The use by vertebrate fauna of the Slaty Creek Wildlife Underpass,

Calder Freeway, Black Forest, Macedon, Victoria.

by

Rodney Abson

B.A. (Nature Tourism)

A dissertation submitted in partial fulfilment of the requirements for the degree of Masters of Environmental Management (Coursework), Centre for Environmental Studies, School of Geography and Environmental Studies, University of Tasmania

February, 2004
Dedication

For the animals that lose their lives on Australian roads.

Statement of authenticity

This dissertation contains no material which has been accepted for the award of any other degree or graduate diploma in any tertiary institution. To the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except when due reference is made in the text of the thesis.

Some parts of the introduction, results, discussion and recommendations have previously appeared in ‘Slaty Creek Wildlife Underpass Study – Final Report’ by Abson & Lawrence (2003).

Rodney Abson
20th February 2004

Declaration of consent

I agree that this dissertation may be available for copying.
Abstract

The Slaty Creek Wildlife Underpass, built as part of the Calder Freeway at Macedon, Victoria, was monitored for a 12-month period to establish its use by vertebrate fauna. Two control sites were established on either side of the underpass in the adjacent Black Forest. A monitoring regime of 14 methods was used, targeting various fauna groups, including ground dwelling mammals, arboreal or semi-arboreal mammals, reptiles, amphibians and birds. Approximately two-thirds of the total number of species detected throughout the monitoring period, across all sites, were detected within the Slaty Creek Underpass. With at least four species of reptile, six species of amphibian, 24 confirmed and seven unconfirmed mammal species and 37 bird species within or above the underpass, the Slaty Creek Underpass has been shown to be one of the most diversely populated underpasses ever studied. Several culverts and a smaller underpass nearby the Slaty Creek Underpass were also monitored and were shown to have fewer species passing through them than the Slaty Creek underpass. There were some species of birds and mammals that were detected in the surrounding forest, but never within the underpass, but were generally detected on too few occasions to provide for statistical analysis. Statistical analysis did demonstrate that native and some introduced species demonstrated an attraction to the underpass, whilst some other native species were rarely detected within the underpass, and were more often detected within the surrounding forest. The Slaty Creek Underpass could be further enhanced with the use of rope canopy bridges or glider poles, suitably designed and maintained fencing and enhanced revegetation within the underpass.
Acknowledgements

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# TABLE OF CONTENTS

Dedication ........................................................................................................... ii
Statement of authenticity ................................................................................... ii
Declaration of consent ......................................................................................... ii
Abstract ............................................................................................................... iii
Acknowledgements ............................................................................................. iv

## CHAPTER 1 - INTRODUCTION

1.1 Introduction .................................................................................................... 1
1.2 Slaty Creek Underpass study site ................................................................. 2
1.3 Aims ............................................................................................................... 8
1.3.1 Constraints of the study ........................................................................... 8
1.4 Thesis outline ............................................................................................... 9

## CHAPTER 2 - LITERATURE REVIEW ................................................................ 11

2.1 Chapter outline ............................................................................................. 11
2.2 The interaction of roads with wildlife ........................................................... 11
2.3 Road networks ............................................................................................ 12
2.4 Wildlife threatened by roads ......................................................................... 13
2.5 Positive interactions of wildlife with roads .................................................... 14
2.6 Negative interactions of wildlife with roads .................................................. 16
2.6.1 Barriers to movement between suitable habitats .................................... 18
2.6.2 Population sink through increased mortality ............................................ 18
2.7 Species behavioural responses to roads and vehicles ................................... 21
2.8 Means for making roads more wildlife friendly ............................................. 21
2.8.1 Driver Warning and fauna exclusion ....................................................... 21
2.8.2 Prevention of animal access to roads ....................................................... 24
2.8.3 Building structures that allow animal passage ......................................... 26
2.8.4 Habitat re-creation or modification ......................................................... 32
2.9 Determination of effectiveness ..................................................................... 33
2.9.1 Evaluation and measures of effectiveness ............................................... 36
2.9.2 Target species ........................................................................................ 37
2.9.3 Ineffectiveness evaluation ...................................................................... 37
2.10 Functions of animals in relation to roads and crossing structures ............... 38
2.10.1 Species Groups ..................................................................................... 38
2.10.2 Amphibians and Reptiles ...................................................................... 38
2.10.3 Mammals ............................................................................................. 39
2.10.3.1 Large mammals ................................................................................ 39
2.10.3.2 Medium sized mammals ................................................................. 40
2.10.3.3 Small-sized mammals ...................................................................... 40
2.10.4 Birds .................................................................................................... 41
2.10.5 Invertebrates ....................................................................................... 41
2.10.6 Fish ..................................................................................................... 42
2.11 Predator & prey relationships ..................................................................... 42
2.12 Summary .................................................................................................... 42

