots will determine the level of community involvement.

9.7.1 Objective 13: Increase public profile of Southern Brown Bandicoots and their conservation status in the former Koo Wee Rup Swamp area

Action 13.1: Educate the community on the conservation status, the importance and benefits of retaining the Southern Brown Bandicoot

A relatively high level of community awareness surrounding the Southern Brown Bandicoot already exists in some areas within the former Koo Wee Rup Swamp area (e.g. Cardinia and Bunyip), although perhaps to a lesser extent in other areas. The species needs to attract greater interest and sympathy for community involvement to increase. This can be done in simple yet effective ways: school programs; fact sheets, pamphlets and posters distributed to local community groups and libraries; coverage in the local media; and web pages can all play a role in increasing the public profile. Information should be aimed at increasing awareness of the threatened status of the bandicoot, their drastic decline and the role of past and present human activities in this decline. Education campaigns should also inform the public of the significance of the former Koo Wee Rup Swamp population in the context of bandicoots in greater Melbourne. It is also important to highlight why and how retaining small mammals benefits ecosystem health and the community, including: the dispersal of hypogeal fungi and seeds and pollination, important for vegetation health; soil aeration; consumption of pasture grubs; and nutrient recycling.

Action 13.2: Design and install uniform signage for conservation reserves to promote awareness of Southern Brown Bandicoot habitats

All conservation reserves (e.g. Bayles Fauna Reserve and Bandicoot Corner) and core habitat should have uniform, interpretive signage, alerting visitors to the presence of bandicoots and increasing their awareness of the conservation significance of bandicoots and these reserves as important habitats for the species. The signs should be clear and informative, describing simple aspects of the ecology and conservation requirements of the Southern Brown Bandicoot. The signage must also remind people to take their rubbish with them, to take care of the native

vegetation at the reserve, and importantly, to remind people of the importance of closing gates when necessary. Similar signage should be erected along roadsides, identified in this plan or in future, as habitat links.

9.7.2 Objective 14: Encourage community participation in the conservation of the Southern Brown Bandicoot

Action 14.1: Compile and distribute simple guidelines and facts about ways individual landholders can help the Southern Brown Bandicoot on their land

Devise a simple fact sheet or pamphlet on ways to encourage the persistence of bandicoots on private land which can be targeted to both agricultural and urban areas. The educational pamphlet should include tips such as retaining understorey vegetation, replanting dense vegetation, and explain the importance of retaining remnant vegetation with an understorey layer, and of responsible pet ownership. Giving the community a basic understanding of the habitat requirements and threats of the species can assist all landholders in encouraging the Southern Brown Bandicoot on their land, to support overall conservation efforts on private land. Explanations of the signs of bandicoot presence such as diggings may also alert previously unaware landholders to the presence of bandicoots on their property. The pamphlet should also list ways to become involved in conservation initiatives and provide a phone number for obtaining further information and guidance for any of these activities, and contacts for community groups.

Action 14.2: Establish a 'Friends of' group for Southern Brown Bandicoots in the former Koo Wee Rup Swamp area

Establish a 'Friends of the Southern Brown Bandicoot group' to co-ordinate conservation activities with the various other community groups, and to discuss new conservation initiatives. This group will have a major role in community involvement projects (e.g. planting or revegetation days, information days and school programs) and be active in involving the wider community in on-ground management activities. Members of this group should be educated on the ecological and biological requirements of this species and trained in recognising signs of bandicoot presence (i.e. diggings and scats) and receive technical support and training in land management, revegetation and vegetation monitoring.

Action 14.3: Involve community groups and increase participation by the wider community in on-ground management actions for the Southern Brown Bandicoot

Community participation in conservation activities through schools and community groups is valuable in assisting with on-ground management actions and conservation initiatives for the Southern Brown Bandicoot, such as habitat enhancement or restoration activities (see section 9.5). Invitations to the community to participate can be made through schools, local media avenues, websites and adverts in libraries or other places of public assemblage. Involving the community in on-ground management actions increases public awareness and appreciation of natural values, reserves and native wildlife by offering the community a sense of ownership over the programs. Participants should be provided with technical support and assistance by trained land managers

during these activities. Interested individuals should also be trained in identifying bandicoot diggings so that they can assist with monitoring and reporting changes in bandicoot presence and absence in their local area, or around their home.

9.8 Habitat Creation and Extension

Habitat for Southern Brown Bandicoots in the former Koo Wee Rup Swamp area is presently limited to small fragmented patches and remnant strips along watercourses and roads. Roadside and riparian corridors provide the most extensive habitats, and while these corridors may be used for dispersal through the landscape, it is not known if the species is capable of persisting within these narrow strips. Few species are likely to be capable of maintaining long-term viable populations within narrow strips of vegetation in the absence of nearby patches of suitable habitat (Bennett 1988). There is currently no evidence to suggest that bandicoots utilising such corridors are capable of this in agricultural landscapes at Portland or Naringal (Bennett 1990, Rees and Paull 2000). However, in the absence of little other habitat in the former Koo Wee Rup Swamp area, it seems likely that bandicoots are able to persist in at least some of the wider corridors (e.g. Cardinia drains). If this is true, how long they are capable of persisting is also unclear.

To ensure the long term viability of Southern Brown Bandicoots in the former Koo Wee Rup Swamp area, additional habitats are required. The amount of habitat currently available seems unlikely to be capable of accommodating any increases in population. If all threats are managed and minimised, then the potential for bandicoot numbers to recover is only limited by the amount of habitat available. Suitable habitat must be created to accommodate a potential increase in population size, and facilitate range expansion (see Figure 9).

9.8.1 Objective 15: Increase the amount of habitat available to Southern Brown Bandicoots in the former Koo Wee Rup Swamp area

Action 15.1: Increase the area of suitable habitat for the Southern Brown Bandicoot through habitat restoration on public land focused around core habitat and habitat links

The 2002 Cardinia Shire Native Vegetation Policy aims to achieve a net 10 % increase in indigenous vegetation, and habitat for the Southern Brown Bandicoot should be included as part of this target. Areas of public land identified in Figures 8 and 9 are suitable candidates for habitat restoration activities. Restoring habitat adjacent to core habitat provides the opportunity to increase the viability of critical habitats (see Figure 9). The network of waterways and roadsides is already a good means of facilitating range expansion and an increase in habitat. These corridors not only provide connectivity but are also under public land tenure, and the opportunity exists to increase the width and overall size of these habitats, to the edge of the Crown land boundary. In particular, the amount of cover and vegetation along watercourses surrounding the small mammal refuges should be increased so that animals dispersing in and out of these enclosures are afforded some degree of cover. This will reduce their predation pressure so that they may disperse out of or into the enclosure effectively.

Action 15.2: Increase the area of suitable habitat for Southern Brown Bandicoots through habitat restoration on private land

Current distribution records of Southern Brown Bandicoots in the forme Koo Wee Rup Swamp area indicate that bandicoots have effectively dispersed throughout the agricultural matrix. However, their ability to persist in limited habitat within the agricultural matrix is not clear. Encouraging landholders to revegetate cleared areas of land can help in increasing overall habitat for Southern Brown Bandicoots throughout the former Koo Wee Rup Swamp area, and assisting in mitigating impacts of habitat loss and fragmentation. Council should make available to landholders, information on the habitat structure and composition required to restore habitat for Southern Brown Bandicoots, as well as guidelines for the revegetation process and the appropriate species to be planted for different EVCs. These are outlined in Section 13. Incentives for encouraging locals to revegetate areas of their land may be offered in the form of technical and monitoring support, provisions of tube-stocks for revegetation or rates rebates to landholders who undertake revegetation. Support from local community groups such as Landcare should be encouraged. This action could be integrated with Action 14.1. In particular, landholders with freehold riparian land should be encouraged to focus their revegetation around watercourses. Council may advise landholders and provide direction on where to revegetate in order to maximise the connectivity of revegetated land, including the best size and shape of patches. Locals can also be encouraged to invest in the *'Spirit of the Bunyip'*, scheme, through widespread promotion.

Action 15.3: Develop and implement a revegetation and management strategy to rehabilitate a habitat link to Lang Lang along the South Gippsland Railway Line from Monomeith to Lang Lang

Large areas of potential habitat in the Lang Lang, Nyora and Heath Hill areas are currently isolated from Southern Brown Bandicoot habitat elsewhere in the former Koo Wee Rup Swamp area. Although there are no recent records in these areas, there are several unconfirmed reports of Southern Brown Bandicoots near the Lang Lang Golf Course and Educational Area (David Nicholls pers. comm.), The Gurdies (Rolf Willig pers. comm.) and GMH Proving Ground (Terry Coates pers. comm.). The disused South Gippsland Railway Line provides a good opportunity to develop a habitat link between Lang Lang and the rest of the former Koo Wee Rup Swamp area (see Section 8.3, Figure 9). Council should liaise with VicTrack to investigate the future use of this section of track as a vegetated conservation corridor. It is possible that the extinction of local populations at Lang Lang were advanced by the lack of connectivity to other populations within the former Koo Wee Rup Swamp area. A vegetated corridor may facilitate range expansion into Lang Lang and provide the opportunity for bandicoots to utilise these large areas of suitable habitat. If possible the disused railway should be dismantled and revegetated with appropriate indigenous species. Habitats within Lang Lang should continue to be monitored for the presence of bandicoots following the rehabilitation of a habitat link. If bandicoots are found to (re)utilise habitats within Lang Lang, a strategic plan for their management and protection should be produced.

Action 15.4: Investigate the possibility of Southern Brown Bandicoot reintroduction to suitable habitats in Lang Lang and develop a management plan

As identified in Section 8, large areas of potential habitat are present within Lang Lang, and it is not definitively known whether bandicoots still occur in these areas. If comprehensive surveys as recommended in Action 12.2 conclude bandicoots no longer occur in these areas, investigations into the species reintroduction should be made.

A suitable management plan should be developed prior to any reintroduction efforts taking place. The management plan should ensure that there is no further loss of habitat and that large areas of potential habitat are secured for conservation. Threats from the extractive sand industry must also be addressed in this plan. Predator control undertaken prior to reintroduction and ongoing control will also be paramount. The management plan would also consider aspects such as hard or soft release options and monitoring of populations prior to, during and after release.

Management Priority

The above management objectives and actions are summarised in Table 9, together with priorities, performance targets, timing, monitoring of actions and management responsibilities. The table should be used in conjunction with the rest of this management plan, with particular reference to Section 9.

Management of threats are given a priority rating of low, medium or high based on a similar risk assessment approach developed by Natural Resources and Environment (NRE 2002). This approach is based upon: (1) identifying Southern Brown Bandicoot life history traits and habitat characteristics and the threats to these values; (2) relating the threats to the values by ordering the threats according to the number of values that are impacted; (3) determining the extent or coverage of each threat (e.g. one cluster, a number of clusters and habitat links, or the entire former Koo Wee Rup Swamp area); (4) assessing any temporal variation in the threat; and (5) analysing the impact of the threat in terms of current and past trends. The final step is to take into account the extent, impact and past trends of the threat to develop a threat rating (low = 1; medium = 2; high = 3). Thus, the assessment of threats enhances the understanding of the relationship between Southern Brown Bandicoot life history traits, habitat characteristics and threats, and provides a framework for prioritising resources to manage the threats.

The proposed management actions are given a priority rating according to their ability to address the threats identified for the Southern Brown Bandicoot in the former Koo Wee Rup Swamp area. Management actions are prioritised in a similar fashion to a scoring scheme developed by Weston (2002). A total score is derived using four criteria (listed below) with higher scores requiring a higher priority for actions.

Actions are therefore prioritised in terms of:

1. the threat being addressed (low = 1; medium = 2; high = 3);
2. the site specificity i.e. is the action likely to benefit a smaller part of the area (e.g. one cluster, score = 1), a moderate proportion of the area (e.g. a number of clusters and habitat links, score = 2), or the entire former Koo Wee Rup Swamp area (score = 3);
3. the number of values being benefited (1= 1, 2= 2, 3= 3); and
4. the likelihood of achieving a favourable outcome if the action is implemented (low = 1; medium = 2; high = 3).

These essentially follow the prioritisation of management actions outlined by NRE (2002), as follows.

Higher (3) = actions, that when implemented, will significantly contribute to the maintenance and enhancement of the Southern Brown Bandicoot population in the former Koo Wee Rup Swamp area

Medium (2) = actions, that when implemented, with Higher priority actions will support the maintenance and contribute to the enhancement of the Southern Brown Bandicoot population in the former Koo Wee Rup Swamp area

Lower (1) = actions that when implemented in conjunction with Higher and Medium priority actions will enhance the Southern Brown Bandicoot population in the former Koo Wee Rup Swamp area.

The Southern Brown Bandicoot Management Committee, responsible for the implementation of this strategic plan will engage an assessor to evaluate the success of this management plan five years from its inception, and to make further recommendations for continued management. Monitoring and review for each of the actions in the management plan is outlined in Table 9. The committee will be responsible for ensuring monitoring and review of actions is undertaken.

A number of elements of this management plan will also contribute the broader conservation aims of the Cardinia Shire and City of Casey, such as revegetation efforts to increase the amount of native vegetation, and the protection and enhancement of waterways.

Table 9 Southern Brown Bandicoot Strategic Management Plan: Summary of management objectives, actions, performance targets, monitoring, responsibility and potential contributors

Objective		Management Action	Priority	Performance criteria/targets	Timing and frequency	Duration and timeframe	Monitoring	Responsibility/potential contributors
1	Secure known and core habitat and important links for conservation	1.1 Revise local planning schemes to ensure core habitats and habitat links identified in Sections 7 & 8 (Figure 8) are secured and protected for conservation	**3 (Higher)**	• Amendment to the local planning schemes to define, develop and implement a specific Southern Brown Bandicoot Overlay as a schedule of an ESO • Core habitats, habitat links and other known habitats identified are protected by the overlay	• Initiate development at commencement of this plan • Integrate into the planning scheme within 12 months	• For the duration of the management plan	• Review progress of amendments 6 monthly • Review efficacy within 2 years of overlay implementation	Cardinia Shire Council, DSE
2	Avoid future habitat loss and fragmentation	2.1 Avoid slashing and the removal of roadside vegetation when not essential and prevent vegetation slashing along important roads identified in Figure 8	**1 (Lower)**	• Reduction in the loss of roadside vegetation and evidence of regeneration along roadsides where slashing has ceased • No evidence of slashing along important roads	• Cease slashing along identified roadsides within 6 months	• For the duration of the management plan	• Assess the condition and extent of regeneration every 6 months and ensure that it does not pose a fire risk	Cardinia Shire Council, Vic Roads, Contractors for Shire maintenance
		2.2 Cease vegetation slashing and clearance along waterways	**2 (Medium)**	• No evidence of slashing along waterways • Evidence of regeneration along watercourses • Development of a Operational Management Strategy by Melbourne Water	• Cease slashing at implementation of this plan	• For the duration of the management plan	• Assess condition and extent of regeneration every 6 months • Ensure that vegetation growth does not pose a fire risk or jeopardise other biodiversity values	Melbourne Water, Cardinia Shire Council
		2.3 Ensure that informed planning decisions and environmental assessments are made where proposed developments have the potential to impact upon Southern Brown Bandicoot habitat	**3 (Higher)**	• Correct procedures are followed for environmental assessments and requirements under the EPBC Act are fulfilled • All development proposals potentially impacting on Southern Brown Bandicoots are referred to DEWHA (see Section 11) • Further loss of Southern Brown Bandicoot habitat is minimised or avoided	• All proposals	• For the duration of the management plan	• Monitor every 6 months that the correct procedures have been followed with reference to the guidelines presented in this management plan • Annually review success of EPBC Referrals process in halting/minimising clearance of Bandicoot habitat	Cardinia Shire Council, Melbourne Water, DSE
3	Increase protection of remnant vegetation on private land	3.1 Implement a Southern Brown Bandicoot Overlay in areas of private land with significant remnant vegetation	**3 (Higher)**	• Southern Brown Bandicoot overlay implemented	• Once • Investigation within 6 months	• Integration into the planning scheme within 12 months	• Review progress every 6 months • Review efficacy within 2 years of overlay implementation	Cardinia Shire Council, DSE
		3.2 Extend the coverage of Vegetation Protection Overlays on private land to increase protection of native vegetation remnants	**3 (Higher)**	• Vegetation Protection Overlays on private land reviewed and extended	• Vegetation Protection Overlays extended within 12 months	• For the duration of the management plan	• Review progress within 6 months • Annually review efficacy of vegetation protection	Cardinia Shire Council, DSE
		3.3 Continue to provide incentives for landholders to retain and manage remnant vegetation on private property	**2 (Medium)**	• Development of new initiatives and revision of existing initiatives to encourage landholders to retain remnant vegetation • Evidence of an increase in the number of landholders protecting remnant vegetation on their land	• Ongoing	• For the duration of the management plan	• Review community support for incentives and success of these incentives	Cardinia Shire Council, CEC, DSE, DPI, Melbourne Water
		3.4 Continue to promote schemes to secure private land parcels of remnant vegetation for conservation	**1 (Lower)**	• An increase in the number of landholders maintaining landholder agreements • Evidence of an increase in conservation covenants to protect native vegetation on private land	• Ongoing	• For the duration of the management plan	• Review community support for conservation schemes and their success	Cardinia Shire Council, CEC, DSE, DPI, Melbourne Water, Trust for Nature
4	Protect and enhance the integrity of remnant vegetation from degradation	4.1 Cease livestock grazing in riparian Crown land parcels and prevent stock access to riparian remnant vegetation	**3 (Higher)**	• Grazing leases on riparian Crown land parcels discontinued • Watercourses fenced off from livestock after removal of grazing • Increase in the density of understorey vegetation	• Discontinuation of leases as soon as possible or when leases expire	• For the duration of the management plan	• Annual monitoring of vegetation regeneration to ensure that it does not pose a fire risk and is compatible with other biodiversity values	Melbourne Water
		4.2 Discourage livestock grazing in vegetation remnants on private property and encourage landholders to fence vegetation remnants from livestock	**1 (Lower)**	• Evidence of an increase in the number of vegetation remnants on private property that are fenced off from livestock	• Ongoing	• For the duration of the management plan	• Review community support within 12 months and efficacy of fencing in providing protection of remnant vegetation	Cardinia Shire Council
		4.3 Continue to implement the Shire of Cardinia Weed Control Strategy and integrate actions for staged weed control	**1 (Lower)**	• Modification and implementation of the Cardinia Weed Control strategy to include staged weed removal techniques	• Initiate within 12 months	• For the duration of the management plan	• Monitor every 6 months the effects of staged weed removal and plant growth	Cardinia Shire Council, DSE, DPI, Private landholders
		4.4 Provide funding and other incentives for strategic revegetation and follow-up weed control on private property	**1 (Lower)**	• Increase in the number of landholders participating in revegetation and weed control efforts	• Ongoing	• For the duration of the management plan	• Monitor every 6 months revegetation and the effects of stated weed removal	Cardinia Shire Council, Melbourne Water, Private Landholders
		4.5 Fence-off reserves and other remnant vegetation in known and potential habitat to prevent access by trail bikes and other vehicles	**1 (Lower)**	• Fences erected and decreased use of vegetation remnants by trail bike riders and other vehicles • No evidence of newly created tracks	• Initiate at implementation of management plan	• For the duration of the management plan	• Monitor every 6 months reserves for evidence of use by trail bikes and other vehicles	Cardinia Shire Council
		4.6 Develop a community education program to promote active	**1 (Lower)**	• Decrease in incidences of rubbish dumping • Distribution of educational material and installation of	• Initiate at implementation of management plan	• For the duration of the management plan	• Annually monitor the condition of reserves and riparian corridors to	Cardinia Shire Council, Melbourne Water, 'Friends'

Objective		Management Action	Priority	Performance criteria/targets	Timing and frequency	Duration and timeframe	Monitoring	Responsibility/potential contributors
		stewardship of reserves, waterways and remnant vegetation		interpretive signs in reserves and along watercourses			determine the effectiveness of education programs	groups and other community groups
5	Reduce the predation pressures of Red Foxes	5.1 Determine the abundance and density of the Red Fox in the former Koo Wee Rup Swamp area	**3 (Higher)**	• Estimate of the number and density of Red Foxes in the former Koo Wee Rup Swamp area	• Initiate at implementation of management plan	• Within 12 months	• Annually review data collected	Cardinia Shire Council, Melbourne Water, DPI, DSE, Parks Victoria, local landholders
		5.2 Develop a broad-scale integrated Red Fox control program	**3 (Higher)**	• Integrated control program developed • Process for establishing co-operation between agencies • Commitment to an official pest control program	• Once, initiate at implementation of management plan	• Within 12 months	• Review progress of program development after first 12 months	Cardinia Shire Council, Melbourne Water, DPI, DSE, Parks Victoria, local landholders
		5.3 Implement the Red Fox control program developed in Action 5.2	**3 (Higher)**	• Baseline estimates of bandicoot abundance • Implementation of the program • Significant reduction in the number of foxes and increase in numbers of bandicoots • Comparisons of fox abundance to baseline data will show trends in decline if control is effective in reducing fox numbers	• Fox counts to be undertaken twice yearly in autumn and spring • Fox abundance and baiting rates are to be reviewed annually	• For the duration of the management plan	• Annually monitor the response of Southern Brown Bandicoot populations to fox control	Cardinia Shire Council, Melbourne Water, Parks Victoria, DSE, DPI
		5.4 Protect core habitat with predator-proof fencing and the creation of small mammal refuges	**3 (Higher)**	• Installation of appropriately designed predator-proof fences	• Initiate at implementation of plan • Ongoing as required	• For the duration of the management plan	• Monitor fence regularly for maintenance and upgrade when necessary. Monitor the use of release gates by bandicoots	Cardinia Shire Council, Melbourne Water, DSE, Community groups
6	Reduce the degradation impacts and control populations of the European Rabbit	6.1 Determine the density of the European Rabbit in the former Koo Wee Rup Swamp area	**3 (Higher)**	• Estimate the number and density of European Rabbits in the former Koo Wee Rup Swamp area • Evaluate condition of vegetation where rabbits are present	• Initiate at the implementation of plan • Ongoing as required	• For the duration of the management plan	• Annual review of data collected	Cardinia Shire Council, Melbourne Water, DPI, DSE, Parks Victoria, local landholders
		6.2 Develop a control program for the European Rabbit to be integrated into the Red Fox Control program	**3 (Higher)**	• Development of a rabbit control program	• Once, initiate at implementation of management plan	• Within 12 months	• Review progress of program development after first 12 months	Cardinia Shire Council, Melbourne Water, DPI, DSE, Parks Victoria, local landholders
		6.3 Implement the European Rabbit control program developed in Action 6.2 concurrently with the Red Fox control program	**3 (Higher)**	• Reduction in the number of rabbits and an improvement of vegetation condition	• Within 2 years • Ongoing as required	• For the duration of the management plan	• Annually monitor rabbit numbers and vegetation regeneration and compare to baseline data	Cardinia Shire Council, Melbourne Water, DPI, DSE, Parks Victoria, local landholders
7	Reduce predation pressures by domestic and feral cats and dogs	7.1 Determine the presence and abundance of feral cats in the former Koo Wee Rup Swamp area	**2 (Medium)**	• Presence and abundance of feral cats within the former Koo Wee Rup Swamp area is established	• Initiate at the implementation of the plan	• For the duration of the management plan	• Review data collected annually	Cardinia Shire Council, Melbourne Water, DPI, DSE, Parks Victoria, local landholders
		7.2 Undertake control of feral cats if they are determined to be a threat to Southern Brown Bandicoots in the former Koo Wee Rup Swamp area	**2 (Medium)**	• Decrease in the number of feral cats in comparison to base line data obtained	• Within 2 years • Ongoing as required	• For the duration of the management plan	• Annually monitor the numbers of feral cats to evaluate the efficacy of the control program	Cardinia Shire Council, Melbourne Water, DPI, DSE, Parks Victoria, local landholders
		7.3 Enforce responsible pet ownership laws and implement curfews	**1 (Lower)**	• Local councils have adopted measures to encourage and enforce responsible pet ownership laws	• Ongoing	• For the duration of the management plan	• Annual review of measures adopted to enforce responsible pet ownership and their efficacy	Cardinia Shire Council
		7.4 Devise an education program to raise awareness of responsible pet ownership and the threat of domestic pets to Southern Brown Bandicoots	**1 (Lower)**	• Increased awareness of and adherence to responsible pet ownership laws due to education campaign	• Ongoing	• For the duration of the management plan	• Annually review effectiveness of education program in increasing responsible pet ownership awareness	Cardinia Shire Council
8	Reduce road mortality	8.1 Establish a mortality register for roads in the former Koo Wee Rup Swamp area to assess current impacts and mortality patterns	**2 (Medium)**	• Mortality register established and maintained	• Initiate at implementation of plan • Ongoing as required	• For the duration of the management plan	• Annually review effectiveness of register (e.g. number of road kills reported)	Cardinia Shire Council, CEC, Community groups
		8.2 Investigate the need for road kill mitigation measures and implement where necessary	**2 (Medium)**	• Assess the mortality patterns and rates to determine the need for mitigation measures • Maintain the mortality register	• After 12 months of data collection	• For the duration of the management plan	• review the data collected in the road mortality register every 6 months • Annually review effectiveness of mitigation measures after implementation	Cardinia Shire Council, CEC, Community groups
		8.3 Erect bandicoot warning signs on roads within and adjoining core habitat and roads identified to be high risk in Action 8.2	**2 (Medium)**	• Installation of bandicoot warning signs • Decrease in the number of road killed bandicoots due to the installation of warning signs and other mitigation measures	• Initiate at implementation of plan • Ongoing as required	• For the duration of the management plan	• Monitor sites where road kill mitigation measures have been implemented for their effectiveness every 6 months by continuing the mortality register. • Compare annually with sites where measures have not been implemented	Cardinia Shire Council, CEC, Community groups

Objective		Management Action	Priority	Performance criteria/targets	Timing and frequency	Duration and timeframe	Monitoring	Responsibility/potential contributors
9	Increase habitat connectivity within the former Koo Wee Rup Swamp area through vegetation enhancement and rehabilitation	9.1 Enhance vegetation along suitable habitat links identified in Figure 9	**2 (Medium)**	• Enhancement of habitat links with supplementary plantings • Increase in the density of understorey vegetation and decrease in weed cover	• Initiate at implementation of plan • Ongoing as required	• For the duration of the management plan	• Monitor revegetation and plant growth every six months to ensure vegetation does not pose a fire risk or compromise other biodiversity values	Melbourne Water, Cardinia Shire Council, CEC, Community groups
		9.2 Revegetate potential habitat links along watercourses identified in Figure 9	**3 (Higher)**	• Undertake revegetation of identified watercourses • Successful growth of suitable vegetation and structure	• Initiate at implementation of plan • Ongoing as required	• For the duration of the management plan	• Monitor revegetation and plant growth every six months to ensure vegetation does not pose a fire risk or compromise other biodiversity values	Melbourne Water, Cardinia Shire Council, CEC, Community groups
		9.3 Revegetate potential habitat links along roads identified in Figure 9	**1 (Lower)**	• Undertake revegetation of identified roads • Successful growth of suitable vegetation and structure	• Initiate at implementation of plan • Ongoing as required	• For the duration of the management plan	• Monitor revegetation and plant growth every six months to ensure vegetation does not pose a fire risk or compromise other biodiversity values	Cardinia Shire Council, VicRoads, CEC, Community groups, private landholders
		9.4 Enhance vegetation along the South Gippsland Railway line from West Dalmore Road Drain to Monomeith	**1 (Lower)**	• Enhancement of habitat with supplementary plantings • Increase in the density of understorey vegetation and decrease in weed cover	• Initiate at implementation of plan • Ongoing as required	• For the duration of the management plan	• Monitor revegetation and plant growth every six months to ensure vegetation does not pose a fire risk or compromise other biodiversity values	Cardinia Shire Council, Pacific National, DSE, Community groups
10	Enhance suitable known habitats	10.1 Enhance existing core habitat and habitat patches through targeted revegetation and restoration	**1 (Lower)**	• Enhancement of core habitat and other known habitat through supplementary plantings • Increase in the density of understorey vegetation and decrease in weed cover	• Initiate at implementation of plan • Ongoing as required	• For the duration of the management plan	• Monitor revegetation and plant growth every six months to ensure vegetation does not pose a fire risk or compromise other biodiversity values	Melbourne Water, Cardinia Shire Council, CEC, Community groups
		10.2 Revegetate disused and informal tracks in remnants of known and potential habitat	**1 (Lower)**	• Undertake revegetation of disused tracks • Increase in the density of understorey vegetation and decrease in weed cover	• Initiate at implementation of plan • Ongoing as required	• For the duration of the management plan	• Monitor revegetation and plant growth every six months to ensure vegetation does not pose a fire risk or compromise other biodiversity values	Parks Victoria, Cardinia Shire Council, CEC, Community groups
11	Enhance connectivity to outside of the study area	11.1 Collaborate with stakeholders and government agencies outside the former Koo Wee Rup Swamp area to develop biolinks to Cranbourne, Drouin, Quail Island and Wonthaggi to increase connectivity between populations in these areas and the former Koo Wee Rup Swamp area	**2 (Medium)**	• Develop location of biolinks with relevant stakeholders • Creation and/or implementation of biolinks • Protection of corridors for proposed biolinks	• Initiate at implementation of plan • Ongoing as required	• For the duration of the management plan	• Annually monitor progress of proposals and implementation of biolinks	City of Casey, Cardinia Shire Council, Baw Baw Shire Council, DSE, Melbourne Water, Vic Track, Pacific National, private landholders, Community groups, GAA
12	Increase knowledge of the distribution, abundance and Ecology of Southern Brown Bandicoots in the former Koo Wee Rup Swamp area	12.1 Develop research partnerships with higher education or research institutions to carry out research projects on Southern Brown Bandicoots in the former Koo Wee Rup Swamp area	**3 (Higher)**	• Research partnerships and project outlines developed	• Initiate at implementation of plan • Ongoing as required	• For the duration of the management plan	• Annual review progress of research partnership development	Cardinia Shire Council, City of Casey, Melbourne Water, Parks Victoria, DSE, Mornington Peninsula and Western Port Biosphere Research Committee, Chisholm Institute of TAFE, Universities
		12.2 Conduct surveys to determine the distribution, extent and abundance of Southern Brown Bandicoots in the former Koo Wee Rup Swamp area	**3 (Higher)**	• Updated distribution maps developed and distribution records entered into the south-central database maintained by DSE • Comprehensive surveys of bandicoots in the former Koo Wee Rup Swamp area conducted, estimates of populations obtained and core populations identified	• Ongoing	• For the duration of the management plan	• Progress reports to be submitted by researchers to the Southern Brown Bandicoot management committee annually • Methods, results and discussion to be documented in report provided to committee	Cardinia Shire Council, City of Casey, Melbourne Water, Parks Victoria, DSE, Mornington Peninsula and Western Port Biosphere Research Committee, Chisholm Institute of TAFE, Universities
		12.3 Carry out research to determine population demographics and life history characteristics of Southern Brown Bandicoots in the former Koo Wee Rup Swamp area	**1 (Lower)**	• Basic information of life history attributes, ecology and population demographics obtained	• Ongoing	• For the duration of the management plan	• Annual progress reports to be submitted by researchers to the Southern Brown Bandicoot management committee • Methods, results and discussion to be documented in report provided to committee	Cardinia Shire Council, City of Casey, Melbourne Water, Parks Victoria, DSE, Mornington Peninsula and Western Port Biosphere Research Committee, Chisholm Institute of TAFE, Universities
		12.4 Carry out research to determine habitat use and micro-habitat preference by Southern Brown Bandicoots in the former Koo Wee Rup Swamp area	**2 (Medium)**	• Determination of habitat use by bandicoots in the former Koo Wee Rup Swamp area, including microhabitat preferences, differences in day and night use and habitat functions of linear road and riparian corridors	• Ongoing	• For the duration of the management plan	• Annual progress reports to be submitted by researchers to the Southern Brown Bandicoot management committee • Methods, results and discussion to be documented in report provided to committee	Cardinia Shire Council, City of Casey, Melbourne Water, Parks Victoria, DSE, Mornington Peninsula and Western Port Biosphere Research Committee, Chisholm Institute of TAFE, Universities

Objective		Management Action	Priority	Performance criteria/targets	Timing and frequency	Duration and timeframe	Monitoring	Responsibility/potential contributors
		12.5 Conduct a study to investigate the genetic diversity and genetic structure of Southern Brown Bandicoot populations in the former Koo Wee Rup Swamp area	**1 (Lower)**	• Determine level of genetic diversity within and between the former Koo Wee Rup Swamp area population and other populations (i.e. Cranbourne). • Estimate levels of genetic exchange between clusters and level of dispersal and movement.	• Ongoing	• For the duration of the management plan	• Annual progress reports to be submitted by researchers to the Southern Brown Bandicoot management committee • Methods, results and discussion to be documented in report provided to committee	Cardinia Shire Council, City of Casey, Melbourne Water, Parks Victoria, DSE, Mornington Peninsula and Western Port Biosphere Research Committee, Chisholm Institute of TAFE, Universities
		12.6 Support research into the possible effects of drought and climate change on Southern Brown Bandicoot habitat and survivorship in the former Koo Wee Rup Swamp area	**1 (Lower)**	• Study into the possible effects of drought and climate change on Southern Brown Bandicoots in the former Koo Wee Rup Swamp area population is supported	• Ongoing	• For the duration of the management plan	• Annual progress reports to be submitted by researchers to the Southern Brown Bandicoot management committee • Methods, results and discussion to be documented in report provided to committee	Cardinia Shire Council, City of Casey, Melbourne Water, Parks Victoria, DSE, Mornington Peninsula and Western Port Biosphere Research Committee, Chisholm Institute of TAFE, Universities
		12.7 Evaluate the feasibility of creating artificial dens for Southern Brown Bandicoots and investigate their likely effectiveness and use by bandicoots in urbanised areas	**1 (Lower)**	• Investigations into possible artificial den use by Southern Brown Bandicoots and appropriate designs and feasibility evaluated	• Ongoing	• For the duration of the management plan	• Annual progress reports to be submitted by researchers to the Southern Brown Bandicoot management committee • Methods, results and discussion to be documented in report provided to committee	Cardinia Shire Council, City of Casey, Melbourne Water, Parks Victoria, DSE, Mornington Peninsula and Western Port Biosphere Research Committee, Chisholm Institute of TAFE, Universities
13	Increase the public profile of Southern Brown Bandicoots and their conservation status in the former Koo Wee Rup Swamp area	13.1 Educate the community on the conservation status and importance and benefits of retaining the Southern Brown Bandicoot	**1 (Lower)**	• Distribution of educational material targeted to various sectors of the community • Increased community awareness of the Southern Brown Bandicoot and its conservation significance	• Initiate at implementation of plan • Ongoing as required	• For the duration of the management plan	• Annually monitor/survey community support for the conservation of the Southern Brown Bandicoot	Cardinia Shire Council, CEC, Community groups, local media
		13.2 Design and install uniform signage for conservation reserves to promote awareness of Southern Brown Bandicoot habitats	**1 (Lower)**	• Signage for reserves designed and installed • Increased awareness of bandicoots in reserve and significance of habitats	• Initiate at implementation of plan • Ongoing as required	• For the duration of the management plan	• Ensure that signs have been installed and checked for vandalism every six months	Cardinia Shire Council, CEC
14	Encourage community participation in the conservation of Southern Brown Bandicoots	14.1 Compile and distribute simple guidelines and facts about ways in which individual landholders can help the Southern Brown Bandicoot on their land	**1 (Lower)**	• Dissemination of information through education materials • Increase in the number of public landholders undertaking activities to encourage Southern Brown Bandicoots on their property	• Initiate at implementation of plan • Ongoing as required	• For the duration of the management plan	• Evaluate effectiveness of educational material every 12 months	Cardinia Shire Council, CEC
		14.2 Establish a 'Friends of' group for the Southern Brown Bandicoot in the former Koo Wee Rup Swamp area	**1 (Lower)**	• Establishment of a Friends of the Southern Brown Bandicoot Group • Co-ordination of on-ground actions with other groups and increased community participation	• Initiate at implementation of plan • Ongoing as required	• For the duration of the management plan	• Regular meetings to discuss management initiatives (e.g. quarterly)	Cardinia Shire Council, CEC, community groups
		14.3 Involve community groups and the wider community in conservation activities	**1 (Lower)**	• Increased involvement by the community in conservation activities for the Southern Brown Bandicoot • Establishment of new community conservation initiatives	• Initiate at implementation of plan • Ongoing as required	• For the duration of the management plan	• Monitor community participation in on-ground works every 12 months	CEC, Friends of the Southern Brown Bandicoot
15	Increase the amount of habitat available to Southern Brown Bandicoots in the former Koo Wee Rup Swamp area	15.1 Increase the area of suitable habitat for the Southern Brown Bandicoot through habitat restoration on public land focused around core habitat	**1 (Lower)**	• Initiation of vegetation rehabilitation schemes around areas identified as core habitat • Expand areas of suitable habitat	• Initiate within 2 years • Ongoing as required	• For the duration of the management plan	• Monitor vegetation growth and survival every six months • Monitor rehabilitated areas for weeds, fire risks and other biodiversity values	Cardinia Shire Council, Melbourne Water, DSE, CEC, Community groups, MPWPBR Committee
		15.2 Increase the area of suitable habitat for Southern Brown Bandicoots through habitat restoration on private land by providing incentives	**1 (Lower)**	• Development of an incentive scheme to encourage habitat creation on private land • Increase in number of landholders undertaking habitat creation	• Initiate within 2 years • Ongoing as required	• For the duration of the management plan	• Annually monitor the effectiveness of the incentives	Cardinia Shire Council, CEC
		15.3 Develop and implement a revegetation and management strategy to rehabilitate a habitat link along the South Gippsland Railway Line from Monomeith to Lang Lang	**1 (Lower)**	• Development of a revegetation and management strategy • Growth of vegetation along corridors that support suitable habitat for bandicoots	• Initiate within 2 years • Ongoing as required	• For the duration of the management plan	• Once implemented, conduct annual surveys to monitor use of revegetated links	Cardinia Shire Council, Vic Track, Pacific National
		15.4 Investigate the possibility of Southern Brown Bandicoot reintroduction to potential habitats in Lang Lang and develop a management plan	**1 (Lower)**	• Feasibility study on the reintroduction of Southern Brown Bandicoots to potential habitats • Management plan developed if considered suitable	• Initiate within 5 years	• For the duration of the management plan	• Review progress of investigations every 6 months	Cardinia Shire Council, CEC, MPWPBR Committee, Chisholm Institute of TAFE, Unimin

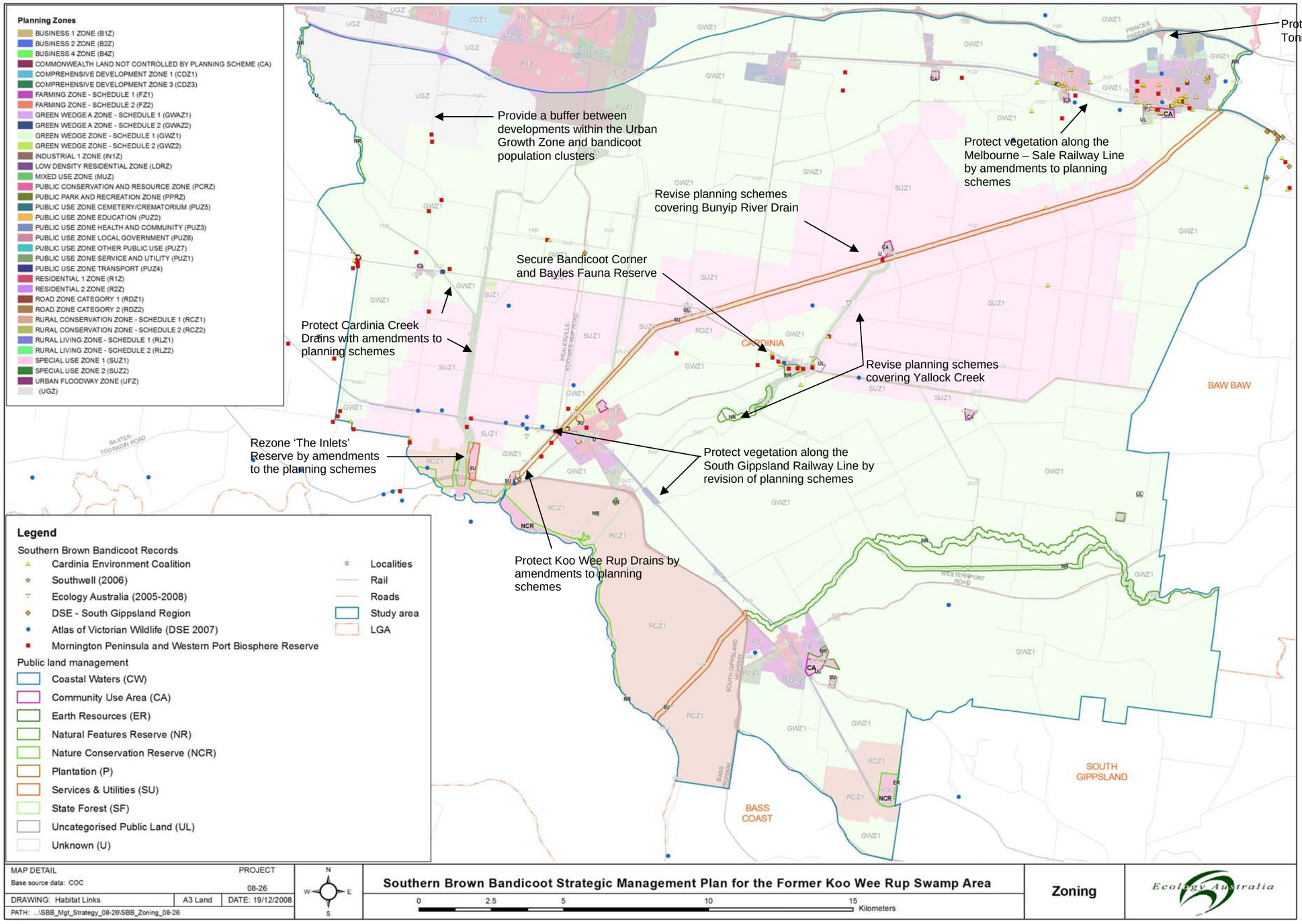


Figure 8 Southern Brown Bandicoot Strategic Management Plan: Key areas recommended for ammendments to secure important habitat for bandicoots in the former Koo Wee Rup Swamp area

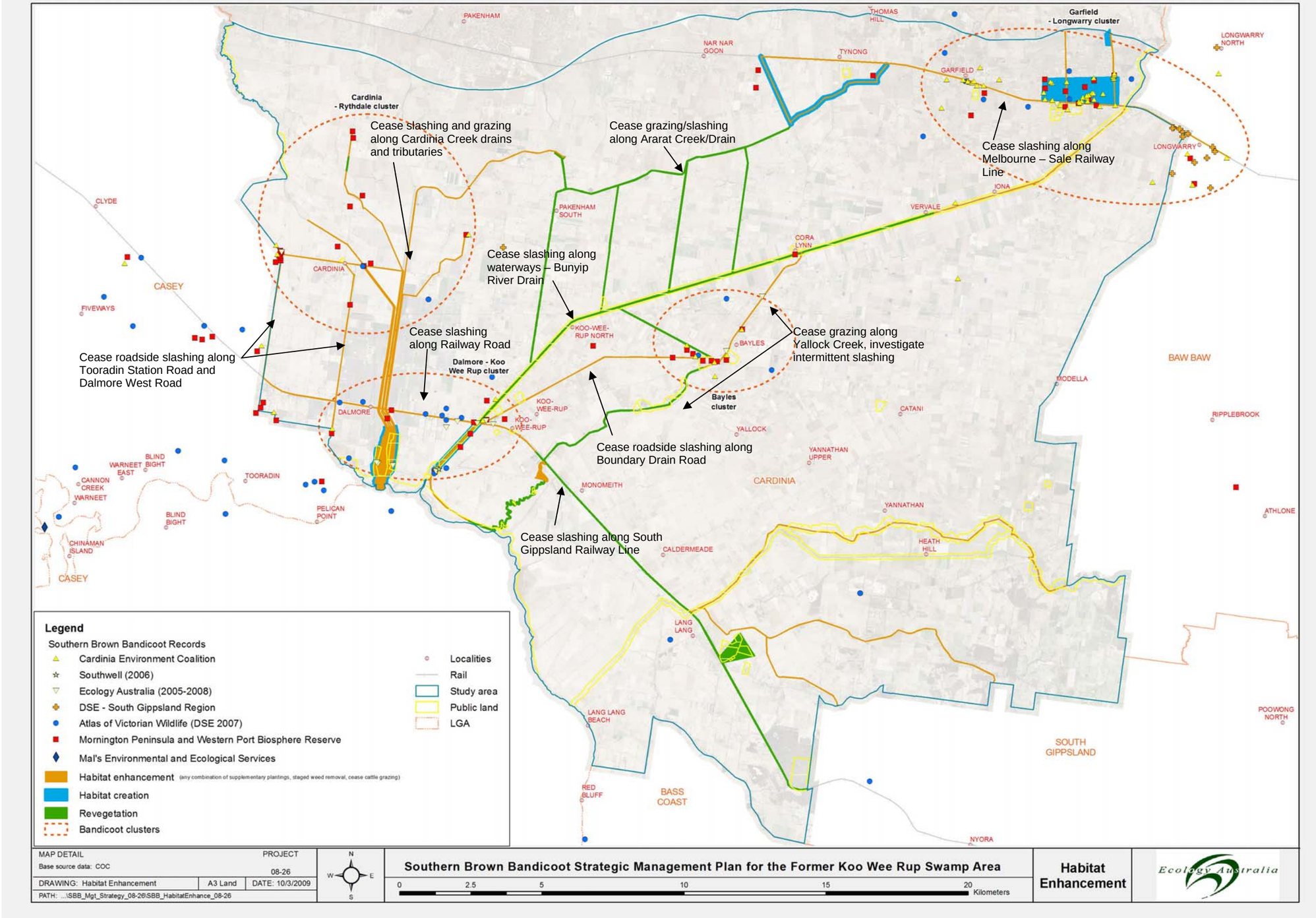


Figure 9 Southern Brown Bandicoot Strategic Management Plan: Key areas recommended for habitat enhancement for bandicoots in the former Koo Wee Rup Swamp area

10 Benefits for biodiversity in the former Koo Wee Rup Swamp area

The former Koo Wee Rup Swamp area supports many important biodiversity values. Subsequently, there is a need for management actions to be compatible with other important values and conservation requirements for the Southern Brown Bandicoot. This section gives a brief summary of some of the other key biodiversity values within the former Koo Wee Rup Swamp area and provides some general recommendations as to how they can be managed in accordance with the Southern Brown Bandicoot Strategic Management Plan.