## CHAPTER 3 - METHODOLOGY ....................................................................... 44

3.1 Study sites and sampling times ...................................................................... 44
3.1.1 Study site information ............................................................................ 44
3.1.1.1 Dimensions of Slaty Creek Wildlife Underpass ................................. 44
3.2 Data collection period ................................................................................. 46
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3</td>
<td>Vegetation monitoring techniques</td>
<td>47</td>
</tr>
<tr>
<td>3.3.1</td>
<td>Vegetation quadrats</td>
<td>47</td>
</tr>
<tr>
<td>3.3.2</td>
<td>Vegetation mapping</td>
<td>48</td>
</tr>
<tr>
<td>3.3.3</td>
<td>Line distance survey</td>
<td>48</td>
</tr>
<tr>
<td>3.4</td>
<td>Fauna</td>
<td>49</td>
</tr>
<tr>
<td>3.4.1</td>
<td>Monitoring techniques</td>
<td>49</td>
</tr>
<tr>
<td>3.4.2</td>
<td>The methods used to monitor fauna in and around the underpass</td>
<td>50</td>
</tr>
<tr>
<td>3.4.2.1</td>
<td>Active Searches</td>
<td>52</td>
</tr>
<tr>
<td>3.4.2.2</td>
<td>Audio recordings</td>
<td>52</td>
</tr>
<tr>
<td>3.4.2.3</td>
<td>Bird Surveys</td>
<td>52</td>
</tr>
<tr>
<td>3.4.2.4</td>
<td>Elliott Traps</td>
<td>52</td>
</tr>
<tr>
<td>3.4.2.5</td>
<td>Hair Funnels</td>
<td>56</td>
</tr>
<tr>
<td>3.4.2.6</td>
<td>Harp Trap &amp; Anabat</td>
<td>57</td>
</tr>
<tr>
<td>3.4.2.7</td>
<td>Incidental Observations</td>
<td>57</td>
</tr>
<tr>
<td>3.4.2.8</td>
<td>Nest Boxes</td>
<td>57</td>
</tr>
<tr>
<td>3.4.2.9</td>
<td>Pitfall Traps</td>
<td>57</td>
</tr>
<tr>
<td>3.4.2.10</td>
<td>Road Walk</td>
<td>57</td>
</tr>
<tr>
<td>3.4.2.11</td>
<td>Sand Tray</td>
<td>58</td>
</tr>
<tr>
<td>3.4.2.12</td>
<td>Scat analysis</td>
<td>58</td>
</tr>
<tr>
<td>3.4.2.13</td>
<td>Spotlighting</td>
<td>59</td>
</tr>
<tr>
<td>3.4.2.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.5</td>
<td>Methods used for evaluation of the effectiveness of the Underpass</td>
<td>59</td>
</tr>
<tr>
<td>3.5.1</td>
<td>Statistical analysis</td>
<td>59</td>
</tr>
<tr>
<td>3.5.2</td>
<td>Direction of movement</td>
<td>60</td>
</tr>
<tr>
<td>3.5.3</td>
<td>Diurnal animal activity</td>
<td>60</td>
</tr>
<tr>
<td>3.5.4</td>
<td>Comparison of effectiveness between Slaty Creek, Blackwood Road and</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>culverts</td>
<td></td>
</tr>
<tr>
<td>3.5.5</td>
<td>Road kill</td>
<td>60</td>
</tr>
<tr>
<td>3.6</td>
<td>Effectiveness of methods</td>
<td>61</td>
</tr>
<tr>
<td>3.6.1</td>
<td>Month</td>
<td>61</td>
</tr>
<tr>
<td>3.6.2</td>
<td>Method</td>
<td>61</td>
</tr>
<tr>
<td>3.7</td>
<td>Efficiency of methods</td>
<td>61</td>
</tr>
<tr>
<td>3.7.1</td>
<td>Time</td>
<td>61</td>
</tr>
<tr>
<td>3.7.2</td>
<td>Expense</td>
<td>61</td>
</tr>
</tbody>
</table>