Objective: Where possible, incorporate other biodiversity benefits into the management actions for the Southern Brown Bandicoot

Vegetation communities and threatened flora species

There are several Ecological Vegetation Classes which have been considerably depleted within the Gippsland Plain Bioregion (DSE 2008b). The most prominent EVC across the study area is Swamp Scrub; this EVC is Endangered in the bioregion. Efforts to protect, secure, enhance and expand areas of habitat (e.g. Swamp Scrub remnants) for the Bandicoot will lead to mutual benefits for this vegetation type. Other EVCs across the study area that would benefit from protection and enhancement are:

- Swampy Riparian Woodland (Endangered in the bioregion);
- Lowland Forest (Vulnerable in the bioregion);
- Estuarine Flats Grassland (Endangered in the bioregion);
- Coastal Saltmarsh (Least Concern in the bioregion); and
- Mangrove Shrubland (Least Concern in the bioregion).

There are several threatened flora species which are known or potentially occur within the former Koo Wee Rup Swamp area (DSE 2005). Some of the the key threatened flora species which would benefit from habitat protection, removal of grazing and enhancement works along waterways and reserves include:

- River Swamp Wallaby-grass (*Amphibromus fluitans*)- EPBC-listed;
- Veined Spear-grass (*Austrostipa rudis* ssp. *australis*) – rare in Victoria;
- Green Scentbark (*Eucalyptus fulgens*) – rare in Victoria;
- Marsh Saltbush (*Atriplex paludosa* ssp. *paludosa*) – rare in Victoria; and
- Grey Mangrove (*Avicennia marina* spp. a*ustralasica*) rare in Victoria.

Threatened fauna species

There are numerous threatened fauna species known to occur within the former Koo Wee Rup Swamp area. Those most relevant to areas which also support bandicoots are summarised below.

The EPBC and FFG-listed **Growling Grass Frog** (*Litoria raniformis*) occurs in creeks, drainage-lines and farm dams across the whole former Koo Wee Rup Swamp area. As some of the habitat they occupy overlaps with bandicoot habitat, it is imperative that potential conflicts between the habitat management requirements for each species are identified.

For example, in Yallock Creek cattle grazing, particularly downstream of the Bayles-Longwarry Road Bridge, has resulted in heavy pugging, trampling and significant loss of vegetation in the Yallock Creek streambed (e.g. grazing of vegetation preferred by frogs, including Tall Spike-rush and Water Ribbon) (Ecology Australia 2006). In contrast, fencing cattle out from a section of the Yallock Creek streambed upstream of the bridge (as mentioned in Section 7.2, Appendix 3 - Plate 6), has resulted in good plant growth and an increase in vegetation density. While Growling Grass Frogs would use these areas of dense vegetation for shelter, movement and/or dispersal, the wetlands no longer form open pools with an open vegetation structure which the frog generally prefers.

This balance was also discussed in a study undertaken in Yallock Creek further downstream of the Bayles Bridge, south of the Gippsland Highway, where it was noted that stock grazing has varying implications for frog habitats (Robertson and Heard 2002). Robertson and Heard (2002) stated that vegetation should be protected from grazing, however, frogs may prefer few shrubby species and no tree canopy over the water bodies in which they breed. Therefore, intermittent grazing was considered desirable to maintain an open structure (Robertson and Heard 2002).

As one of the management actions recommended in this strategy is to remove grazing from all watercourses across the former swamp area to re-habilitate habitat for bandicoots, there may be implications for Growling Grass Frog habitat, in that, areas could become choked or overgrown by riparian vegetation, which may exclude the frog or reduce suitable breeding habitat in the area.

Considering the extensive degradation of vegetation and waterway values cattle grazing causes (e.g. removal of understorey vegetation, pugging and compaction of the soil, and eutrophication), it is recommended that an intermittent slashing regime be investigated rather than intermittent grazing. This could be conducted in the areas where Growling Grass Frogs and bandicoots are known to occur and where grazing has been removed, and should be assessed on a case-by-case basis. A suitable slashing regime should allow the vegetation to re-establish, but also allow certain target areas to form a more open vegetation structure, particularly within the stream beds of creeks and waterways. This can also be undertaken on the banks and levees along some waterways, as an open foraging habitat adjacent to dense vegetation providing shelter is favoured by bandicoots. The open grassy levees may also provide foraging opportunities for Growling Grass Frogs. This

species has been recorded foraging up to 100 m from waterbodies in open pasture in search of invertebrates and other prey (Geoff Heard pers. comm.).

The protection and enhancement of Southern Brown Bandicoot habitat will benefit adjoining habitats and waterways that are known to support native threatened fish species such as the EPBC and FFG-listed **Dwarf Galaxias**, particularly in Yallock Creek, and the EPBC and FFG-listed **Australian Grayling** (*Prototroctes maraena*), in Cardinia Creek. In addition, habitat for the FFG-listed **Swamp Skink** (*Egernia coverntryi*) will benefit from habitat protection, removal of grazing, predator control and habitat enhancement, particularly along the coastline in Estuarine Flats Grassland, Coastal Saltmarsh and Swamp Scrub and in the lower reaches of drains and rivers under tidal influence. Where Swamp Skinks occur, it is also important that vegetation does not become overgrown and prevent sunlight reaching the ground level. Open areas for basking in, is one of the key habitat requirements for the Swamp Skink.

Threatened water bird species also likely to benefit from the above actions are:

- FFG-listed **Lewin's Rail** (*Rallus pectoralis*) and **Great Egret** (*Ardea alba*); and
- State classified threatened species- **Latham's Snipe** (*Gallinago hardwickii*), **Royal Spoonbill** (*Platalea regia*) and **Nankeen Night-Heron** (*Nycticorax caledonicus hilli*).

These management actions will also have positive effects for many other locally-common fauna species throughout the former swamp area.

Waterways

Melbourne Water is currently developing '*Biodiversity Targets for Waterways - 20 Year Vision Waterway Templates*' an initiative driven by the River Health Strategy 2025, which aims to have all waterways in the Port Phillip and Westernport Catchment Management Area in good ecological condition by 2025.

As part of the River Health Strategy, Melbourne Water has developed a database of threats and management actions for each of their Sub-management Units. The Waterways Templates project aims to develop a '20 year vision' template for each waterway reach, which provides a management target for each reach, assuming all management actions are implemented.

Seven descriptors are being developed for integration into the Templates:

- geomorphology (using the River Styles classification);
- Riparian Vegetation;
- Buffer width;
- Flow regime;
- Water Quality, including degree of imperviousness and land use;

- Fauna; and
- Recreational opportunities.

The data for each descriptor will be provided in a GIS layer, which is to be integrated into the template.

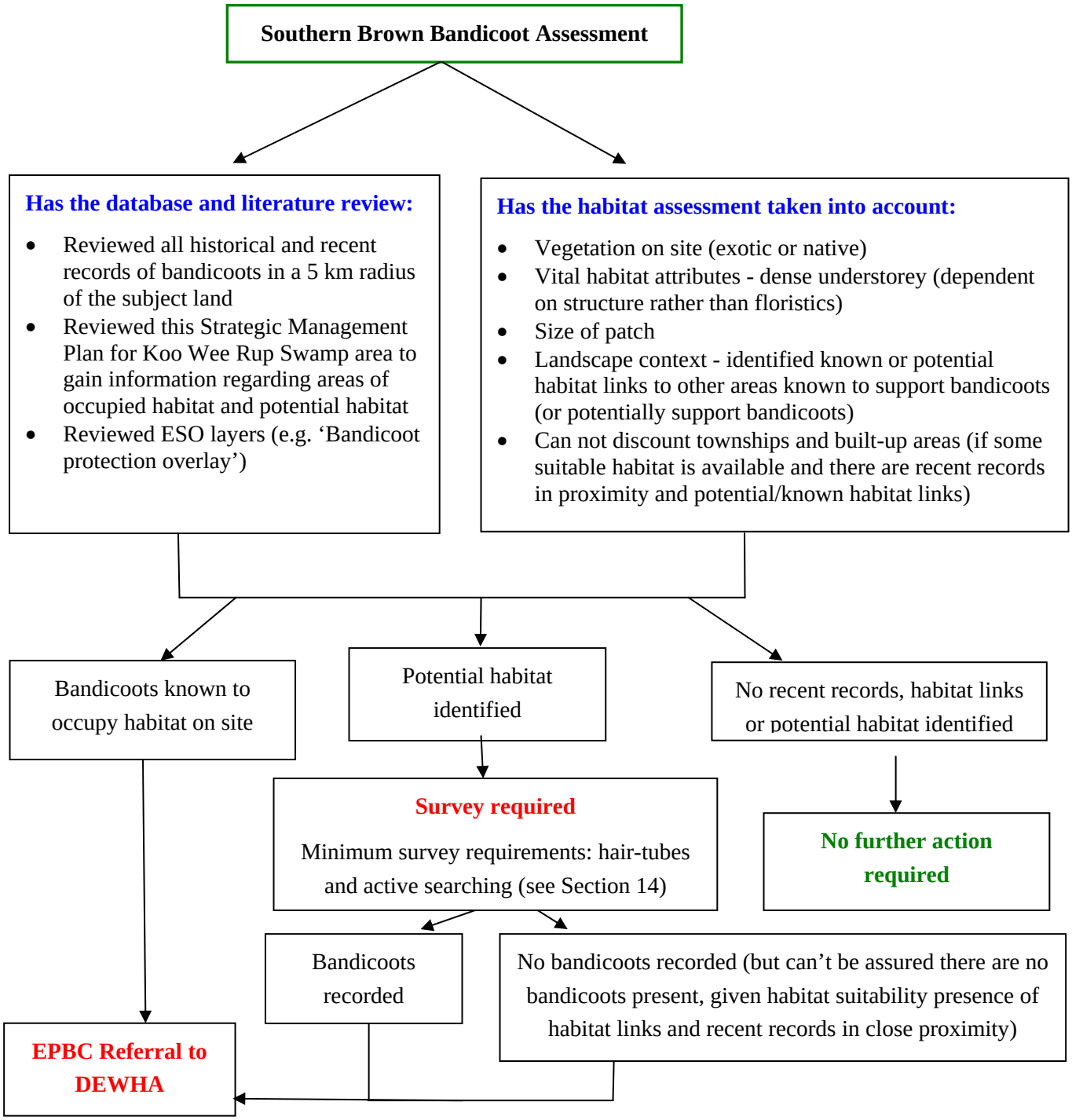
Using the seven descriptors as the framework, a GIS query would interrogate the database and produce an output of the 'Vision' or the biodiversity values we may expect in each waterway reach, in 20 years time, under best management practice. The fauna template would provide a list of all fauna species that may be found along a particular reach in 20 years, which can effectively be used as a target for management and as an indicator of the success of those management actions.

Since a major focus of the '20 year vision' is to manage existing native riparian vegetation and revegetate areas lacking native vegetation, strategic management actions recommended in this document, could form the basis of the '20 year vision' for waterways within the former Koo Wee Rup Swamp area. A primary target of the '20 year vision' for fauna, could be to maintain or enhance existing populations of Southern Brown Bandicoots in vegetation along waterways, or return bandicoots to areas where they have been lost through appropriate management actions.

An operational management plan for waterways, sympathetic to the needs of conserving and enhancing environmental values, has also been recommended for development by Melbourne Water in this management plan. This will not only provide benefits for the Southern Brown Bandicoot, but will provide additional benefits for a diversity of flora and fauna species and opportunities to improve overall biodiversity values in the area.

11 Decision guidelines for council planners

This section outlines the decision guidelines for council planners on how to evaluate information provided by a developer and ensure that appropriate and informed planning decisions are made. Prospective developers should complete a Southern Brown Bandicoot assessment, as shown below as the first step.



Once an assessment of the proposed development site has been made, the developer will be aware of which areas on the site are either known to support bandicoots or potentially support bandicoots. As described above, the potential of an area to support bandicoots will be based on the quality and extent of the habitat, landscape context and proximity of other known records. The assessment of a proposed development site should be undertaken by a qualified zoologist, in order for an accurate assessment to be made.

When it has been established that the developer has undertaken an appropriate and thorough assessment, Council should be satisfied that development planners have made all attempts to protect bandicoot habitat by following the basic principles of avoidance and minimisation:

1. As a first priority, it is most important that all known bandicoot habitat is avoided, and potential bandicoot habitat is avoided wherever possible, through careful planning and design of the development.
2. Where habitat loss is unavoidable, the loss must be minimised as best possible.
3. All known or potential habitat for the Southern Brown Bandicoot which is to be lost must be offset at equal or greater value by the developers. There are a number of ways in which offsets can be accomplished, and these are described in further detail below.

Southern Brown Bandicoot Habitat Offsets

All habitat which is to be lost should be assessed by a qualified botanist. If the habitat to be lost is determined to support a remnant patch of vegetation, then the vegetation offsets required under Victoria's Net Gain legislation may be regarded as a sufficient bandicoot habitat offset, without the need for further offsets (see Section 2.1).

In this case, the type and quality of the offset required will depend upon the quality, extent and conservation significance of the habitat/vegetation to be lost, and must match this on a like-for-like basis. As the former Koo Wee Rup Swamp area is considered to support the best 50 % of habitat for the Southern Brown Bandicoot in the Gippsland Plain Bioregion, under Net Gain legislation, the conservation significance of the habitat to be lost is elevated to 'very high'. Therefore, habitat offsets must be made on a like-for-like basis at a minimum of twice the area (ha) to be lost. This same rule could also be applied to habitat offsets for bandicoot habitat which is to be lost, but is not considered to support a remnant patch.

Potentially suitable offset sites must be assessed on a case by case basis, as candidate sites will be assessed depending on factors including whether or not the site supports bandicoots, the landscape context and connectivity of the site, and the protection and management of the site in perpetuity.

Alternately, a proponent may choose an offset other than a habitat offset, which may involve contributing funds towards the conservation of the Southern Brown Bandicoot. Local government may choose to set up a trust fund into which contributions can be made and funds administered as considered appropriate. This fund is probably best administered through the Council but decisions as to how the fund can be used should be made in consultation with the Southern Brown Bandicoot Management Committee, proposed in Section 9.

Two types of offsets may be made using these funds. Direct offsets can be made by using these funds to purchase and secure land for the Southern Brown Bandicoot which would be managed with a conservation covenant. Indirect offsets can by made by directing the funds towards conservation efforts such as predator proof fencing or funding research projects.

Prospective developers should liaise with council and other relevant stake holder groups throughout the planning process and when deciding on appropriate offsets.

EPBC Act Referrals to Department of Environment, Water Heritage and the Arts

In some cases, if bandicoot habitat will be significantly impacted upon by a proposed development (or action), a referral to the DEWHA must be submitted by the developer, for a decision by the Federal Minister on whether the action requires assessment and approval.

Whether or not a referral will be required can be established during the initial habitat assessment for the Southern Brown Bandicoot, by following the above flowchart. An EPBC referral is required whenever a proposed action will have or is likely to have a significant impact on a matter of National Environmental Significance (i.e. EPBC item). For a significant impact to be likely it is not necessary for there to be a greater than 50 % chance, only that significant impacts are a real or not remote possibility (Commonwealth of Australia 2006). The proposal should be considered in its broadest scope and also take into account indirect, off-site and facilitated impacts. The precautionary principle should be followed. The EPBC Guidelines state that urban development of a housing sub-division or industrial estate which supports an EPBC listed item must be referred to the Environment Minister. Therefore, a referral will be required if the site supports known or potential habitat for the Southern Brown Bandicoot. EPBC criteria for significants impact to an endangered species (i.e. Southern Brown Bandicoot) are outlined in the EPBC Act Policy Statement 1.1 - Significant Impact Guidelines (Commonwealth of Australia 2006).

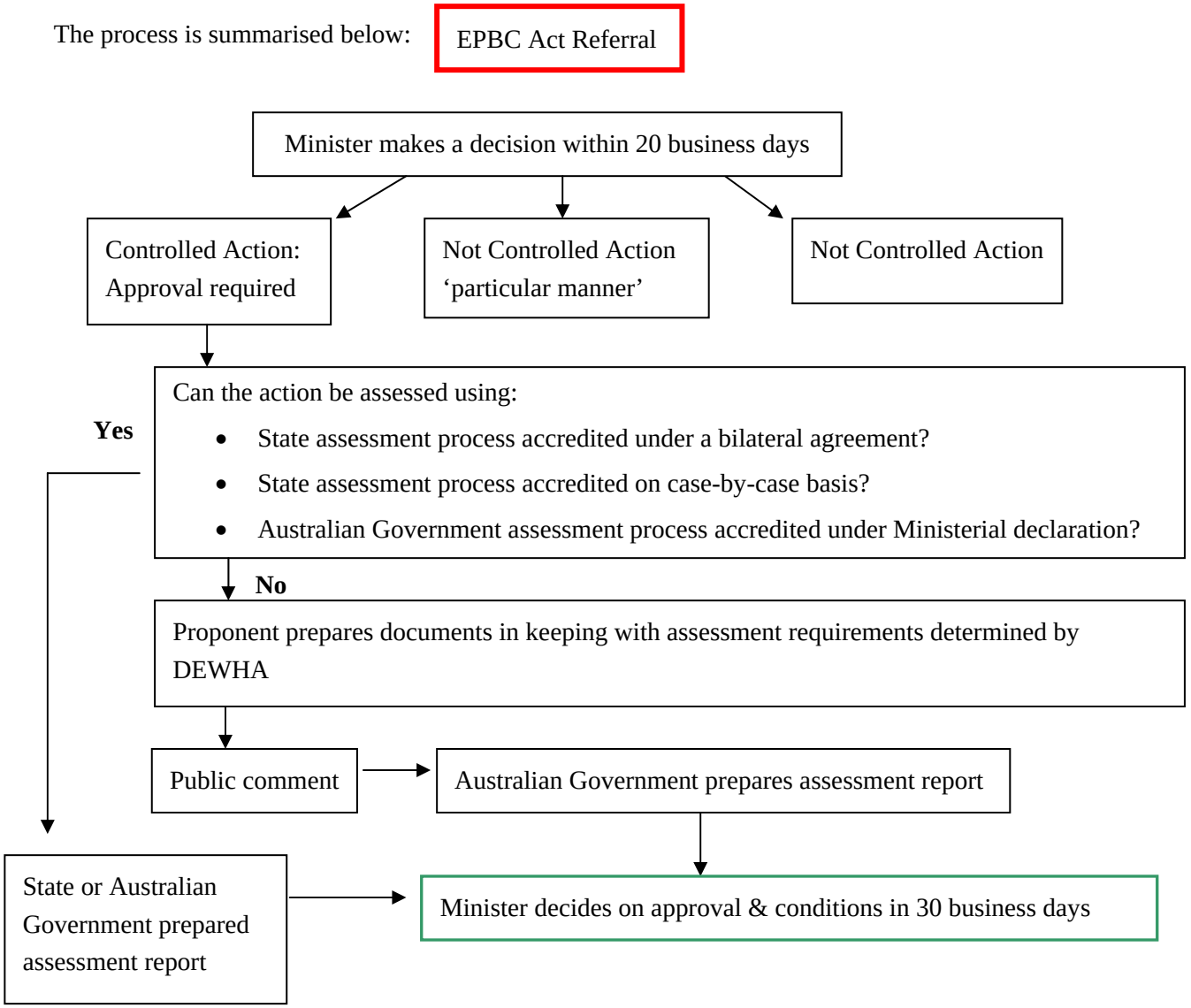
To make an EPBC referral, the proponent is required to fill out a referral form which supplies all relevant information required by the minister to make a decision on whether the action requires assessment and approval. The form identifies the persons proposing the action, a description of the proposal, location and the nature and extent of any impacts, considered in their broadest scope. The referral will also require the proponent to provide evidence that impacts or habitat loss has been avoided wherever possible, minimised where they are

unavoidable and if any mitigation measures have been proposed. Any proposed offsets could also be submitted with the referral for consideration by the minister.

Based on this information, the minister will make a decision in 20 business days. There are three likely outcomes:

1. Not Controlled Action: Approval is not required if the action is undertaken in accordance with the referral
2. Not Controlled Action 'particular manner': Approval is not required if the action is undertaken in a 'particular manner' that is specified
3. Controlled Action: Approval is required. Significant impacts are likely and the action must be subject to the assessment and approvals process under the EPBC Act.

The process is summarised below:



Best Management Practices for Urban Township Development

In several areas throughout the former Koo Wee Rup Swamp area, Southern Brown Bandicoots inhabiting remnant vegetation around urban townships are at risk from further development and urban expansion. A number of areas outside of the Urban Growth Zone such as Bunyip, Garfield and Lang Lang have been identified as areas for future development and subdivision within the current boundaries. Since this is likely to have adverse impacts on the viability of Southern Brown Bandicoot populations, some broad principles and best management guidelines have been provided for council planners and developers.

- Following extensive Southern Brown Bandicoot assessments of land proposed for development, known and potential habitat for the bandicoot should be avoided where possible. Whenever habitat loss is unavoidable, the loss should be minimised.
- Reserve the best areas of known or potential Southern Brown Bandicoot habitat, as identified by the habitat assessments and with reference to this management plan. Known habitat should be reserved as a first priority, followed by potential habitat. Prime areas to reserve are those that are well connected to additional habitat via links along roadways or waterways. Reserved areas should be as large as possible, and ideally a combination of large and smaller areas would be reserved. If possible they should be scattered throughout the township rather than in one area, with a view to providing loose connectivity between them. Developments must not isolate these areas from habitat outside of the township.
- Reserved areas should be secured in perpetuity and managed appropriately for threats to the Southern Brown Bandicoots, including fencing, predator control, rabbit and weed control.
- Supplementary plantings along roadsides and waterways can provide some connectivity throughout the township between reserved ‘nodes’, and also provide connectivity to outside the study area.
- Encourage landholders to plant habitat for the Southern Brown Bandicoot on their land with the incentives and education resources outlined in the management plan.
- Provide landholders with a list of prohibited plant species including weeds and a list of permitted plants including species that provide habitat for the bandicoot.
- Introduce and enforce strict pet ownership laws and enforce curfews and control of straying pets.
- Use baffled lighting; avoid floodlighting and discourage landholders from installing floodlighting, particularly near bandicoot habitat.
- Consider implementing ‘development concession’ schemes as discussed in Section 9.

12 Directions for site-specific management plans

The aim of this document is to provide strategic management actions for bandicoot conservation within the former Koo Wee Rup Swamp area. These management actions should be developed in more detail into site-specific management plans.

There are currently three known site-specific management plans within the study area:

- Bayles Fauna Reserve (core habitat);
- Bunyip Sanctuary (potential habitat); and
- The Inlets Reserve (core habitat)

Each habitat type identified in the former Koo Wee Rup Swamp area which supports bandicoots requires a site-specific management plan (see Section 7). These include:

1. All areas of core habitat, for example:
    - Vegetation adjoining the Koo Wee Rup Swamp lookout, Koo Wee Rup drains, and South Gippsland Railway Line. Management guidelines have been prepared for the inlets (Biosis 2008a), however management guidelines in regards to the bandicoot are still required;
    - Bandicoot Corner and Yallock Creek from South Gippsland Highway to Cora Lynn.
    - Cardinia Creek from the South Gippsland Railway Line to Cardinia North;
    - Vegetation adjoining Nar Nar Goon – Longwarry Road/Railway Line.
2. Habitat links; and
3. Habitat patches.

Key elements required for site-specific management plans in regards to bandicoot conservation and management would include:

Introductory information

- Site details and history;
- Habitat types and EVCs;
- Threats to the site and its values and constraints for management;
- Outline past and current management regimes (if any); and

- Identify values that require management, there may be several (e.g. Southern Brown Bandicoot, Growling Grass Frog, Swamp Scrub EVC).

Environmental Management Plan Elements:

- Conservation zones;
- Revegetation and enhancement of native vegetation and fauna habitats;
- Fencing (delineation of reserves and predator-proof fencing);
- Weed management;
- Hydrology, drainage and waterways management (where applicable);
- Buffer and interface zones (e.g. between reserves and farmland/private property);
- Biodiversity benefits (ensure compatibility between habitat requirements for threatened species which may occur within the reserve);
- User-related issues (e.g. recreation, dog restrictions, pet curfews);
- Pest animal control (foxes and rabbits);
- Domestic animal control;
- Fire management; and
- Community education.

For each management plan element, the following should be detailed:

- Objective;
- Implementation of actions;
- Follow-up or ongoing actions;
- Performance measures, monitoring and review; and
- Responsibilities.

Timing, frequency and duration should also be provided for each action and performance measures.

13 Revegetation guidelines

Revegetation together with staged, minimal disturbance weed control is an important element of habitat management for the Southern Brown Bandicoot. Revegetation with tube-stock will be the primary method of habitat enhancement for many species, due to the limited capacity for natural recruitment of indigenous species to take place within the study area (see Section 6).

Whether the aim of revegetation is the creation of bandicoot habitat, or the enhancement of extant vegetation using supplementary plantings, revegetation should be based on the original vegetation of the local area. All plants used in revegetation must be of indigenous species naturally occurring in the former or current EVC.

For vegetation to be of value to Southern Brown Bandicoots, it is also important that plantings are of the appropriate growth form and structure. The most essential habitat requirement for the Southern Brown Bandicoot is a low dense layer of understorey vegetation, up to approximately 1.5 m in height, which provides shelter and protection from predators (see Appendix 2). This is a requirement dependent on the structural rather than floristic characteristics of the vegetation. Therefore, habitat creation and rehabilitation for the Southern Brown Bandicoot must be carried out to promote the development of a continuous, dense layer of understorey vegetation.

To achieve this it is imperative that plants are planted at the correct densities, which will provide 'rapid closure' or the rapid growth of an impenetrable ground and understorey layer. As such, it is important that when planting overstorey or canopy species (i.e. trees), that plants are set at sufficient distances apart, so that their growth does not impede the understorey. A dense canopy can prevent light from reaching the lower strata impeding the growth of midstorey or understorey vegetation. Therefore trees should be planted sparsely to form an open canopy. Similarly, *Melaleuca* species are capable of rapidly forming dense stands to the exclusion of other species, and should therefore be planted in scattered clumps, allowing dense understorey vegetation to establish and persist in intervening areas. Medium shrubs and small shrubs can be planted relatively close together, and at the field layer, large graminoids should be spaced very closely to provide the maximum amount of cover. Dense plantings will also suppress the growth of weeds. A list of appropriate species for revegetation of five of the most common EVCs in the former Koo Wee Rup Swamp area is provided in Table 10, together with their structural class and appropriate planting densities. This list is an abbreviated list of the EVC benchmarks outlined by DSE, and includes additional plant species known to occur in these EVCs, which will provide suitable habitat.

All revegetation efforts should follow these simple principles:

- Species selected must be part of the former or current EVC, and plantings should provide the vegetation structure required by bandicoots;
- Propagation material should be from indigenous species sourced from the nearest natural populations locally or regionally. Propagation material must be collected in accordance with the appropriate Department of Sustainability and Environment permits and protocols;
- Depending on the species being planted, either tube-stock or direct seeding may be appropriate. Direct seeding can be effective for trees and large shrubs. However, for other species including graminoids, only planting of tube-stock may be viable within the former Koo Wee Rup Swamp area, as competition from weeds (especially perennial grasses) would severely restrict the effectiveness of direct seeding and/or natural recruitment;
- Plants should be propagated with sufficient lead time to achieve good growth by the time of planting, and all tube-stock should be of high quality (i.e. appear healthy, have well developed roots and not be root bound);
- The components of revegetation must be well documented (e.g. date and location of plantings and associated weed control activities, provenance of species used, etc.);
- To reduce competition from weeds, it will be necessary to undertake preparatory and ongoing weed control of revegetation sites. However, weed removal should be staged to ensure adequate habitat is retained for Southern Brown Bandicoots throughout the restoration process. While seriously invasive environmental weeds would preferably be removed, if these species must be retained for a period efforts should be made to ensure the population is contained;
- Plants should also be protected from grazing. For supplementary plantings within suitable habitat, tree guards placed around individual plants may be appropriate. However, for high-density plantings and large areas, fencing may be necessary to exclude herbivores; and
- All revegetation plots must be monitored. Effectively timed monitoring will allow various degradation processes (weeds, grazing) to be managed before they adversely affect the revegetation. Maintenance timing should coincide with ecological timelines (e.g. undertake weed control before seed-set). All plant losses should be replaced unless mortality has been the result of unmanageable site conditions (e.g. prolonged drought).

Table 10 Southern Brown Bandicoot Strategic Management Plan: Plant species recommended for revegetation in the former Koo Wee Rup Swamp area

Common Name	Scientific Name	Structural Class	Planting Density
Swamp Scrub (EVC 53)			
Woolly Tea-tree	*Leptospermum lanigerum*	Medium Shrub	0.5 m
Swamp Paperbark	*Melaleuca ericifolia*	Medium Shrub	0.5 m
Prickly Currant-bush	*Coprosma quadrifida*	Medium Shrub	0.5 m
Prickly Tea-tree	*Leptospermum continentale*	Medium Shrub	0.5 m
Common Tussock-grass	*Poa labillardierei*	Large Graminoid	0.3 - 1 m
Red-fruit Saw-sedge	*Gahnia sieberiana*	Large Graminoid	0.3 - 1 m
Variable Sword-sedge	*Lepidosperma laterale (*var. *majus)*	Large Graminoid	0.3 - 1 m
Swampy Riparian Woodland (EVC 83)			
Swamp Gum	*Eucalyptus ovata*	Tree	10 - 15 m
Narrow-leaf Peppermint	*Eucalyptus radiata* s.l.	Tree	10 - 15 m
Blackwood	*Acacia melanoxylon*	Tree	10 - 15 m
Swamp Paperbark	*Melaleuca ericifolia*	Medium Shrub	0.5 - 1 m
Woolly Tea-tree	*Leptospermum lanigerum*	Medium Shrub	0.5 - 1 m
Prickly Tea-tree	*Leptospermum continentale*	Medium Shrub	0.5 - 1 m
Prickly Currant-bush	*Coprosma quadrifida*	Medium Shrub	0.5 - 1 m
Sweet Bursaria	*Bursaria spinosa*	Medium Shrub	0.5 - 1 m
Prickly Moses	*Acacia verticillata* var. *verticillata*	Medium Shrub	0.5 - 1 m
Tall Sedge	*Carex appressa*	Large Graminoid	0.3 - 0.5 m
Variable Sword-sedge	*Lepidosperma laterale (*var. *majus)*	Large Graminoid	0.3 - 0.5 m
Red-fruit Saw-sedge	*Gahnia sieberiana*	Large Graminoid	0.3 - 0.5 m
Spiny-headed Mat-rush	*Lomandra longifolia*	Large Graminoid	0.3 - 0.5 m
Lowland Forest (EVC 16)			
Messmate Stringybark	*Eucalyptus obliqua*	Tree	10 - 15 m
Narrow-leaf Peppermint	*Eucalyptus radiata* s.l.	Tree	10 - 15 m
Blackwood	*Acacia melanoxylon*	Medium Shrub	0.5 - 1 m
Prickly Tea-tree	*Letpospermum continentale*	Medium Shrub	0.5 - 1 m
Silver Banksia	*Banksia marginata*	Medium Shrub	0.5 - 1 m
Heath Tea-tree	*Leptospermum myrsinoides*	Medium Shrub	0.5 - 1 m
Hedge Wattle	*Acacia paradoxa*	Medium Shrub	0.5 - 1 m
Swamp Goodenia	*Goodenia ovata*	Small Shrub	0.5 - 1 m
Common Correa	*Correa reflexa*	Small Shrub	0.5 - 1 m
Spiny-headed Mat-rush	*Lomandra longifolia*	Large Graminoid	0.3 - 0.5 m
Damp Heathy Woodland (EVC 793)			
Green Scentbark	*Eucalyptus fulgens*	Tree	10 - 15 m
Mealy Stringybark	*Eucalyptus cephalocarpa* s.l.	Tree	10 - 15 m
Narrow-leaf Peppermint	*Eucalyptus radiata* s.l.	Tree	10 - 15 m
Swamp Gum	*Eucalyptus ovata*	Tree	10 - 15 m
Prickly Tea-tree	*Letpospermum continentale*	Medium Shrub	0.5 m
Silver Banksia	*Banksia marginata*	Medium Shrub	0.5 m

Common Name	Scientific Name	Structural Class	Planting Density
Burgan	*Kunzea ericoides*	Medium Shrub	0.5 m
Swamp Goodenia	*Goodenia ovata*	Small Shrub	0.5 m
Estuarine Flats Grassland (EVC 914)			
Seaberry Saltbush	*Rhagodia candolleana*	Medium Shrub	3 m
Chaffy Saw-sedge	*Gahnia filum*	Large Graminoid	1 m
Coast Tussock-grass	*Poa poiformis*	Large Graminoid	0.5 m

14 Southern Brown Bandicoot survey and monitoring protocols

Survey methods to detect Southern Brown Bandicoots can include a variety of techniques. The various methods demand a range of low to high expenditure of money and labour, and result in various levels of cost-effectiveness and efficiencies. They provide varying levels of information from definitive observations about the numbers of animals in a given area, to a definitive detection or indication of the species only (i.e. presence in a given area), to potentially erroneous records. The following techniques have been used to survey for, or detect presence of, Southern Brown Bandicoots or other species of bandicoot:

- searches for the characteristic diggings of Southern Brown Bandicoots (i.e. conical pits excavated by bandicoots in the soil in search of food) (Appendix 3 - Plate 7);
- spotlighting;
- analysis of hair samples from hair tubes set in a specified area;
- analysis of hair samples in predator scats collected from a specified area;
- cage trapping (i.e. capture-mark-recapture); and
- use of surveillance cameras.

The relative merits of each technique are compared in Table 11 in terms of:

- costs out-layed (initial and ongoing for equipment and labour);
- survey coverage (area and time);
- detection success; and
- quality of records in terms of identification issues and utility of data.

Based on the qualitative comparison, searches for diggings (and scats), and hair-tube surveys are the most cost-effective techniques for detecting bandicoot presence in a given area. Ideally, a number of techniques should be employed simultaneously to maximise the potential of detection. The use of surveillance cameras in biological work is increasing based on success with numerous mammalian and avian species. Surveillance cameras should be considered if sufficient funds are available and if there is reason to suspect bandicoot presence in an area, and if the target study area has restricted public visitation (e.g. occurs on private land with restricted human access). Collection of predator scats during the routine course of fauna habitat assessment and survey work using recommended survey techniques is a cost-effective means of increasing survey effort and may provide useful on-going indication of the rate of predation in the former Koo Wee Rup Swamp study area (e.g. see Ecology Australia 2008).

However, the survey technique adopted would depend on the data and detail of information required. For example, detection of Southern Brown Bandicoot presence in a proposed development area could be ascertained with rapid techniques which yield indirect evidence (i.e. indicative signs) of 'presence' only. This level of information would be all that is required to refer matters to the Federal Government. Data on population sizes and measurement of biological variables would only be accurately obtained through a cage trapping and capture-mark-recapture study with periodic monitoring of the population.

Table 11 Southern Brown Bandicoot Strategic Management Plan: a summary of the relative merits of the different techniques for survey or monitoring of the Southern Brown Bandicoot

Technique	**Efficiencies**			**Data/information quality**			**Residual Values**
Survey	***High***	***Moderate***	***Low***	***Indicators/signs***	***Observations***	***Monitoring / Biological data***	
SBB 'Digging' (and scat) survey	Relatively low cost involved			'Presence' only data at the site			Reliable and cost-effective means of determining presence of SBB if survey undertaken by trained observers
	Relatively easy for trained observers			Potential for mis-identification with untrained observers (e.g. Swamp Rats, Rabbits) and potential for mis-identification/confusion with diggings of the Long-nosed Bandicoot			
	Suitable for coverage over a broad area			There is potentially seasonal influence (though unknown) on digging activity resulting in differences in detection success between seasons			
	No impact on target species						
Spotlighting	Relatively low cost involved		Detection success invariably low		Definitive record - 'Presence' only at the site		Not a cost-effective or reliable means of determining presence of bandicoots at a site because of low detection probability
	Suitable for coverage over a broad area						
	Minimal impact disturbance to target species						
Hair tubing	Relatively low on-going cost	Moderate to high initial cost for hair tubes	Variable levels of success due to trap-shy nature of species		Indirect evidence of 'Presence' only at the site		Useful and cost-effective means of determining presence of bandicoots if hair analysis undertaken by trained specialists (low probability of mis-identification)
	Coverage over a broad area	Restricted to colder months to avoid capture and death of (non-target) reptiles on hair tube wafers			Potential for misidentification of hair sample depending on quality and adequacy of material obtained		
	Potential for longer survey periods as tubes can be left in place for a while (e.g. for two weeks or longer)						
	No or minimal impact on target species						
Predator scats	Low cost involved		Coverage potential over a relatively small area		'Presence' only data obtained in area/vicinity		Only useful if used in conjunction with other 'presence' indicators for a given area
	Can obtain information about (an index of) predation rates				Prey species may not have been caught where predator deposited scats		Hair analysis must be undertaken by trained specialists (low probability of mis-identification)
	No impact of survey on target species						
Surveillance cameras	Potential for longer survey periods with minimal human input, depending on battery life	Potentially labour intensive (depending on the number of visits needed to relocate camera)	High initial cost		Definitive records obtained of 'Presence' only at a site		Reliable way of obtaining or confirming 'presence' data and cost-effective in the long term
	Minimal/no impact on target species		Coverage over a relatively small area (i.e. point data)		'Presence' only data and behavioural information obtained at a site		Use of cameras in public areas limited by potential vandalism and camera loss
Monitoring							
Cage trapping	Potential for coverage over a broad area	Trapping success of small mammals possibly increases over time	Potentially high initial cost involved			Definitive records obtained and allows measurement of various biological variables	Moderately reliable, but not cost-effective
		Trapping success possibly dependent on seasonal availability of foods in environment (e.g. success is higher when food in habitat is scarce)	Capture success invariably low			Population data obtained if capture success is high	Not very useful for a once-off survey if initial trapping success is low and natural food availability in environment is high
			Labour intensive				Should be considered for monitoring populations and measuring biological variables
			Highest impact on target species				

14.1 Survey protocols

Southern Brown Bandicoot Digging (and Scat) surveys

Like all bandicoot species, Southern Brown Bandicoots dig in the soil in search of subterranean food sources (e.g. hypogeal fungi, soil-dwelling invertebrates, etc.). In doing so, bandicoots excavate characteristic conical pits in the soil. These conical pits can be used by trained observers to indicate bandicoot presence in an area. However, there is room for observer error and the potential to misidentify diggings created by other species, such as the Long-nosed Bandicoot and Swamp Rat, for those created by the Southern Brown Bandicoot.

The size of a particular block of land needing an assessment for Southern Brown Bandicoot presence/habitat suitability will determine the time required to adequately sample the area. The configuration of the parcel will determine whether line transects or a criss-cross pattern of searching is the most suitable technique for traversing the land. These decisions should be left to the discretion of the consultant.

Protocol

There are no specific guidelines available in the literature for using as a basis for developing protocols for searches for Southern Brown Bandicoot diggings. Furthermore, the effort required will depend on habitat complexity, ease of access, etc. We suggest as a minimum the following:

1) a two hour search per 1 ha of potential habitat in non-linear patches/blocks; or
2) a half hour search within a 10 m strip each side of a 100 m transect line in linear habitats (e.g. less than 50 m wide strips); and
3) in the case of doubt as to the identification of the species which excavated a digging, a photograph should be taken and forwarded to experienced Southern Brown Bandicoot researchers along with a description of the locality and habitat.

Hair-tube sampling

Various types of hair-tubes are available, and the effectiveness of different designs appears to vary between mammalian species (Andrew Murray pers. comm., and see Nelson 2006). Hair-tube sampling using Faunatech hair-tubes (Faunatech Pty Ltd, Bairnsdale, Victoria) has been successful in detecting the Southern Brown Bandicoot in the former Koo Wee Rup Swamp study area (e.g. see Ecology Australia 2006). However, unless studies clearly demonstrate that a particular design is superior in detecting this species, we don't advocate the use of any particular design over another type of hair-tube. Most designs are likely to have a varying success rate, due to the trap-shy nature of the Southern Brown Bandicoot.