**CHAPTER 4 – RESULTS & DISCUSSION**

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Plant species comparison between sites</td>
<td>63</td>
</tr>
<tr>
<td>4.1.1</td>
<td>Vegetation Biomass</td>
<td>64</td>
</tr>
<tr>
<td>4.1.2</td>
<td>Connectivity and composition of vegetation</td>
<td>66</td>
</tr>
<tr>
<td>4.1.3</td>
<td>Rainfall for Macedon Region</td>
<td>71</td>
</tr>
<tr>
<td>4.2</td>
<td>Fauna use of the Slaty Creek Wildlife Underpass</td>
<td>72</td>
</tr>
<tr>
<td>4.2.1</td>
<td>Mammals</td>
<td>72</td>
</tr>
<tr>
<td>4.2.2</td>
<td>Reptiles and Amphibians</td>
<td>75</td>
</tr>
<tr>
<td>4.2.3</td>
<td>Birds</td>
<td>76</td>
</tr>
<tr>
<td>4.3</td>
<td>Faunal site preferences</td>
<td>79</td>
</tr>
<tr>
<td>4.3.1</td>
<td>Scats</td>
<td>82</td>
</tr>
<tr>
<td>4.3.2</td>
<td>Direction of movement</td>
<td>84</td>
</tr>
<tr>
<td>4.4</td>
<td>Diurnal animal activity</td>
<td>85</td>
</tr>
<tr>
<td>4.5</td>
<td>Comparison of effectiveness for Slaty Creek, Blackwood Road and culverts</td>
<td>89</td>
</tr>
<tr>
<td>4.5.1</td>
<td>Road kill</td>
<td>92</td>
</tr>
<tr>
<td>4.6</td>
<td>Effectiveness and efficiency of data collection methods</td>
<td>93</td>
</tr>
<tr>
<td>4.6.1</td>
<td>Effectiveness and efficiency by months of monitoring</td>
<td>94</td>
</tr>
<tr>
<td>4.6.2</td>
<td>Effectiveness of methods</td>
<td>98</td>
</tr>
<tr>
<td>4.7</td>
<td>Efficiency of data collection methods</td>
<td>102</td>
</tr>
</tbody>
</table>
FIGURES

Figure 1: Location of the Slaty Creek Underpass in relation to the Black Forest section of the Calder Freeway.................................3
Figure 2: Land tenure of blocks surrounding the Black Forest.........................................................6
Figure 3: Map of Black Forest Section of Calder Freeway, study areas and surrounding landscape.................................................................7
Figure 4: Negative effects of individual animals and the wildlife population..............17
Figure 5: Diagrammatic representation of the relationship between road systems and wildlife. Road reserves can provide habitat for wildlife, serve as a conduit for movement, create a barrier, be a source of mortality, and act as a source of biotic and abiotic effects on the surrounding environment.................................18
Figure 6: Map of road walk, active search and spotlighting..........................................................53
Figure 7: West Site Trap and Nest box locations..........................................................57
Figure 8: Slaty Creek Underpass Site Trap and Nest box locations.............................58
Figure 9: East Site Trap and Nest box locations..........................................................59
Figure 10: The distribution of upper and middle story vegetation in the Slaty Creek Underpass.................................................................67
Figure 11: A cross-section depicting slope and upper storey vegetation in the Slaty Creek Underpass.................................................................68
Figure 12: The distribution of ground story vegetation in the Slaty Creek Underpass....69
Figure 13: The distribution of logs and stumps in the Slaty Creek Underpass.................70
Figure 14: Rainfall for Macedon Region..........................................................71
Figure 15: Direction of animal movement detected from Sand Tray..........................85
Figure 16: New species per month.................................................................................95
Figure 17: Species accumulation curve....................................................................102

PLATES

Plate 1: Oblique aerial photograph of the Calder Freeway and the Slaty Creek Underpass.................................................................4
Plate 2: The silhouette of the Kangaroo warns drivers animals may be in the area. The phone numbers provide emergency assistance if there is a collision with an animal.................................................................22
Plate 3: When warning signs are not entirely effective at preventing animal-vehicle collisions, leaving the remains of animals, such as this swamp wallaby (Wallabia bicolor), can be a sufficient deterrent to drivers to encourage them to slow down.................................................................22
Plate 4: Fencing design to prevent wildlife accessing a freeway.........................................24
Plate 5: Wildlife overpass on the Pacific Highway, New South Wales........................................29
Plate 6: A Colobus Monkey sits atop a 'colobridge' in Kenya.............................................29
Plate 7: Wombat inside a culvert near Slaty Creek..............................................................31
Plate 8: An amphibian underpass built into a road near Albany, USA showing the size of a passage that can be suitable for these taxa.................................................................38
Plate 9: An amphibian underpass built into a road near Albany, USA showing the size of a passage that can be suitable for these taxa.................................................................38
Plate 10: Slaty Creek Wildlife Underpass showing the distance between carriageways and mature Eucalypts that have been retained.................................................................45
Plate 11: Tape measures aligned in grids for vegetation surveying...........................................49
Plate 12: Sand Tray at Slaty Creek Underpass...............................................................58
Plate 13: Road killed Koala.........................................................................................60
Plate 14: Southern Brown Tree Frog within the Slaty Creek Underpass.................................75
Plate 15: Truck running over a dead animal on the Calder Freeway next to Slaty Creek Underpass