The size of a particular parcel of land needing survey for the Southern Brown Bandicoot will determine the density of hair-tubes required to adequately sample the area with a higher density of hair-tubes achievable on smaller parcels. The configuration of the parcel will determine whether line transects or a grid pattern of hair-tube placement is the most suitable. These decisions should be left to the discretion of the consultant. However, we recommend a density

of one hair-tube every 20 m which equates to 25 hair tubes per ha. In other words, transect lines should comprise hair tubes spaced at c. 20 m intervals. Grids should compromise rows and lines of hair tubes with each hair tube spaced at c. 20 m intervals.

Protocol

1) Hair-funnels should be set along transect lines if the habitat being sampled is long and narrow (e.g. less than 50 m wide). Hair-funnels should be placed in a grid pattern if the habitat being sampled is rectangular or square-shaped.
2) Funnels should be baited with a mixture of peanut butter, rolled oats, honey and truffle oil,
3) Funnels should be placed on the ground and spaced at c. 20 m intervals.
4) The hair-tubes should be left in place in the field for approximately two weeks.
5) Wafers collected from funnels and yielding definite hair samples or possible hair samples (e.g. items where the identification is uncertain but may resemble hairs, such as fibre) should be forwarded to an experienced hair analysis consultant (e.g. Dr. Hans Brunner or Barbara Triggs) for identification of hair samples via the unique hair structure of mammal species (see Brunner and Coman 1974; Lobert et al. 2001; Brunner and Triggs 2002).

N.B. Faunatech hair-funnels should set during the cooler months only to avoid a bi-catch of small reptiles.

Surveillance Cameras

Surveillance cameras with motion sensing triggers can be employed as an effective means of determining the presence of Southern Brown Bandicoots in an area. Their success in detecting small and medium sized mammals such as the Southern Brown Bandicoot has been relatively high when compared to conventional techniques such as hair-tube sampling (Terry Coates, Rolf Willig and David Paull pers. comm.). However, surveillance cameras are most useful when there is recent indication or other reason to suspect bandicoot presence in an area (David Paull pers. comm.). In conjunction with methods that may yield indirect evidence of bandicoot occurrence such as digging searches or scat analyses, cameras can be used efficiently to definitively confirm the presence of bandicoots.

The use of surveillance cameras in the former Koo Wee Rup Swamp area is best suited to relatively large and secure areas (i.e. limited public access) within the Lang Lang vicinity, such as the Unimin Site, The Gurdies, Education Area or GMH Proving Ground, where the status of bandicoots is uncertain but anecdotal evidence provides reason to believe that they may persist. Ordinarily, the labour required to adequately survey these areas with conventional methods would be very high. Among the advantages of this technique is that despite the initial high costs of purchase, cameras can supply high quality data (e.g. definitive record, behavioural observations) and survey large areas over long periods of time, with little human involvement.

Cameras may be left in place for weeks or even months, substantially lowering labour costs (Scroggie 2008).

The use of surveillance cameras is a relatively new technique for studying wildlife and currently, the technology allows for the positive identification of species as small as marsupial mice, but not the identification of individual animals.

The detection range of a camera for small mammals is only a few meters, and the scent of bait may only carry for around 100 m. Therefore, when surveying large areas, it may be necessary to periodically move the cameras, as it is unlikely that enough cameras would be available to survey the area at once. This also extends survey time and accommodates for changes in bandicoot ranges, to maximise detection success.

There are no widely accepted protocols for the use of surveillance cameras to survey for bandicoots. However, some guidelines based on trials and research carried out by the University of New South Wales, are provided below (David Paull pers. comm.).

Guidelines

1) The size and configuration of the land being surveyed will ultimately determine the spacing and arrangement of cameras. However, a grid pattern may be suitable in most cases, with a pair of cameras set 100 m apart and pairs of cameras set 250 m apart. The number of cameras available would determine how often the cameras would need to be shifted to adequately cover the area. Use Cameras which take rapid fire stills (i.e. pseudo-video) for high quality images that allow the identification of species;
2) Place a steel star picket in the ground, and attach cameras to the picket, approximately 30 cm above the ground;
3) Place a sent attractant (i.e. bait station) near the camera, using a mixture of rolled oats, honey, peanut butter and truffle oil as bait. Truffle oil is not essential;
4) Leave cameras in place for 1-2 weeks. A rotating system of deployment, where cameras are left in place for a fortnight, then removed for a fortnight before being returned, may be best. The position of the camera may be moved within this time to extend the survey period and maximise detection success; and
5) Focus camera installation in areas with the most suitable bandicoot habitat, or where indirect evidence has been obtained (e.g. around diggings). Even within large areas of remnant vegetation, often only a portion of the area may be utilized by bandicoots.

14.2 Monitoring protocols

Monitoring of bandicoot populations across the forme Koo Wee Rup Swamp area will be required to evaluate the success or otherwise of management actions recommended in this plan. Small mammal trapping using a capture-mark-recapture technique is the most suitable means for ascertaining changes in population size, fecundity, survivorship, etc. A survey protocol for monitoring populations as part of this management plan is described below.

The persons undertaking the monitoring should be suitably qualified biologists experienced in small mammal capture, handling and measurement. They should also be holders of a current Research Permit under the *Wildlife Act 1975* and *Flora and Fauna Guarantee Act 1988* obtained from the Environmental Research Co-ordinator of the DSE, and should have Animal Ethics Approval from the Department of Primary Industries. A procedure for individually marking captured bandicoots would also need to be developed in association with DSE, together with a procedure for dealing with any sick or injured bandicoots (e.g. take animal to nearest vet or wildlife shelter).

Monitoring of core (habitat) populations (e.g. Dalmore - Koo Wee Rup Cluster and Bayles Cluster) to assess the success or otherwise of management actions should be undertaken as a priority as core populations are considered most important to the persistence of the species in the former Koo Wee Rup Swap study area. Monitoring of core populations would also provide better feedback about management actions because: these are a high management priority; and are likely to be the most stable population group in the study area, fluctuating less in response to stochastic events and environmental conditions. Monitoring of habitat links may not yield sufficient capture records to ascertain the status of bandicoots in an area, or the success of management actions, as trapping success can often be low especially when bandicoots are at low population densities.

The size and configuration of a particular parcel of land needing to be for Southern Brown Bandicoots will determine the density of traps required to adequately sample the area, as well as whether line transects or a grid pattern of trap placement is the most suitable. We recommend a density of one cage trap every 20 m (or 25 traps per ha). Transect lines should comprise traps spaced at c. 20 m intervals; grids should compromise rows and lines of traps with each trap spaced at c. 20 m intervals.

Protocol

1) Establish two 1 ha trapping grids each at the Inlets, Koo Wee Rup Swamp Lookout and Bayles Fauna Park;
2) Space traps at 20 m intervals;
3) Use cage traps with an appropriate dimension for capturing bandicoots (e.g. approximately 55 x 20 x 20 cm);
4) Treadle or bait-hook designed traps may either be used, but the treadle traps are easier to operate;

5) Traps with spring-loaded doors should not be used because of the potential risk of injury and death to capture animals;

6) Bait traps with a standard bait mixture of rolled oats, peanut butter, honey and truffle oil;

7) Cover each trap with polythene to protect captured animals from wind and rain and reduce visual disturbance to bandicoots while they are in the trap;

8) Place nesting material in the trap (e.g. straw, cotton wool, shredded newspaper);

9) Open traps in the evening, check for captured animals as early as possible in the morning and close the trap after checking until the next evening;

10) Transfer captured animals to a cloth bag for examination and weighing;

11) After restraining animals, weigh, sex and measure bandicoots and examine female bandicoots for the presence of pouch young or reproductive status;

12) After marking the animal or checking the identity of marked bandicoots, release at the point of capture immediately after examination;

13) undertake trapping (monitoring) twice per year, including once during the breeding (e.g. September) and non-breeding seasons (e.g. April) (the latter when the percentage survival of cohorts appeared to be highest at Cranbourne, (see Lobert and Lee 1990);

14) continue monitoring for the life of the Plan;

15) analyse data annually; and

16) evaluate demographic (e.g. trend) data against management objectives and actions.

15 References

Alessio, J. (2002). Bandicoot Studies at Scott Creek in 2000. *South Australian Naturalist* **76**; 19.

ANZECC (Australian and New Zealand Conservation Council) (2001). Biodiversity Conservation Research: Australia's Priorities. (Environment Australia: Canberra).

Bailey, C. (1996). Western Shield: bringing wildlife back from the brink of extinction. *Landscope* **11(4);** 41-48.

Bennett, A. F. (1988). Roadside vegetation: a habitat for mammals at Naringal, south-western Victoria. *Victorian Naturalist* **105(5);** 106-113.

Bennett, A. F. (1990). Habitat corridors and the conservation of small mammals in a fragmented forest environment. *Landscape Ecology* **4(2/3)**; 109-122.

Bennett, A. F. (1991). Roads, roadsides and wildlife conservation: a review. In 'Nature Conservation 2: The role of corridors.' Ed by D. A. Saunders and R. J. Hobbs (Surrey Beatty and Sons: Syndey).

Bennett, A. F. (1993). Microhabitat use by the long-nosed potoroo *Potorus tridactylus* and other small mammals in remnant forest vegetation of south-western Victoria. *Wildlife Research* **20**; 267-285.

Bennett, S., Brereton, R., Mansergh, I., Berwick, S., Sandiford, K. and Wellington, C. (1991). The potential effect of the enhanced greenhouse climate change on selected Victorian Fauna. Technical Report 123 (Arthur Rylah Institute for Environmental Research: Heidelberg).

Biosis (2008a). Flora and fauna of The Inlets, Koo Wee Rup, Victoria. Report prepared for Melbourne Water by J. Yugovic (Biosis Research Pty Ltd: Port Melbourne).

Biosis (2008b). Flora and Fauna Assessment: Desalination Project – Addendum Report. Spring 2008 Flora and Fauna Surveys. Report prepared for GHD Pty Ltd by N. Garvey, S. Koehler, D.Gilmore and R. Steer (Biosis Research Pty Ltd: Port Melbourne).

Biosis (2008c). Cranbourne East Precinct Structure Plan: Review of Ecological Issues. Report prepared for the Growth Area Authority by J. Yugovic (Biosis Research Pty Ltd: Port Melbourne).

Bloomfield, T. (2001). Foxes: Integrated Control. Landcare Notes. Updated by M. Rosier (2007). (Department of Primary Industries: Melbourne).

Braithwaite, R. W. (2002). Southern Brown Bandicoot. In 'The Mammals of Australia.' Ed by R. Strahan. (Australian Museum, Reed New Holland: Sydney).

Braithwaite, R. W. and Gullan, P. K. (1978). Habitat selection by small mammals in a Victorian heathland. *Australian Journal of Ecology* **3**; 109-127.

Broughton, S. K. and Dickman, C. R. (1991). The effect of supplementary food on home range of the southern brown bandicoot, *Isoodon obesulus obesulus* (Marsupialia: Peramelidae). *Australian Journal of Ecology* **16;** 71-78.

Brown, P. (1989). Management Plan for the Conservation of the Eastern Barred Bandicoot, *Perameles gunnii*, in Victoria. Ed. by J. H. Seebeck. Report to the Department of Conservation, Forest and Lands, Victoria and the World Wildlife Fund, Australia. Cited in: DEH (2005).

Burbidge, A. A. and McKenzie, N. L. (1989). Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. *Biological conservation* **50;** 143-198.

Brunner, H., and Coman, B.J. (1974). The Identification of Mammalian Hair. (Inkata Press: Melbourne).

Brunner, H. and Triggs, B. (2002). Hair ID: An Interactive Tool for Identifying Australian Mammalian Hair. (CD-ROM). (CSIRO Publishing, Collingwood).

Cardinia Shire (2004). Cardinia Shire Council Environment Management Strategy. (Cardinia Shire Council: Pakenham).

Cardinia Shire (2007). Cardinia Shire Council Weed Management Strategy. (Cardinia Shire Council: Pakenham).

Cardinia Shire (2008). http://www.cardinia.vic.gov.au

Catling, P (1988). Similarities and contrasts in the diets of foxes, *Vulpes vulpes* and cats, *Felis catus*, relative to fluctuating prey populations and drought. *Australian Wildlife Research* **15;** 307-317.

CEC (2008a). Management Plan for Bandicoot Corner. December 2008. (Cardinia Environment Coalition Inc: Pakenham).

CEC (2008b). Biolinks Project Action Plan: Linking Habitats Across the Western Port Catchment Central Region. (Cardinia Environment Coalition Inc: Pakenham).

Claridge, A. and Barry, S. C. (2000). Factors influencing the distribution of medium-sized ground-dwelling mammals in southeastern mainland Australia. *Austral Ecology* **25**; 676-688.

Claessen, S. (2007). Bunyip Sanctuary Master Plan. (Cardinia Shire Council: Pakenham).

Clarke, D. J. and White, J. G. (2008). Recolonisation of powerline corridor vegetation by small mammals: Timing and the influence of vegetation management. *Landscape and Urban Planning* **87;** 108-116.

Coates, T. D. (2008). The effect of fox control on mammal populations in an outer suburban conservation reserve. *Australian Mammalogy* **30(2);** 51-63.

Coates, T. D. and Wright, C. J. (2003). Predation of Southern Brown Bandicoots *Isoodon obesulus* by the European Red Fox *Vulpes vulpes* in South-East Victoria. *Australian Mammalogy* **25**; 107-110.

Coates, T. D., Nicholls, D. and Willig, R. (2008). The distribution of the Southern Brown Bandicoot in South Central Victoria. *The Victorian Naturalist* **125(5);** 128-139.

Cockburn, A. (1990). Life history of the bandicoots: developmental rigidity and phenotypic plasticity. In 'Bandicoots and Bilbies'. Ed by J.H. Seebeck, P.R. Brown, R.L. Wallis and C.M. Kemper. (Surrey Beatty and Sons: Sydney).

Commonwealth of Australia (2006). EPBC Act Policy Statement 1.1 – Significant Impact Guidelines. Matters of National Environmental Significance. May 2006. (Department of Environment and Heritage: Canberra).

Commonwealth of Australia (2008). Threat Abatement Plan for predation by the European Red Fox. (Department of Environment, Water, Heritage and the Arts: Canberra).

DEC (Department of Environment and Conservation, NSW). (2005). Draft Recovery Plan for the Southern Brown Bandicoot (*Isoodon obesulus*). (NSW DEC: Hurstville NSW).

DEH (Department for Environment and Heritage, SA). (2005). Recovery Plan for the Southern Brown Bandicoot in the Mount Lofty Ranges, South Australia 2004 to 2009. (Department for Environment and Heritage and Natural Heritage Trust).

DNRE (2002). 'Victoria's Native Vegetation Management: A Framework for Action.' (Department of Natural Resources and Environment: East Melbourne.)

DOI (2002). Melbourne 2030 planning for sustainable growth. October 2002. (Department of Infrastructure: Victoria).

DSE (2005). Advisory list of rare or threatened plants in Victoria – 2005. (Department of Sustainability and Environment: East Melbourne).

DSE (2006) Bayles Fauna Reserve Management Plan. (Department of Sustainability and Environment).

DSE (2007a). Advisory List of Threatened Vertebrate Fauna in Victoria - 2007. Department of Sustainability and Environment, East Melbourne, Victoria.

DSE (2007b). Atlas of Victorian Wildlife. Victorian Fauna Display. (DSE/Viridans Biological Databases: Brighton East).

DSE (2008a). Ecological Vegetation Class Benchmarks at: http://www.dse.vic.gov.au.

DSE (2008b). 'Interactive Mapping Tool' located at: http://nremap-sc.nre.vic.gov.au/MapShare.v2/

DSE (2008c). Victorian Desalination Project. Environmental Effects Statement. Volume 4. Environmental Effects of the Transfer Pipeline. (Department of Sustainability and Environment: Melbourne).

Dexter, N., Meek, P., Moore, S., Hudson, M. and Richardson, H. (2007). Population responses of small and medium sized mammals to fox control at Jervis Bay, southeastern Australia. *Pacific Conservation Biology* **13;** 283-292.

Dixon, J. M. (1966). Bandicoots: Partial survival in times of possible extinction. *Victoria's Resources* **8**; 62-63.

Donaldson, A. and Bennett, A. (2004). Ecological effects of roads: Implications for the internal fragmentation of Australian parks and reserves. Parks Victoria Technical Paper Series No. 12 (Deakin University: Victoria).

DPI (2008). Victorian Resources Online. Port Phillip and Westernport. http://www.dpi.vic.gov.au

Ecology Australia (2002). Proposed Bridge Re-alignment, Koo Wee Rup – Longwarry Road, Bayles: Additional Fauna Assessment. Report prepared by L. M. Williams, for VicRoads (Ecology Australia Pty Ltd: Fairfield).

Ecology Australia (2005a). Bayles – Yallock Creek Oil Spill – Preliminary Assessment of Potential Impacts on Matters of National Environmental Significance Report prepared for Scalzo Food Company by D.G Quin, L.E. Conole and A.R.G McMahon (Ecology Australia Pty Ltd: Fairfield).

Ecology Australia (2005b). Results of a Follow-up Growling Grass Frog Survey along Yallock Creek at Bayles. Report prepared by D.G. Quin, C. Wilson, L.V. Crowfoot and C. Campbell for VicRoads (Ecology Australia Pty Ltd: Fairfield).

Ecology Australia (2005c). Unimin Australia Limited, Lang Lang – Flora and Fauna Assessment. Report prepared by E.D. Moysey, C. Campbell, N. Roberts, C. Wilson, D. G. Quin and A.R.G. McMahon for Unimin (Ecology Australia Pty Ltd: Fairfield).

Ecology Australia (2006). Healesville- Koo Wee Rup Road- Southern Brown Bandicoot Survey. Unpublished report prepared by C. Renowden, D.G. Quin, and E.M. Moysey for VicRoads (Ecology Australia Pty Ltd: Fairfield).

Ecology Australia (2008a). Healesville – Koo Wee Rup Road Upgrade – Targeted Surveys for the Southern Brown Bandicoot. Unpublished report prepared by C. Renowden and R. Marr for VicRoads (Ecology Australia Pty Ltd: Fairfield).

Ecology Australia (2008b). Manks Road Bridges Upgrade – Preliminary Flora and Fauna Assessment. Unpublished report prepared by B.Schmidt and F.Sutton (Ecology Australia Pty Ltd: Fairfield).

FFGSAC (1991). Flora and Fauna Guarantee Scientific Advisory Committee. *Isoodon obesulus* (Shaw 1797) – Southern Brown Bandicoot. Final recommendation on a nomination for listing. (Flora and Fauna Guarantee: Melbourne).

FFGSAC (2008). Flora and Fauna Guarantee Scientific Advisory Committee. Preliminary recommendation on a nomination for listing, *Isoodon obesulus obesulus* Shaw 1797 – Southern Brown Bandicoot. Nomination no. 802. (Flora and Fauna Guarantee: Melbourne).

FFGSAC (2009). Flora and Fauna Guarantee Scientific Advisory Committee. Final recommendation on a nomination for listing, *Isoodon obesulus obesulus* Shaw 1797 – Southern Brown Bandicoot. Nomination no. 802. (Flora and Fauna Guarantee: Melbourne).

Friend, J. A. (1990a). Status of bandicoots in Western Australia. In 'Bandicoots and Bilbies'. Ed by J.H. Seebeck, P.R. Brown, R.L. Wallis and C.M. Kemper. (Surrey Beatty and Sons: Sydney).

Friend, J. A. (1990b). The numbat *Myrmecobius fasciatus* (Myrmecobiidae): history of decline and population recovery. *Proceedings of the Ecological Society of Australia* **16;** 369-377.

GAA (2008). Growth Area Authority Cranbourne East Structure Plan: Urban Structure Options Evaluation Report, Draft June 2008 (Growth Areas Authority: Victoria).

Green, R. H. (1979). A survey of the vertebrate fauna of the Sumac Forest, and Dempster Plains, North-West Tasmania. *Records of the Queen Victoria Museum* **65**; 1-9.

Heinsohn, G. E. (1966). Ecology and reproduction of the Tasmanian bandicoots (*Perameles gunnii* and *Isoodon obesulus*). *University of California Publications in Zoology* **80**; 1-107.

Kinnear, J. E., Onus, M. L. and Bromilow, R. N. (1988). Fox control and rock-wallaby population dynamics. *Australian Wildlife Research* **15;** 435-450.

Lechner, A. (2006). Population Viability Analysis of the Southern Brown Bandicoot in the Greater Melbourne Area. M.Sc. Thesis. RMIT University, Melbourne.

Lobert, B. (1985). The Ecology of the Southern Brown Bandicoot in South-East Australian Heathland. M.Sc. Thesis. Monash University, Melbourne.

Lobert, B. (1990). Home range and activity period of southern brown bandicoots (*Isoodon obesulus*) in a Victorian heathland. In 'Bandicoots and Bilbies'. Ed by J.H. Seebeck, P.R. Brown, R.L. Wallis and C.M. Kemper. (Surrey Beatty and Sons: Sydney).

Lobert, B. and Lee, A. K. (1990). Reproduction and Life History of *Isoodon obesulus* in Victorian Heathland. In 'Bandicoots and Bilbies'. Ed by J.H. Seebeck, P.R. Brown, R.L. Wallis and C.M. Kemper. (Surrey Beatty and Sons: Sydney).

Lobert, B. Lumsden, L. Brunner, H., and Triggs, B. (2001). An assessment of the accuracy and reliability of hair identification of south-east Australian mammals. *Wildlife Research* **28;** 637-641.

Maxwell, S., Burbidge, A. A. and Morris, S. (1996). 'The 1996 Action Plan for Australian Marsupials and Monotremes.' (Australian Marsupial and Monotreme Specialist Group, IUCN Species Survival Commission: Canberra).

May, S. A. and Norton, T. W. (1996). Influence of fragmentation and disturbance on the potential impact of feral predators in Australian forest ecosystems. *Wildlife Research* **23(4);** 387-400.

McIlroy, J. C. (1983). The sensitivity of Australian animals to 1080 poison. VI. Bandicoots. *Wildlife Research* **10**; 507-512.

McPhee, S. and Bloomfield, T. (2004). Strategy for the Eradication of Foxes from Phillip Island. Report prepared for the Phillip Island Nature Park (Agricultural Technical Services Pty Ltd: Werribee).

Menkhorst, P. (ed.) (1995). 'Mammals of Victoria. Distribution, ecology and conservation'. (Oxford University Press/ Department of Conservation and Natural Resources: Melbourne).

Menkhorst, P. W. and Seebeck, J. H. (1990). Distribution and conservation status of bandicoots in Victoria. In 'Bandicoots and Bilbies'. Ed by J.H. Seebeck, P.R. Brown, R.L. Wallis and C.M. Kemper. (Surrey Beatty and Sons: Sydney).

Moro, D. (1991). The distribution of small mammal species in relation to heath vegetation near Cape Otway, Victoria. *Wildlife Research* **18**; 605-618.

MPWBRF (Mornington Peninsula and Western Port Biosphere Reserve Foundation) (2008). Recovery of the Southern Brown Bandicoot *Isoodon obesulus obesulus* in the Mornington Peninsula and Western Port Biosphere Reserve and surrounding districts. A report on the public meeting, 14 November 2006. (Mornington Peninsula and Western Port Biosphere Reserve Foundation Pty Ltd: Hastings).

Nelson, J.L. (2006). A comparison of three hair-tube types for the detection of the spot-tailed quoll *Dasyurus maculatus* in south-eastern New South Wales. *Australian Mammalogy* **28;** 229-233.

NRE (2002). Management of Victorias Wetlands. Strategic Directions Statement (Natural Resources and Environment: East Melbourne, Victoria).

Opie, A. (1980). Habitat selection and diet of *Isoodon obesulus*. *Australian Mammal Society Bulletin* **6(2)**; 56.

Opie, A., Gullan, P. and Mansergh, I. (1990). Prediction of the geographic range and habitat preferences of *Isoodon obesulus* and *Perameles nasuta* in Gippsland. In 'Bandicoots and Bilbies'. Ed by J.H. Seebeck, P.R. Brown, R.L. Wallis and C.M. Kemper. (Surrey Beatty and Sons: Sydney).

Paull, D. (1995). The distribution of Southern Brown Bandicoot (*Isoodon obesulus obesulus*) in Southern Australia. *Wildlife Research* **22**; 585-600.

Paull, D. (1999). Habitat selection by the southern brown bandicoot (*Isoodon obesulus*) at multiple spatial scales. In 'Geodiversity: Readings in Australian Geography at the Close of the 20th Century.' Ed. by A. Kesby, J.M. Stanley, R.F. McLean and L.J. Olive. (School of Geography and Oceanography. University College, UNSW: Canberra).

Penman, T. D. and Slade, C. P. (2007). Is there value in reviewing distribution models? A case study using critical weight range mammals in southeastern Australia. *Pacific Conservation Biology* **13**; 227-234.

Platt, S. (1999). Rabbit control in wildlife habitat. Land for Wildlife Notes. (Department of Natural Resources and Environment: Victoria).

PLC (Public Land Consultancy) (2008). A review of the management of riparian land in Victoria. Report prepared for the Department of Sustainability and Environment (Public Land Consultancy: Fitzroy).

PoHC (2006). Report on the Port of Hastings Land Use and Transport Strategy. Consultation Draft September 2006. The Port of Hastings Corporation's Response to the Victorian Ports Strategic Framework (Port of Hastings Corporation: Victoria).

Pope, L. C., Storch, D., Adams, M., Moritz, C. and Gordon, G. (2001). A Phylogeny for the genus *Isoodon* and a range extension for *Isoodon obesulus peninsulae* based on mtDNA control region and morphology. *Australian Journal of Zoology* **49;** 411- 434.

Quin, D. G. (1985). Aspects of the feeding ecology of the bandicoots, *Perameles gunnii* (Gray 1838) and *Isoodon obesulus* (Shaw and Nodder 1797) (Marsupialia: Peramelidae) in southern Tasmania. B.Sc. Honours. Thesis. University of Tasmania.

Quin, D. G. (1988). Observations on the diet of the Southern Brown Bandicoot, *Isoodon obesulus* (Marsupialia: Peramelidae), in southern Tasmania. *Australian Mammalogy* **11**; 15-25.

Quin, D. G. (1992). Observations on prey detection by the bandicoots, *Isoodon obesulus* and *Perameles gunnii* (Marsupialia: Peramelidae). *Australian Mammalogy* **15**; 131-133.

Reese, N. (2000). A Study of *Isoodon obesulus obesulus* and the effects of pest species in Melville Gully, Belair National Park. Honours Thesis. Flinders University. Cited in: DEH (2005).

Rees, M. and Paull, D. (2000). Distribution of the southern brown bandicoot (*Isoodon obesulus*) in the Portland region of south-western Victoria. *Wildlife Research* **27**; 539-545.

Robertson, P. and Heard, G. (2002). Yallock Creek and Yallock Cut Amphibian Study. Report of a Field Evaluation of the Habitat for Amphibians in the Yallock Creek Area, south of the South Gippsland Highway. Report prepared for Melbourne Water by Wildlife Profiles. (Wildlife Profiles Pty Ltd: Heidelberg).

Richardson, D. G. (2003). Habitat preferences of the Southern Brown Bandicoot in Belair National Park. *South Australian Naturalist* **77**; 37-38.

Russell, B. G. and Banks, P. B. (2005). Responses of four critical weight range (CWR) marsupials to the odours of native and introduced predators. *Australian Zoologist* **32(2);** 217-222.

Sanderson, K. J., and Kraehenbuehl, J. (2006). Southern Brown Bandicoots *Isoodon obesulus obesulus* in Belair National Park. *Australian Mammalogy.* **28(2)**; 147-152.

Saunders, G., Coman, B., Kinnear, J. and Braysher, M. (1995). 'Managing Vertebrate Pests: Foxes' (Australian Government Publishing Service: Canberra).

Scroggie, M. P. (2008). An evaluation of occupancy methods for monitoring of Southern Brown Bandicoots in Gippsland, Victoria. Report prepared for the Department of Sustainability and Environment (Arthur Rylah Institute: Heidelberg).

Seebeck, J. H. (1977). Mammals in the Melbourne metropolitan area. *Victorian Naturalist* **94**; 165-171.

Seebeck, J. H. (1978). Diet of the fox *Vulpes vulpes* in a western Victorian forest. *Australian Journal of Ecology* **3;** 105-108.

Short, J. and Smith, A. (1994). Mammal decline and recovery in Australia. *Journal of Mammalogy* **75;** 288-297.

Short, J., Kinnear, J. E., Robley, A. (2002). Surplus killing by introduced predators in Australia – evidence for ineffective anti-predator adaptations in native prey species? *Biological Conservation* **103;** 283-301.

Smith, A. P. and Quin, D. G. (1996). Patterns and causes of extinction and decline in Australian Conilurine rodents. *Biological Conservation* **77**; 243-267.

Southwell, D. (2006). The sensitivity of population viability analysis to uncertainty about habitat requirements: Implications for the management of the endangered southern brown bandicoot (*Isoodon obesulus*). B.Sc. Honours Thesis. The University of Melbourne.

Southwell, D. M., Lechner, A., Coates, T. and Wintle, B. A. (2008). The sensitivity of population viability analysis to uncertainty about habitat requirements: Implications for the management of the endangered southern brown bandicoot. *Conservation Biology* **22(4);** 1045-1054.

Stoddart, M. D. and Braithwaite, W. (1979). A strategy for utilization of regenerating heathland habitat by the Brown Bandicoot (*Isoodon obesulus;* marsupialia, Peramelidae). *Journal of Animal Ecology* **48**; 165-179.

Thomas, L. N. (1990). Stress and population regulation in *Isoodon obesulus* (Shaw and Nodder). In 'Bandicoots and Bilbies'. Ed by J.H. Seebeck, P.R. Brown, R.L. Wallis and C.M. Kemper. (Surrey Beatty and Sons: Sydney).

TransNet (2007). Leongatha Rail Line. Reintroduction of Passenger Train Services. Review Summary and Transport Options, Assessment Report. Report prepared by N. Currie for Department of Infrastructure (TransNet Logistics Pty Ltd: Melbourne).

TSSC (2001). Threatened Species Scientific Committee (TSSC). Advice to the Minister for the Environment and Heritage from the TSSC on Amendments to the List of Threatened Species under the *Environment Protection and Biodiversity Conservation Act 1999.*

Twigg, L. E., Low, T. J., Martin, G. R. and Gray, G. S. (1999). A Review of the anti-coagulant pesticide Pindone (Vertebrate Pest Research Services: Agriculture Western Australia).

Victorian Government (2007). Directions for the Use of 1080 Pest Animal Baits in Victoria. (Victorian Government: Melbourne).

Weston (2002). Managing the Hooded Plover in Victoria: a review of Existing Information (Parks Victoria and Natural Resources and Environment, Victoria).

Winnard, A. L. and Coulson, G. (2008). Sixteen years of Eastern Barred Bandicoot *Perameles gunnii* reintroductions in Victoria: a review. *Pacific Conservation Biology* **14;** 34-53.

Yugovic, J. and Mitchell, S. (2006). Ecological review of the Koo Wee Rup Swamp and associated grasslands. *Victorian Naturalist* **123(5);** 323-334.

Zenger, K. R. and Johnston, P. G. (2001). Isolation and characterization of microsatellite loci in the Southern Brown Bandicoot (*Isoodon obesulus*), and their applicability to other marsupial species. *Molecular Ecology Notes* **1;** 149-151.

Zenger, K. R., Eldridge, M. D. B., and Johnston, P. G. (2005). Phylogenetics, population structure and genetic diversity of the endangered southern brown bandicoot (*Isoodon obesulus*) in south-eastern Australia. *Conservation Genetics* **6;** 193-204.

16 Acknowledgments

The authors would like to thank the following people for their assistance in preparing this document:

- Ian Stevenson – Cardinia Shire Council
- Lachlan Marshall – Casey City Council
- William Steele – Melbourne Water
- Andrew McMahon, Ruth Marr, Jamie McMahon, John Kershaw and Lisa Crowfoot – Ecology Australia
- Rolf Willig - Department of Sustainability and Environment, Gippsland
- Terry Coates – Royal Botanic Gardens Cranbourne
- David Nicholls – Mornington Peninsula and Western Port Biosphere Reserve Foundation
- John Hick – Department of Sustainability and Environment, Port Phillip
- Clare White – Department of Sustainability and Environment
- Rob Jones – Cardinia Shire Council
- Sarah Maclagan – Cardinia Environment Coalition
- Hans Brunner – Consultant Zoologist
- Darren Southwell – Climate Impact Sciences Department of Agriculture, Forestry and Fisheries
- Alex Lechner – RMIT University
- David Paull – University of New South Wales
- Malcolm Legg – Mal's Environmental and Ecological Services
- Jeff Yugovic – Biosis Research Pty Ltd
- Geoff Brown – Arthur Rylah Institute
- Geoff Heard – LaTrobe University, Bundoora
- Tim Bloomfield – Phillip Island Nature Park
- John White – Deakin University
- Tamara Griffiths – Bunyip Urban Landcare group
- Alan Cole – Bunyip Sanctuary
- Mark Cairns – Endangered Species Recovery
- Andrew Murray – Department of Sustainability and Environment
- David Martin - Bass Coast Parks and Reserves Parks Victoria
- Dan Bowen – Parks Victoria, Gembrook
- Corey Bixler - Cardinia Shire Council
- Matthew Driessen - Baw Baw Shire Council
- A. Rowe – Resident, Tooradin
- C. Manning – Resident, Cardinia

Appendix 1 Southern Brown Bandicoot Strategic Management Plan: Biodiversity Legislation and Policy

Legislation or Policy	Scope	When and where it applies	Relevance to the Southern Brown Bandicoot and the study area
Federal			
Environment Protection and Biodiversity Conservation Act 1999	Pertains to matters of National Environmental Significance including listed threatened species and ecological communities, listed migratory species and Commonwealth Marine Areas and Ramsar Wetlands. A proponent is obliged to refer matters to the Commonwealth Environment Minister if such values may be affected by a proposed action. The Department of Environment, Water, Heritage and the Arts (DEWHA) decides whether there will be a significant impact and if the action requires approval. The Commonwealth can intervene to modify or block an action if it deems this necessary for the protection of a species or community of national significance.	Public and Private land. A referral is necessary whenever a proposed action is considered likely to impact on an item of National Environmental Significance listed under the Act.	The Southern Brown Bandicoot is listed as Endangered under the EPBC Act Under the EPBC Act, a 'population' of an Endangered species is defined as either: ▪ a geographically distinct regional population, or collection of local populations; or ▪ a population, or collection of local populations, that occurs within a particular bioregion (EPBC Act Significant Impact Guidelines 2006). Considering the presence and distribution of bandicoots, we consider bandicoots within the former Koo Wee Rup Swamp area to be a 'population of an endangered species,' as defined under the EPBC Act. Any proposed development within the former Koo Wee Rup Swamp area which may impact on a population, or at least part of a population (as defined under the EPBC Act, see above), of Southern Brown Bandicoots would require a referral to DEWHA (also see Section 12 for decision guidelines). Under the EPBC Act, a National Recovery Plan is currently in preparation.
State			
Flora and Fauna Guarantee Act 1988	Lists species and ecological communities recognized as rare or threatened in Victoria. There are also provisions for listing of threatening processes. If a species is listed under the FFG Act, it requires the production of an Action Statement for their management. This is the State's primary legislature for flora and fauna; however, it is dated and poorly tied to the planning process. It effectively does not apply to private land.	Public land (may have implications for private to the extent planning authorities enforce).	Until now, the Southern Brown Bandicoot has been considered ineligible for listing under the FFG Act 1988, and so has not been protected by state legislation. The species was nominated for listing in 1990 but was rejected (FFGSAC 1991). At the time of the nomination, Menkhorst and Seebeck (1990) considered that the species was still well protected in flora and fauna reserves and therefore was not under immediate threat in Victoria. The Southern Brown Bandicoot has recently been re-nominated due to ongoing declines and threats across its range within Victoria. The Scientific Advisory Committee has made a final recommendation that species be supported for listing under the FFG Act (FFGSAC 2009).
Victoria's Biodiversity Strategy 1997	This strategy was produced as a requirement under the FFG Act 1988. The strategy sets out five key management objectives for biodiversity in Victoria: including the principle of Net Gain, maintenance and restoration of ecological processes and the present diversity of species and communities, no preventable decline in rare species or communities, and an increase in the variability of threatened items.	Released as a whole-of-Government policy statement on the protection and conservation of Victoria's biodiversity	Conservation of the Southern Brown Bandicoot is addressed in regards to the objectives of the biodiversity strategy.
Victoria's Native Vegetation Framework 2002 (DNRE 2002)	Victoria's Native Vegetation Framework is a policy is designed for the protection, enhancement and revegetation of native vegetation in Victoria. The Framework is based on the principle of a 'Net Gain' in vegetation. Under the Framework, all vegetation losses must be offset at an equal or higher value of the vegetation being lost, resulting in an overall gain in vegetation. Vegetation offsets are determined by the quality, quantity and conservation significance of the EVC in the bioregion. Under clause 52.17 of the planning scheme, all proposals to remove vegetation must follow a three step process. Steps 1 and 2 must be adequately addressed before step 3 can be considered: 1. To avoid adverse impacts; 2. If impacts cannot be avoided, to minimise impacts through appropriate consideration in planning; and 3. Identify appropriate offset options.	Private and public land. Net Gain is now incorporated into the Victoria Planning Provisions. Applies whenever the removal of a remnant patch of native vegetation and/or scattered old trees are proposed	If in the course of current and/or future developments, there is a requirement for the removal of native vegetation (e.g. bandicoot habitat), Net Gain offsets would apply to: ▪ Loss or alteration of a remnant patch; and ▪ Loss of old trees. A proposal to remove vegetation will need to be assessed against the relevant EVC Benchmarks. The former Koo Wee Rup Swamp area is considered to form part of the best 50% of habitat for the Southern Brown Bandicoot in the Gippsland Plain Bioregion, based on the distribution of records. Therefore, under Victoria's Native Vegetation Management – A Framework for Action (DNRE 2002), the Conservation Significance of the EVC will be elevated to Very High. This influences the quality and area of the offset required, and in this case offsets must be at least twice the area to be lost.

Legislation or Policy	Scope	When and where it applies	Relevance to the Southern Brown Bandicoot and the study area
Wildlife Act 1975	Lists protected fauna species. Section 12 specifies that DSE is responsible for management of wildlife reserves for the propagation or management of wildlife or preservation of wildlife habitat.	Public and private land.	A permit may be required under the Act to 'take' protected wildlife which may be directly or indirectly lost as a consequence of habitat clearance. If salvage and translocation of animals (e.g. Southern Brown Bandicoot) associated with any proposed development in the former Koo Wee Rup Swamp area is required, an application for a Management Authorization under the Wildlife Act would need to be submitted to DSE.
Catchment and Land Protection Act 1994 (CaLP Act) (amended 2003)	Provides a legislative framework for the management of land including the control of declared noxious weeds and pest animals. The 2003 amendments include increased maximum penalties for poor land management.	Private and public land. If pest plants or animals are detected (or other poor land management practices identified) land managers are given notice and fined if no action is taken.	Weeds and feral animals (e.g. foxes) that are declared under the Act require control in the study area and surrounds.
Environment Protection Act 1970 State Environmental Protection Policy (Waters of Victoria) 2003	Provides a legal framework to protect and rehabilitate Victoria's surface water. The policy recognises the benefits of protecting rivers, creeks, drainage lines and wetlands for ecosystem values and human uses. Impacts must not exceed specific EPA water quality objectives. Key aspects include minimising land disturbance (e.g. roading, forestry, construction), erosion, sedimentation, pollution, removal of riparian vegetation and instream barriers.	Applies to all sectors of the Victorian community, including all levels of government, and the public, private, business, industrial and domestic sectors.	The former Koo Wee Rup Swamp now encompasses many drainage-lines, creeks and rivers. Current and future management regimes will need to address potential impacts to these watercourses.
The Planning and Environment Act 1987	Provides for the protection of natural resources, ecological processes and genetic diversity through the State section, and for regional planning controls in all planning schemes. This Act established native vegetation retention controls: these require a controls require a planning permit to be obtained to remove, destroy or lop native vegetation (subject to certain exemptions).	Applies to private or public land greater than 0.4 ha. This 0.4 ha threshold does not necessarily apply if land is affected by a planning overlay (e.g. ESO, SLO). DSE is the mandatory referral authority for permit applications to remove: • More than 15 trees < 40 cm DBH (diameter at breast height); • More than 5 trees > 40 cm DBH; • More than 0.5 ha of an Endangered, Vulnerable of Rare EVC; and • More than 1.0 ha of a depleted or Least Concern EVC.	This Act is implemented through local Council and permits will be required to remove native vegetation.
The Crown Land (Reserves) Act 1978	Provides the framework for reserving areas as public land for certain purposes and reservation status of existing public land.	Private and public land. This Act enables the reservation, either temporarily or permanently, of any Crown lands which are required for any public purposes. This may include: • the preservation of areas of ecological significance; • the preservation of species of native plants; and • the propagation or management of wildlife or the preservation of wildlife habitat.	Land deemed to have high conservation value and/or areas necessary for the preservation of flora and fauna species may be reserved under the *Crown Land Act 1978.* Provides mechanisms for increasing the conservation status of land (e.g. from State Park to National Park etc.).
The Local Government Act 1989	Provides regulations for local community bylaws including conservation regulations and permit requirements for land clearance. Drainage is covered under this Act as well as in the *Water Act 1989*.	Private and Public land.	The Local Government Act 1989 sets a framework for governance in Cardinia Shire and City of Casey. These Councils undertake strategic and land use planning for their municipal districts. This would include refusal or issuing of permits for vegetation clearance, thus effecting protection of remaining Southern Brown Bandicoot habitat.

Legislation or Policy	Scope	When and where it applies	Relevance to the Southern Brown Bandicoot and the study area
The Water Act 1989	Establishes a framework for conservation and use of water, enhancement of environmental qualities of waterways and protection of catchments.	Public and private land	The former Koo Wee Rup Swamp now consists of many drainage-line, creeks and streams. Current and future management regimes will need to address potential impacts to these watercourses.
The Land Act 1958	Provides policy on dealing with Crown Land (e.g. selling, leasing etc), including issues with use.	Public and private land.	The Land Act 1958 administers agricultural permits for leasing or usage of public land, including water courses (water front access). Current and future land practices on Crown land need to reflect a conservation focus (i.e. cease stock access to water courses and riparian environs known to be important for the bandicoot).
Regional			
Port Phillip and Western Port Native Vegetation Plan (2006) and West Gippsland Native Vegetation Plan (2003)	These plans: (i) provide a reference document on the status of native vegetation across all land tenures; (ii) determine strategic directions and priorities for the protection, management, and replanting of indigenous vegetation; (iii) establish regional goals and targets; and, (iv) provide a regional framework for the application and assessment of native vegetation retention controls.	These plans are a key action of the Regional Catchment Strategies, Victorian Planning Provisions and Victorian Native Vegetation Management Framework.	Regional standards and priorities need to be taken into consideration when planning for revegetation and habitat enhancement for bandicoots.
The Port Phillip and Westernport Regional River Health Strategy (2007)	The Regional River Health Strategy aims to have all waterways with the Port Phillip and Western Port Catchment management area, in good ecological condition by 2025. This strategy focuses on protecting rivers within the catchment as well as wetland areas such as the internationally significant Ramsar sites of Western Port and Port Phillip Bay.	Public and Private Land. The River Health Strategy provides a region wide framework to protect rivers, creeks and wetlands.	This strategy provides focus for improving river health in the Western Port Catchment and includes major rivers and creeks including Bunyip and Tarago Rivers and Cardinia and Toomuc Creeks. Work objectives include revegetation of riparian zones, stabilizing stream banks, and improvements to current land management strategies.
Melbourne Water			
Environmental policy	Integrates safe environmental practice and protection of the environment in all Melbourne Water activities.	Melbourne Water land (i.e. beds and banks of rivers/creeks)	This management plan recommends that Melbourne Water reviews its management of waterways in the former Koo Wee Rup Swamp area, and develops an Operation Management Plan to address the issues associated with waterway management highlighted throughout the plan.
Sites of Biodiversity Significance Management Strategy 2007	Provides guidelines for the protection and recognition of sites meeting the criteria for a Site of Biodiversity Significance (SOBS). These sites are managed specifically to enhance biodiversity values and promote conservation of target flora and fauna on-site.	Sites of Biodiversity Significance recognized by Melbourne Water.	Cardinia Creek Retarding Basin and the Inlets Waterway Reserve are recognised as SOBS (Melbourne Water 2007). There should be a long-term aim to provide guidelines and specific management plan for each SOBS site.
Local	The Local Planning Policy (Cardinia Shire) contains the Municipal Strategic Statement (MSS) and Local Planning Policies. MSS encapsulates significant planning directions for the municipality and in turn provides the strategic basis for the application of the zones, overlays and particular provisions in the planning scheme. Further information can be found on the DSE web page (Planning Schemes On-line).	It applies to both public and private land. A planning scheme is binding on all people and corporations, on every Minister, government department, public authority and municipal council.	Some areas within the former Koo Wee Rup Swamp area which are known to support bandicoots are not zoned with a conservation focus or protected by the planning scheme. Rather, zoning reflects other land use requirements. This is a constraint in regards to conservation initiatives for the bandicoot. Therefore, the aim should be to undertake an amendment to the planning scheme, to develop a specific Southern Brown Bandicoot overlay, as a schedule of an Environmental Significance Overlay. An appropriate overlay should cover all areas of core habitat, habitat links, other known habitats and areas with significant remnant vegetation on private land.