Plate 16: Cocoon from insect attached to a bridge pier in Slaty Creek Underpass

Plate 17: Sugar Gliders inside a nest box in the West Site

TABLES

Table 1: Comparisons in population size with land mass and total road kilometres
Table 2: Methods of detection used for monitoring crossing structures
Table 3: Objectives and measures for evaluating the effectiveness of a crossing structure
Table 4: Detection methods used at three sites along Slaty Creek
Table 5: Detection methods used for road and culverts between Slaty Creek and Blackwood Road
Table 6: Details of frequency of monitoring
Table 7: Vegetation Species list for the Black Forest and Slaty Creek Underpass
Table 8: Comparisons of biomass
Table 9: Mammals species list for Slaty Creek and the Black Forest
Table 10: Reptiles species list for Slaty Creek and the Black Forest
Table 11: Amphibians species list for Slaty Creek and the Black Forest
Table 12: Bird species list for Slaty Creek and the Black Forest
Table 13: Chi-squared analyses of species observed preferences within the Black Forest and Slaty Creek Underpass
Table 14: Chi-squared analysis of scat collection
Table 15: Species profiles for species demonstrating a significant preference within or away from the Slaty Creek Underpass
Table 16: Diurnal animal activity for the underpass and forest areas as detected by Elliott Traps, Pitfall Traps and Sand Tray
Table 17: Diurnal animal activity for the underpass and forest areas (Anabat, Audio, Bird Survey, Incidental Observations, and Spotlighting)
Table 18: Animals found to be utilising culverts and the Blackwood Road corridor
Table 19: A comparison of the animal use of the Slaty Creek Underpass, culverts and the Blackwood Road corridor as detected by sand tray analysis
Table 20: Animal traces found within Slaty Creek Underpass, and Blackwood Road corridor
Table 21: Species detected from evidence found on the Calder Freeway between Blackwood Road and Alex Evans Bridge
Table 22: Mammal species detected each month in the Slaty Creek Underpass (+) & Black Forest region (●). Shaded boxes indicate species detected once or not detected within January and April
Table 23: Detection methods successful in identifying mammal species in the Slaty Creek Underpass & Black Forest
Table 24: Reptiles species list for the Slaty Creek Underpass and the Black Forest by detection method
Table 25: Amphibians species list for the Slaty Creek Underpass and the Black Forest by detection method
Table 26: Bird list for Black Forest and Slaty Creek by detection method
Table 27: Species accumulation by most species detected
Table 28: Analysis of cost and time efficiency of monitoring methods
Table 29: Calculations for determining the amount of time spent for each method
CHAPTER 1 - INTRODUCTION

1.1 Introduction

The field of road ecology (Forman, Sperling et al. 2003) has emerged as a discipline largely within the past decade. Road ecology examines both the impacts of roads on the natural environment as well as mitigation techniques to minimise negative impacts. In Victoria, there are over 155,000 km of roads, and in Australia there is in excess of 800,000 km of roads (Australian Bureau of Statistics 2002). This constitutes an enormous amount of land impacted upon by roads. The area affected ecologically by roads is referred to as the 'road-effect zone' and can amount to substantial hectarage. For example, the road-effect zone has been estimated to cover 1/5th of the United States (Forman 2000). There is also significant money involved in the building and maintenance of such infrastructure, with public and private engineering construction of roads, highways, subdivisions and bridges within Victoria in 2000 being $5, 856 million (Australian Bureau of Statistics 2002).

There have been many studies identifying the broad-scale negative ecological impacts of roads (Forman and Alexander 1998; Spellerberg 1998; Forman 2000; Trombulak and Frissell 2000; Noss n.d.). Trombulak and Frissell (2000, p. 19) identified the following seven ways roads affect terrestrial and aquatic ecosystems:

1. increased mortality from road construction;
2. increased mortality from collision with vehicles;
3. modification of animal behaviour;
4. alteration of the physical environment;
5. alteration of the chemical environment;
6. spread of exotic species; and
7. increased alteration and use of habitats by humans.