Appendix 2 Southern Brown Bandicoot Literature Review

Species Information

Species description

The Southern Brown Bandicoot is a medium sized (400 - 1600 g) ground-dwelling marsupial, belonging to the family Peramelidae (Appendix 3, Plate 1). Like other members of this family it has a long tapered snout with a naked, tessellated nose. It has a compact body, large rump and a sparsely furred, pointed tail which is approximately half the length of its body. It has small, black eyes and small, rounded ears which barely extend above the crown. The dorsal surface of the coat is coarsely furred and typically grey-brown in colour. Barred, spiny guard hairs give a grizzled appearance of golden–brown flecks. The underbelly is more softly furred and creamy–white, as is the underside of the tail. The ventral and inner sides of the limbs are often yellow-grey. The fore legs are short and strongly clawed while the hind limbs are longer, resembling that of a macropod, with the second and third digits fused (syndactylus) for grooming. Sexual dimorphism is apparent from about 12 months of age, with males typically larger than females. Males continue to grow throughout their life, whereas females rarely grow beyond 600 g, reaching their peak at about 18 – 24 months (Lobert and Lee 1990).

The Southern Brown Bandicoot is most easily confused with the Long-nosed Bandicoot (*Perameles nasuta*), which often occurs in similar habitats and has an overlapping distribution in some parts of Victoria. The Long-nosed Bandicoot is generally larger, and is distinguished by a relatively longer body and snout, longer and more pointed ears, and by distinctively white hind feet.

Taxonomy and distribution

The Southern Brown Bandicoot (*Isoodon obesulus*) has a wide distribution across southern Australia. It is found on the south-eastern mainland (New South Wales, Victoria and South Australia), on the far south-west of the mainland (Western Australia), in Tasmania, and on some islands off the coast of South Australia. There is also an isolated and disjunct occurrence on the Cape York Peninsula, Queensland. Five geographically distinct sub-species are currently recognized (Braithwaite 2002). However, there is some debate surrounding the taxonomic classification of the species, with some workers advocating the recognition of only three sub-species (Pope et al. 2001, Zenger et al. 2005), based on low genetic diversity between geographic regions (Zenger and Johnston 2001, Zenger et al. 2005). The sub-species occurring in Victoria is the south-eastern mainland sub-species, *Isoodon obesulus obesulus*.

In Victoria, the Southern Brown Bandicoot is a predominantly coastal species of the coastal or fluviate plains, with a range that extends along the entire coast of Victoria, with gaps in areas of the Volcanic Plain and Latrobe Valley (Figure 10). It is rarely found more than 50 km from the coast line, except for in the Glenelg Plain, in the south-west of the state where its range extends 100 km inland along a band of sandy coastal plain, and for populations at Mt William in the Grampians and in the Dandenong Ranges (Menkhorst and Seebeck 1990, Opie et al. 1990,

Menkhorst 1995). Although it occurs at altitudes of up to 1000 m in the Grampians (Menkhorst and Seebeck 1990), the species is generally absent from eastern and western Victorian Uplands. Southern Brown Bandicoots are also known from Wilson's Promontory and the Yarra Ranges, and there are scattered records elsewhere in Victoria. Although large areas of apparently suitable habitat exist, it is absent from Islands such as French, Phillip, Snake and Sunday Islands (Menkhorst and Seebeck 1990).

The Southern Brown Bandicoot now has a patchy distribution over a much reduced range, with disjunct occurrences across its distribution. There are five main sub-populations of bandicoots in Victoria (Figure 10); East Gippsland population, the far west population (close to the South Australian border), Grampians population, Anglesea population and the south-central population (Melbourne down the Mornington Peninsula to Western Port and Wilson's Promontry).

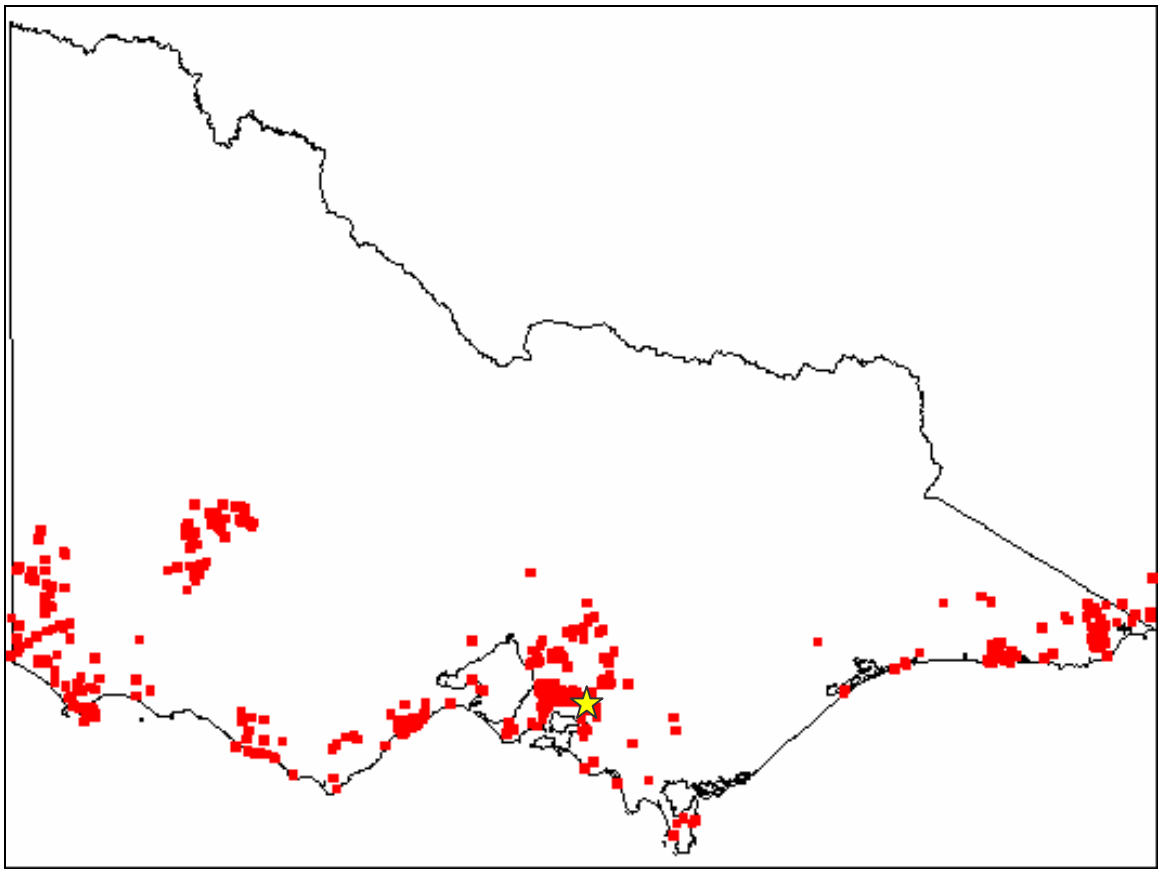


Figure 10 Southern Brown Bandicoot Strategic Management Plan: Victorian distribution of the bandicoot, and approximate location of the former Koo Wee Rup Swamp area

Habitat requirements

Low, dense vegetation cover is the primary habitat requirement of the Southern Brown Bandicoot (Heinsohn 1966, Friend 1990a, Moro 1991, Paull 1995, Claridge and Barry 2000, Sanderson and Kraehenbuehl 2006, Southwell 2006, Penman and Slade 2007). The species occupies a variety of habitats with this structural characteristic, ranging from heathland communities, shrubland, and heathy open forests and woodlands, to sedgelands along drainage lines (Braithwaite and Gullan 1978, Stoddart and Brathwaite 1979, Menkhorst and Seebeck 1990, Menkhorst 1995), and temperate rainforest in Tasmania (Green 1979). Their presence is usually associated with deep, well drained, sandy soils and 'dry' heath communities (Braithwaite and Gullan 1978, Opie et al. 1990, Menkhorst 1995, Paull 1999, Rees and Paull 2000, Southwell et al. in press), and they are typically absent from wet forests or tall open forests (Quin 1985, Menkhorst 1995).

In eastern Victoria the Southern Brown Bandicoot has been recorded in Swamp Scrub, Swampy Riparian Woodland, Heathy Woodland, Coastal Heathland, Silky Tea-tree (*Leptospermum myrsinoides)* Heathland, Lowland Sclerophyll Forest and Banksia Woodlands (Braithwaite and Gullan 1978, Stoddart and Braithwaite 1979, Opie et al. 1990, Ecology Australia 2008). In western Victoria, they appear to prefer Brown Stringybark Forest and Silver Banksia Heath rather than wetter Messmate forest and Scented Paperbark Scrub (Menkhorst 1995) and have also been recorded in Closed Heathland and Heathy Open Forests and Woodlands (Moro 1991).

In many areas of outer south-eastern Melbourne, where these habitats have diminished greatly in extent, bandicoots have been confined to remnants of vegetation in highly disturbed areas, which are often degraded, and have been known to make use of market gardens, rough pasture, roadside reserves (Seebeck 1977, Bennett 1990, 1993) and golf courses, presumably for foraging (Quin 1985, Rees and Paull 2000). In the suburban and semi-rural areas of south-eastern Melbourne as well as around Sydney and the Mt Lofty Ranges in South Australia, bandicoots have been observed living in residential areas, around and under houses and in gardens, making use of anthropogenic debris such as scrap woodpiles and car bodies for shelter (A. Rowe pers. comm.).

Where native vegetation cover is low, or has been degraded by weeds, Southern Brown Bandicoots have also been known to inhabit thickets of Blackberry (*Rubus fructicosus*), Gorse (*Ulex europaeus*), African Boxthorn (*Lycium ferocissimum*), and Broome (*Cytisus scoparius*), particularly around waterways and drainage lines (Heinsohn 1966, Quin 1985, Friend 1990, Paull 1995, Alessio 2002, Sanderson and Kraehenbuehl 2006). However, the use of Blackberry by bandicoots has also been observed in National Parks, where other, relatively intact and presumably suitable habitat is available (Richardson 2003, Sanderson and Kraehenbuehl 2006). Such weeds may provide a degree of protection from predators, not provided by native vegetation.

Nest sites are typically situated amongst dense vegetation, often under tussocks of sedges. The above-mentioned weeds, as well as abandoned rabbit burrows, have also been used by

bandicoots as permanent nest sites (Heinsohn 1966, Broughton and Dickman 1991, Sanderson and Kraehenbuehl 2006).

The importance of dense vegetation has been well illustrated for numerous small mammals (Moro 1991, Bennett 1993). Dense vegetation reduces the chances of detection by aerial and terrestrial predators, and reduces access for terrestrial predators. It also ameliorates local environmental and weather conditions and provides shelter (Bennett 1993). Early studies of bandicoot ecology revealed a preference for habitats with low vegetation cover, dense, yet sufficiently open at ground level to permit free movement (Heinsohn 1966). This structure allows bandicoots to escape rapidly whilst impeding predators. A study modelling the habitat preferences and distribution of Southern Brown Bandicoots in New South Wales, found that their probability of occurrence increased with the percentage of ground cover that was between 0.5 and 2.0 m tall, and was highest in areas with vegetation cover greater than 50 % (Clarridge and Barry 2000). Further modelling studies emphasized the density of shrub cover and ground cover as important variables influencing their presence (Southwell et al. 2008, Penman and Slade 2007). In Tasmania, they have been observed in a variety of habitats but never far from dense cover (Quin 1985).

Open habitats, adjacent to areas of dense cover are frequently used for foraging. At night bandicoots are often observed foraging in open areas such as golf courses, paddocks and gardens (Heinsohn 1966, Quin 1985), and diggings can often be seen in mown buffers along creeks and drains. In woodland habitats hypogeous (underground) fungi, a known food source for bandicoots, grows best where light penetrates through natural clearings (Bennett 1993).

Leaf litter may also be an important habitat resource for the Southern Brown Bandicoot. Research has shown that this species is often associated with a layer of leaf litter between 3-4 cm thick (Richardson 2003).

Diet and feeding ecology

Southern Brown Bandicoots are qualitatively opportunistic omnivores, consuming a combination of invertebrates, plant matter, seeds, and the sporocarps of hypogeous (underground) fungi. Their diet appears to reflect locally and seasonally abundant food items, sampling from the entire range of prey available to them (Quin 1985, 1988). They have been described as diet generalists and habitat specialists (Braithwaite and Gullan 1978). Dietary studies in Tasmania and Victoria have shown the major invertebrate items in the diet to comprise ants, larvae and scarab beetles, with spiders, mites, slaters, centipedes, millipedes, bugs, bees, wasps, earwigs, crickets, earthworms and Lepidoptera larvae consumed to lesser and varying degrees (Heinsohn 1966, Opie 1980, Quin 1985, 1988, Broughton and Dickman 1991). The Southern Brown Bandicoot has also been known to consume some small vertebrates such as skinks and tree frogs (Heinsohn 1966). A range of plant materials including leaves, grasses, mosses, seeds, roots and clover nodules, as well as Zygomycete and Gasteromycete fungi, are consumed, with grasses, seeds and clover root nodules forming major components (Quin 1985, 1988). During spring, the proportions of fungi in the diet increase (Quin 1985), and when ripe,

the fruits of Blackberry and African Boxthorn provide a seasonal supplement to the diet (Heinsohn 1966, Quin 1985, 1988).

Prey is primarily located by olfaction (Quin 1992). The strong fore limbs and claws of the Southern Brown Bandicoot are used to burrow in the topsoil for fungi, roots and invertebrates. The excavations produce distinctive, conical shaped diggings, which accommodate the snout of the animal (Plate 7). The soil is usually thrown behind the animal, and between the legs. These diggings can sometimes be confused with those of the Long-nosed Potoroo (*Potorous tridactylus*) or the Swamp Rat (*Rattus lutreolus*).

Home range and behaviour

Southern Brown Bandicoots are solitary animals, with a low social tolerance (Stoddart and Braithwaite 1979, Cockburn 1990). Aggression between males is often high unless they are of approximately the same size. Individuals nest alone amongst dense vegetation, usually in a shallow depression in the ground that is lined with grass, leaves and twigs. The upper covering may be mixed with earth to waterproof the nest (DEC 2005). Internally, the nest is a small chamber with an opening at either end. The roof and walls of the two openings collapse whenever the animal enters of leaves the nest, making it inconspicuous (Lobert 1990).

In most areas of its range, the Southern Brown Bandicoot is nocturnal, although, in Victoria and Tasmania, it has been known to be at least partly diurnal (Heinsohn 1966, Quin 1985). This is thought to be afforded by the dense vegetation they inhabit, which provides them with protection from predators. At Cranbourne, where the vegetation has been described as impenetrable and the predator proof fence keeps predator abundance low, the species is predominantly diurnal (Lobert 1990).

Home ranges reported for Southern Brown Bandicoots vary between 0.5 and 9 ha (DEC 2005). Factors such as habitat configuration and structure, productivity and the local abundance and dispersion of food influence the size and shape of home ranges (Broughton and Dickman 1991). However, most studies of home range have reported similar findings, within this range. At Cranbourne home ranges varied between 0.82 and 3.15 ha (Lobert 1990).

Some studies have suggested that the species is territorial (Heinsohn 1966, Thomas 1990), however, at Cranbourne, there is considerable home range overlap within and between the sexes (Lobert 1990), and it has been suggested that home ranges are flexible (Broughton and Dickman 1991). Male home ranges are often larger than female home ranges (Heinsohn 1966, Cockburn 1990, Broughton and Dickman 1991) suggesting a promiscuous or polygynous mating system (Cockburn 1990).

Reproduction and life history

In Victoria, maximum longevity for both males and females is about 3.5 years on average (Lobert and Lee 1990), four years has been recorded as the maximum in South Australia (Sanderson and Kraehenbuehl 2006).

The gestation period for *Isoodon* species is approximately 11.5 to 12.5 days, the shortest known for any mammal (Cockburn 1990). Development of young is rapid. Pouch life lasts approximately two months (Lobert and Lee 1990), and by three months, females reach maturity and by four and a half months, males reach maturity (Cockburn 1990). In some parts of Australia this means that individuals may breed in the season of their birth (Heinsohn 1966, Lobert and Lee 1990, Cockburn 1990), but in Victoria, individuals only reach sexual maturity in the breeding season following their birth (Lobert and Lee 1990).

Breeding in Victoria is generally seasonal and highly predictable, timed to coincide with a peak in food abundance (Stoddart and Braithwaite 1979, Lobert and Lee 1990), although in the Grampians, as in some other parts of Australia, breeding may occur year round (Lobert and Lee 1990). The breeding season usually commences around July/August and ends in December/January (Stoddart and Braithwaite 1979, Lobert and Lee 1990). The cessation of the breeding season has been linked to a decline in food and water availability, particularly drought, which impacts upon invertebrate abundance or accessibility (Stoddart and Braithwaite 1979, Cockburn 1990).

Females have eight teats which are rarely saturated by one litter. Litter sizes range from one to six, but are commonly two to three in south-eastern Australia (Stoddart and Braithwaite 1979, Cockburn 1990, Lobert and Lee 1990). All females breed at least once per season, regardless of food abundance (Lobert and Lee 1990). The extent of the breeding season determines the annual fecundity of females. At Cranbourne an average of two to three litters has been recorded per season per female (Lobert and Lee 1990).

Juvenile dispersal in bandicoots is high. Young disperse soon after weaning, or shortly before the birth of the next litter (Lobert and Lee 1990). Large numbers of juveniles disperse in the hope of colonizing habitat some distance from the mother's home range (Cockburn 1990). Local recruitment is very low (Stoddart and Braithwaite 1979), which also suggests high levels of juvenile dispersal and mortality (Cockburn 1990). At Cranbourne, 80% of new animals in the population came from elsewhere (Stoddart and Braithwaite 1979). This indicates that dispersal between different populations and habitats is important for the viability of populations.

The high fecundity of Southern Brown Bandicoots and the pattern of juvenile dispersal are consistent with a life history strategy that is well adapted to exploiting patchy and ephemeral environments such as heathland, which is prone to regular disturbance from fire (Cockburn 1990, Lobert and Lee 1990). It is also a strategy which allows them to rapidly exploit alienated environments such as rubbish tips, urban areas and farmland (Heinsohn 1966).

Decline and status

Bandicoots have suffered the greatest rate of extinction of any marsupial group, since European settlement (Maxwell et al. 1996). Despite its wide distribution range throughout Australia, the Southern Brown Bandicoot is patchily distributed, even within suitable habitat, and is rarely abundant where it does occur (Braithwaite and Gullan 1978, Rees and Paull 2000). Prior to the turn of the century the Southern Brown Bandicoot was widespread and described as one of the most common mammals in south-eastern Australia (Coates et al. 2008, DEC 2005). Evidence suggests that this species has suffered a considerable reduction in range and abundance in New South Wales and South Australia, as well as in Victoria, and appears to be restricted to a few isolated regions in each state (DEC 2005). The Western Australian subspecies has suffered a 40 % reduction in range (Friend 1990a). The Southern Brown Bandicoot has disappeared from most areas of intensive agricultural and urban development (Menkhorst and Seebeck 1990). It is estimated that the south-eastern mainland subspecies has suffered a 50-90 % decline in range (Maxwell et al. 1996).

Southern Brown Bandicoots are thought to be more common in south-western than south-eastern Victoria (Menkhorst and Seebeck 1990). However, recent surveys have demonstrated that large areas of suitable habitat in western Victoria are now unoccupied (Rees and Paull 2000), suggesting a general continuing decline across the state.

In eastern Victoria, large areas of apparently suitable habitat around Lang Lang and Nyora appear to be unoccupied, and populations in conservation reserves such as the Pines Flora and Fauna Reserve and the Langwarrin Flora and Fauna Reserve appear to have declined dramatically or disappeared. Bandicoots were common in the Langwarrin Flora and Fauna Reserve until the 1980s but have not been recorded there for many years (Coates et al. in press).

Southern Brown Bandicoots were common in pockets of heathland, rough pasture and market gardens in the outer south-eastern suburbs of Melbourne, until the late 1960s (Dixon 1966, Seebeck 1977). Since then, records have declined dramatically as a result of land clearance for housing developments and infrastructure, and the effects of predation by Red Foxes (*Vulpes vulpes*) on remaining isolated populations (Menkhorst and Seebeck 1990, Coates and Wright 2003, Lechner 2006).

Remaining populations in outer, south-eastern Melbourne are vulnerable, confined now to only a few remnants, reserves and corridors. Individual bandicoots or small family groups are sometimes sighted around houses and gardens, however, most remaining populations are small and isolated, confined to small fragmented habitats. A recent population viability analysis of populations around Cardinia, Casey, Frankston and the Mornington Peninsula predicted that most of these populations would disappear without active management (Lechner 2006, Southwell 2006, Southwell et al. 2008).

In contrast to other states, the Southern Brown Bandicoot has not been protected by Victorian legislation. Until recently, the Southern Brown Bandicoot was considered ineligible for listing under the FFG Act 1988, Victoria's prime legislation for the protection of fauna. A nomination for listing under the FFG Act was assessed by the Scientific Advisory Committee in 1990 and

1991. At the time of this nomination, Menkhorst and Seebeck (1990) considered that the species was still well catered for in a network of flora and fauna reserves and therefore was not under immediate threat in Victoria. As a consequence, the nomination was rejected (FFGSAC 1991). Despite this, only one population (Royal Botanic Gardens, Cranbourne) is secure and protected from predators. Furthermore, records of the species have declined substantially, and it has disappeared from many areas where it was once common.

Since European settlement, 17 species of mammals have become extinct in Australia, representing 50 % of worldwide mammalian extinctions (Short and Smith 1994). Most of the mammalian species which have become extinct or which are at risk of extinction, are small to medium sized species which fall within what has been termed the Critical Weight Range (35 g-5500 g) (Burbidge and McKenzie 1989). Mammals within this weight range are considered to be at greater risk of extinction due to introduced predators and herbivores, disease, pastoralism, altered fire patterns and climate changes (Burbidge and McKenzie 1989, Smith and Quin 1996). The Southern Brown Bandicoot falls within this category and extensive declines in range suggest that it is at similar risk without active management. Thus, it is our belief, and that of many others, that its conservation status in Victoria deserves review.

The Southern Brown Bandicoot was recently re-nominated for listing under the FFG Act, in the face of continuing declines. The Scientific Advisory Committee concluded that the nomination for the species satisfied criteria 1.1 and 1.2 under Section 11 of the FFG Act that: *the taxon is in a demonstrable state of decline likely to result in extinction*; and *the taxon is significantly prone to future threats which are likely to result in extinction*. In October 2008, the Scientific Advisory Committee made a preliminary recommendation and in February 2009 made a final recommendation, that the Southern Brown Bandicoot be supported for listing under the FFG Act. This listing is yet to be finalised.

Threats

As stated above, there is a combination of threats thought to be responsible for the decline of Southern Brown Bandicoots across its range. These are discussed further below.

Habitat loss, fragmentation and isolation

Habitat loss and fragmentation through the clearance of native vegetation is considered to be the greatest threat to biodiversity conservation (ANZECC 2001), and has been implicated in the decline of a variety of Australian mammal species (Maxwell et al. 1996). The large scale clearance of native vegetation for housing, agriculture and industry has also been implicated in the decline and local extinction of bandicoot populations in New South Wales (DEC 2005), South Australia (DEH 2005) and in several areas within Victoria (Seebeck 1977, Menkhorst and Seebeck 1990).

Habitat loss frequently results in fragmentation, where continuity of habitat is disrupted. Extensive habitat destruction and fragmentation leaves small fragments of vegetation remnants that are isolated. Threats and degradation within these small, fragments become greatly exaggerated, due to what has been termed as 'edge effects'. Fragmentation creates new edges leaving the smaller remaining patches with a higher perimeter to area ratio than larger patches. Long, narrow habitats in particular (e.g. roadside remnants), suffer more from edge effects than compact and rounded habitats. Consequently, these habitats suffer increased effects of microclimates (e.g. wind, rain and heat), increased weed invasion, and increases in noise (e.g. from vehicles) and other human disturbances (e.g. rubbish) around the edges.

Small habitats also have a limited capability to support numbers of individuals due to limited resources. The minimum patch size required to sustain a population of bandicoots is unknown. Even within areas of continuous suitable habitat, bandicoots may not occupy the entire site (Rees and Paull 2000). However, fragmentation in south-western Victoria has confined Southern Brown Bandicoots to larger forested fragments, greater than 8 ha (Bennnett 1990).

Risk to small populations

The isolation of habitats created by fragmentation limits the dispersal and movement of individuals between populations, affecting gene flow, population dynamics and demographics. This can lead to inbreeding depression and a reduction in genetic fitness. The reduction in genetic diversity means that the population is genetically, at greater risk of extinction. Isolated and small populations are also at greater risk of extinction from stochastic events such as fire or disease. This, among other things, can alter a population's age structure and sex ratios which in turn can limit its ability to recover. Isolated habitats also have a lower likelihood of re-colonisation following an extinction or stochastic event.

Habitat degradation

Habitat degradation and modification frequently leads to a loss of habitat by rendering areas of habitat unsuitable. This may be due to the loss or degradation of a key habitat element, such as ground layer vegetation.

Environmental Weeds

Environmental weeds have the potential to significantly degrade native vegetation and native fauna habitats, including vegetation which is considered to constitute good quality habitat for bandicoots. Weeds compete with native vegetation for nutrients, light and space, eventually displacing native plant species and inhibiting their regeneration. Paradoxically, Southern Brown Bandicoots have been shown to benefit from the dense cover provided by some of these weeds, both in areas where native vegetation is sparse or has been degraded, as well as in conservation reserves and National Parks (Heinsohn 1966, Paull 1995, Alessio 2002). Thus, the clearance of weeds can expose bandicoots to increased threats of predation. In New South Wales, the removal of Blackberry was found to alter the sizes of home ranges, while the removal of *Erica spp.* was found to cause a localised decline in the utilisation of an area by Southern Brown

Bandicoots (Reese 2000). Therefore, staged removal of weeds, following revegetation of native plants is recommended.

Grazing and Soil Compaction

Grazing by cattle in vegetation remnants can simplify and alter the vegetation structure by removing the understorey. Trampling by cattle can also reduce or inhibit the regeneration of vegetation and cause soil compaction which impacts upon soil invertebrates. The loss of understorey vegetation can facilitate and increase access for predators, increasing the vulnerability of bandicoots to predation, while soil compaction can lead to reduced food resources. Grazing pressures and soil compaction are considered to affect foraging patterns of Eastern Barred Bandicoots in Victoria, which avoid intensively grazed areas (Brown 1989).

Rabbits

The European Rabbit (*Oryctolagus cuniculus*) is thought to cause significant degradation to bandicoot habitat (DEH 2005). Grazing pressures by rabbits can inhibit the regeneration of understorey vegetation, destroy seed production, facilitate erosion, and create soil disturbance which provides opportunities for the invasion of environmental weeds (DPI 2008). Preferential grazing by rabbits may also alter vegetation structure and species composition, which can reduce areas of suitable habitat. Rabbits can also hamper revegetation efforts by ringbarking young plants and selectively grazing native seedlings.

In addition to this, large rabbit populations sustain high numbers of Red Foxes, increasing predation pressure upon bandicoots and small mammals in general (Seebeck 1978, Catling 1988). Smith and Quin (1996) termed this the hyper-predation hypothesis. Whilst an initial decline in rabbits may lead to prey switching, where foxes opportunistically prey on native species, numbers of foxes are expected to decline in the long term if rabbits are controlled.

Predation

Fox predation has been implicated in the population declines of most small to medium sized (critical weight range) ground-dwelling native mammal species in Australia (Burbidge and McKenzie 1989). Mammals within the critical weight range are particularly at risk because they fall within the preferred prey size range of the Red Fox (Smith and Quin 1996). Fox predation is listed as a Threatening Process under the EPBC and FFG Acts.

The Red Fox has been identified as a major predator of the Southern Brown Bandicoot across its mainland distribution (TSSC 2001). The abundance of Southern Brown Bandicoots in Tasmania and on Kangaroo Island has been attributed to the absence of the Red Fox on these islands. Studies of predator avoidance in New South Wales, found Southern Brown Bandicoots to be unresponsive to the odour of introduced foxes, which may at least partly explain their vulnerability (Russell and Banks 2005).

Although previous studies of fox scat analyses have not identified Southern Brown Bandicoots to be a major component of the diet of Red Foxes, Coates and Wright (2003) suggest that this

simply reflects the low abundances of bandicoots. At the Botanic Gardens in Cranbourne, which supports the largest population of bandicoots in the South-Central district, bandicoots were the third most common item in the diet of Red Foxes (Coates and Wright 2003).

Domestic stray and feral cats (*Felis catus*) and presumably dogs (*Canis familiaris*), are also thought to prey on Southern Brown Bandicoots (Lobert 1990, Rees and Paull 2000). However, there is a paucity of data regarding the impacts of predation by cats and dogs. Although predation by cats on the Eastern Barred Bandicoot (*Perameles gunnii*) and Long-nosed Bandicoot (*Perameles nasuta*) has been well documented in the literature, most reports of cat predation on Southern Brown Bandicoots have been anecdotal (DEH 2005). Generally, cats are not considered as great a threat to small native (or critical weight range) mammals as foxes (May and Norton 1996, Lechner 2006). However, mammals smaller than the critical weight range may be at greater risk of predation by cats. Native predators of the Southern Brown Bandicoot include quolls, diurnal and nocturnal raptors and tiger snakes (Heinsohn 1966, Lobert 1990, Rees and Paull 2000).

Vulnerability to 1080 poison

Fox baiting is routinely carried out with the compound 1080 (sodium monofluroacetate), a poison that is naturally present in a number of Australian native plants. It is widely accepted that herbivorous mammals in Western Australia have a very high tolerance of 1080 poison through natural exposure to the poison in native plants. Although these plants do not naturally occur in eastern Australia, bandicoots are more tolerant of 1080 poison than most other mammals in eastern Australia (McIlroy 1983). It has been shown that bandicoots would have to ingest twice the amount of 1080 than contained in a standard dose bait, to receive a lethal dose. Thus, the risk posed by 1080 fox baiting to Southern Brown Bandicoots is considered to be minimal (McIlroy 1983, DEC 2005). However, McIlroy (1983) noted that bandicoots may be capable of consuming enough 1080 used in rabbit baits to receive a lethal dose, but this would depend on the palatability of the bait.

Road mortality

Roads can not only create a physical barrier to the movement and dispersal of animals across the landscape, the vehicular traffic carried by roads also poses a mortality risk where suitable habitat is near to, or intersected by roads (Bennett 1991). Species that are attracted to some aspect of roadside reserves are most frequently killed by vehicles. Thus, the risk of collision with traffic is trebled when suitable habitat present in road reserves is utilised by animals for foraging, shelter or dispersal. Species which have a high rate of dispersal, such as bandicoots, are particularly at risk from road mortality (Donaldson and Bennett 2004).

The effects of road mortality on Southern Brown Bandicoots in Australia have not been quantified, however, road mortality has been shown to exert a significant impact on populations of species, throughout the world, that are declining or have restricted distributions (Bennett 1991).

Effects of drought and a drying climate

Although current climate change modelling may be too simplistic to realistically or precisely determine future environmental effects, it is possible that a change in climate can affect the distribution of bandicoot habitat, through the migration of bioclimates which support suitable habitats. Climate change scenarios predict a bioclimate contraction away from coastal areas, including from several major National Parks (Bennett et al. 1991). Rapid climate change accentuates the need for changes in range. However, given the current agricultural landscape matrix and limited connectivity across the landscape to facilitate this migration, an increase in habitat loss and fragmentation may be more likely, as drought can reduce the amount of vegetation cover available.

A drying climate can also have indirect impacts on bandicoots, with the drying of soils which can affect macro-invertebrate abundance. Reductions in food availability or quality can impact upon individual animals and wildlife populations in a number of ways, including a reduction in body mass, reduced reproduction, biased sex ratios, larger home ranges and lower densities, and ultimately death. The decline of the Eastern Barred Bandicoot, at several sites of reintroduction has been at least partially attributed to drought conditions (Winnard and Coulson 2008). If the abundance of rabbits also declines, then Red foxes could switch to bandicoots as their preferred prey.

Appendix 3 Plates

Plate 1 Southern Brown Bandicoot (*Isoodon obesulus obesulus*)

Plate 2 Vegetation adjoining Koo Wee Rup Swamp Lookout area, core habitat (February 2008)

Plate 3 Koo Wee Rup Drains, the southern section, upstream of the South Gippsland Highway, core habitat (February 2008)

Plate 4 The Inlets, east side of Cardinia Creek, downstream of the South Gippsland Highway, bandicoot remains were found in fox scats (core habitat) (February 2008). Swamp Skinks were recorded here also in 2008

Plate 5 Vegetation adjoining the South Gippsland Railway Line, core habitat (May 2008)

Plate 6 Yallock Creek, interface between grazed (left) and un-grazed (right) sections, c. 500 m upstream of Bayles Longwarry Road, core habitat (June 2008)

Plate 7 Typical bandicoot diggings observed along the levees of Yallock Creek, core habitat (June 2008)

Plate 8 Private property on the corner of Ballarto and Tooradin-Station Road, Cardinia, land owners are revegetating areas to create habitat for bandicoots. A fox scat with bandicoot hair was found on this property, habitat patch (July 2008).

Plate 9 Typical heath woodland vegetation at the Unimin mine and Lang Lang Nature Conservation Reserve, highly suitable potential habitat (December 2004)

Plate 10 Lang Lang Bushland Reserve, in Lang Lang, potential habitat (July 2008)

Plate 11 Swampy Riparian Woodland adjoins Yallock Creek , north of the South Gippsland Highway, requires rehabilitation, potential habitat (July 2008)

Plate 12 Section of Cardinia Creek drains, from Island Road, saltmarsh on edges and exotic grasses on the levees, habitat link (July 2008)

Plate 13 Habitat patch on Tonimbuk Road, south of the Princes Freeway, Damp Heathy Woodland, potential habitat (August 2008)

Plate 14 South Gippsland Railway Line, south of Cardinia Township, habitat link (potential within and between clusters) with dense Blackberry providing cover (August 2008).

Plate 15 Roadside vegetation along Boundary Drain Road, between Koo Wee Rup and Bayles, potential habitat link (June 2008).

Plate 16 Wetland on Yallock Creek downstream of the Bayles-Longwarry Bridge showing extent of instream habitats, adjoining terrestrial vegetation is habitat link (August 2004)

Plate 17 Same wetland as Plate 16, showing extent of drying, grazing and pugging (February 2006)

Plate 18 Ararat Creek/Drain and associated levees, part of a potential habitat link between Cardinia and Nar Nar Goon - Longwarry (August 2008)

Appendix 4 Glossary

Dimorphism: Of two forms or difference in morphology (e.g. size differences). Sexual dimorphism refers to a difference in a trait between males and females.

Dispersal: The movement of an organism; often when an individual moves away from its place of birth (natal dispersal) or breeding site (breeding dispersal). Dispersal is affected by a number of factors including the shape and size of the source area, presence or absence to habitat leading to a destination area and dispersal capability of the species.

Dispersal barrier: An area of unfavourable habitat that can pose a physical or psychological barrier to movement of an organism across it, preventing dispersal

Diurnal: Meaning during the day time. Often applied to describe a species daily rhythm of being active during daylight hours

Fecundity: The reproductive capacity of an individual to produce viable offspring

Gasteromycete: Fungi of the Phylum Basidiomycete. Reproduces through spores contained in a fruiting body

Genetic fitness: The ability of a species or individual organism to adapt and respond to natural selection. Depends of the amount of genetic variability; higher levels of genetic variability mean an increased capacity to adapt and evolve with changing conditions

Inbreeding depression: A loss in genetic diversity/genetic fitness due to inbreeding leading to a loss of the evolutionary capacity of the species (i.e. inbreeding reduces genetic variability and results in less successful matings and production of vigorous, viable offspring)

Lepidoptera: Order of insects that includes the moths and butterflies

Metapopulation: A set of local populations connected by dispersal. The metapopulation may persist if local extinctions are balanced by re-colonisation

Olfaction: Detection by means of smell

Polygynous: A mating system in which a male has more than one female partner

Population Viability Analysis: A mathematical representation about what biologists believe to be true about a species. Usually involves a systematic examination of the interacting factors that affect a population and make it vulnerable to extinction. The probability of extinction is assessed within a specified time frame, under certain circumstances and a certain set of life history variables. Allows the comparison of a number of different management scenarios under different conditions in regards to the probability of extinction

Recruitment: Immigration or birth of a new individual

Ramsar Site: Ramsar Sites/Wetlands are internationally important wetlands listed under the Convention on Wetlands (i.e. the Ramsar Convention). These wetlands are important especially

in regard to total numbers and/or numbers of species of waterbird, and are also matters of national environmental significance, listed under the EPBC Act

Stochastic events: Short term random or unpredictable events such as fire, flood, drought and disease

Viability: The capacity for survival and growth of a species/population. The long-term viability of a species refers to its ability to persist for many generations over a long period of time

Zygomycete: Fungi belonging to the Phylum Zygomycota

Appendix 5 Southern Brown Bandicoot Field Surveys

Field surveys throughout the former Koo Wee Rup Swamp area were undertaken prior to the development of this management plan to:

- Clarify the distribution of Southern Brown Bandicoots in the study area;
- Characterise and determine the importance of known bandicoot habitats;
- Identify potential habitat in the study area; and
- Identify potential habitat links along which suitable habitat occurs or where revegetation could be undertaken to increase connectivity across the landscape.

This was done in conjunction with aerial photographs, EVC maps, and maps showing records of bandicoots in the area that were collected from a number of sources, to gain an appreciation of the landscape context of bandicoots and their habitats in the former Koo Wee Rup Swamp area. The field surveys were also carried out to glean an understanding of the threats to bandicoots in the study area and opportunities for management.

Field surveys were carried out between 24 June and 24 July 2008. Faunatech Hair tubes were employed to survey for bandicoots in additional areas to where they were already known from and where habitat appeared suitable.

Faunatech Hair-tubes are injection moulded half-tubes, with glue covered plastic wafers placed and secured across their ceiling. The funnel is baited a standard bait mixture of peanut butter, rolled oats and honey. For bandicoots, small amounts of truffle oil can be added to increase the attractiveness of the bait. Fauna attracted to the scent of the bait enter the funnel leaving behind hairs that brush against the sticky wafer. Mammals have a unique hair structure and hair samples may be identified to species level (Brunner and Coman 1974, Brunner and Triggs 2002).

A total of 125 hair-tubes were set out in transects within patches of potential habitat and along potential habitat links throughout the former Koo Wee Rup Swamp area. Potential habitat was determined by assessing the suitability of the habitat in regards to structure, and density of understorey vegetation. Potential habitat links were identified by examining corridors of vegetation near clusters of Southern Brown Bandicoot records that could feasibly provide a link to another cluster, and by assessing the suitability of the vegetation within the corridor.

Hair-tubes were set along roadside reserves, riparian corridors of creeks and drainage lines, as well as within remnant patches. This was done to help clarify the distribution of Southern Brown Bandicoots, but mostly to help to establish which habitat corridors may be providing links between cluster/areas that are utilised by bandicoots. Hair-tubes were left in place for two weeks and then collected. Any wafers containing hair samples were sent to Hans Brunner (zoologist) for identification.

In addition to this, many areas where the habitat appeared suitable for Southern Brown Bandicoots were traversed on foot. During this time, the areas were scanned for any signs of bandicoot presence, such as scats or diggings. Predator scats were also collected opportunistically and sent to Hans Brunner for the analysis of the hair content.

No records of the Southern Brown Bandicoot were obtained from hair identified in hair-tubes. However, during the course of field assessments, evidence of their presence was established at four sites through indirect signs and hair identified from predator scats. The table provided below summaries the records of Southern Brown Bandicoots in the study area, collected during the field surveys.

Date	Location	Waypoint/s	Record	Habitat
24/6/08	Old pine plantation adjoining Primary School, Bunyip	E 55 H 387761 N 5788193	Diggings	Disused Pine plantation with a very dense and mainly exotic understorey. Also many native sedges present. Diggings abundant within plantation and adjoining strip of lawn at the school car park. Sandy soils.
17/7/08	Yallock Creek, Bayles	E 55 H 375395 N 5773693; and E 55 H 375458 N 5773779	Diggings and bandicoot scats	High abundance of diggings along the levees within the narrow mown strip of grass adjacent to dense shrubby vegetation. Contains mixture of native and exotic species.
18/7/08	Ballarto Road, Cardinia	E 55 H 359732 N 5777175	Hairs identified from predator scat	Predator scat found in residential garden. Resident has regularly reported bandicoots living in anthropogenic debris around house and garden.
24/7/08	Yallock Creek at Murray Road, Bayles	E 55 H 376652 N 5775610	Diggings and dead specimen of juvenile male bandicoot	Numerous diggings observed along the levees within the narrow mown strip of grass. Male specimen found at the same site, with head partially missing. Presumed to be a cat kill (Terry Coates pers. comm.).

The known distribution of bandicoots in the former Koo Wee Rup Swamp area was determined by the collation of recent and past records from:

- Atlas of Victorian Wildlife (DSE 2007b)
- Southwell 2006
- DSE- Gippsland Office
- CEC (public sightings)
- Ecology Australia (2006a, b)
- MPWBRF
- Mal's Environmental and Ecological Services

Appendix 6 The Gibb Activity Index (1-10) for estimating rabbit densities

Scale	Description of Dung Densities
1	Very few droppings, sometimes grouped and overlooked
2	Very infrequent heaps; little if any scatter
3	Infrequent heaps; very light and patchy scatter
4	Frequent heaps; light and patchy scatter
5	Heaps occasionally within five paces of each other; moderate scatter over almost whole area
6	Heaps often within 5 paces of each other; moderate scatter over whole area
7	Usually two or three heaps within five paces of each other; dense scatter
8	Usually three or more heaps within five paces of each other; dense scatter over whole area
9	Some heaps almost merging; scatter very dense
10	Some heaps merging; very dense scatter overall