This study relates to the second point from Trombulak and Frissell (2000), mortality from collision with vehicles’, and examines the effectiveness of mitigation methods in the form of several under-crossings beneath the road and wildlife resistant fencing along the Black Forest section of the Calder Freeway, Macedon, Victoria. In 1998, The National Road Motorists’ Association (NRMA) estimated the cost of animal/vehicle collisions in Australia, including damage to property and injuries to humans, to be $10 million (Cooper 1998; Bender 2001). Mitigation measures such as underpasses and modified culverts are being used in many new road constructions to assist the passage of animals from one side of a road to another.
One of the most challenging aspects in researching road ecology is that there are very few published articles, particularly within Australia. When a road was constructed that contained an underpass, or other mitigation method to reduce the impact the road has on fauna:

1. the structure usually did not have follow up studies, or adequate monitoring to determine its effectiveness; and/or
2. the study was conducted as part of a private consultancy or university study which has produced a report or thesis which remains in 'grey literature' within the library of the state road authority, shire council, or university.

1.2 Slaty Creek Underpass study site

The Calder Highway is an important link in Victoria's rural highway network, carrying high volumes of traffic between Melbourne in the south and Bendigo, Mildura and southwestern New South Wales to the north. The Victorian and Australian Governments identified Bendigo as the only major provincial city in Victoria not connected to Melbourne by a high standard freeway. Thus the Calder Freeway was planned, and construction is being delivered in sections throughout the 1990s and is continuing to be worked on into at least 2006. The planning process for the Gisborne to Woodend section, undertaken by VicRoads, resulted in the production of an Environment Effects Statement (EES), which identified five possible options for the freeway alignment. The EES was made available to the public in 1995. An independent panel appointed by the Minister for Planning, held an enquiry to consider the findings of the EES to see that all view points were accounted for and a balanced outcome was achieved. The Minister for Planning then provided an assessment and recommendation to the Minister for Roads and Ports who decided upon the final route location and form of the freeway. The chosen route (Figure 1) for the freeway bisected a patch of high quality remnant forest. From the EES, VicRoads identified that fauna movements could be maintained by the provision of a wildlife corridor to link the two patches of remnant forest bisected by the freeway. The chosen location for this wildlife corridor was at the freeway crossing of Slaty Creek (Grid Reference E: 282 450, N: 585 050), which is a tributary to the Maribyrnong River.

Construction of the freeway infrastructure and carriageway for the Black Forest section of the Calder Freeway near Macedon occurred during 1998 and 1999. The infrastructure for the Slaty Creek wildlife underpass was completed in 1999. The underpass comprised twin carriageways 100 metres in length, with piers twelve metres in height. The width of the underpass at ground level was 70 metres, and the distance between the remnant forest stands east and west of the underpass was about 100 metres (Plate 1). To enhance the use of the
Slaty Creek wildlife underpass for fauna, a fence was built along the eastern and western borders of the Calder Freeway from the Mount Macedon Road Interchange in the south, to the Alex Evans Bridge to the north, a distance of approximately seven kilometres (Figure 3). The fence was intended to funnel animals wishing to move between the eastern and western forest stands through the Slaty Creek underpass, rather than having them cross the freeway carriageways. The cost of construction for the Black Forest section of the Calder Freeway was $46 million and for the underpass was $3 million.

Figure 1:  Location of the Slaty Creek Underpass in relation to the Black Forest section of the Calder Freeway. Source: VicRoads (2000)
VicRoads instructed the contractors charged with the construction of the Slaty Creek wildlife underpass to retain the native vegetation at the underpass site. This was partially achieved. Some remnant eucalypts were retained between the northbound and southbound carriageways, and several other eucalypts were retained between the northbound carriageway and an access road adjacent to the western forest stand (Plate 1). Other eucalypts that had to be felled, to make way for the access roads and piers, were left on site as ground cover. Unfortunately, a lot of the understorey and middle-storey vegetation was seriously disturbed whilst the bridge was being constructed, thus negatively affecting the integrity of the underpass ecosystem. VicRoads then engaged other contractors to plant appropriate understorey species in the vicinity of the underpass. The replanting was conducted during the spring months of 1999. Subsequent to the replanting, unauthorised removal of several felled eucalypts occurred for use as firewood by local residents. The Black Forest and Slaty Creek Underpass are surrounded by residential development (Figure 2).

Given the large monetary outlay that was invested in the Slaty Creek wildlife underpass, VicRoads wished to determine if the structure was actually being used by animals passing between the forest stands to the east and west of the twin carriageway. VicRoads compiled a
list of questions, and invited tenders from interested parties to address the effectiveness of the structure as a wildlife corridor. The Centre for Sustainable Regional Communities, La Trobe University, Bendigo, was awarded VicRoads Contract No. 5495 to monitor the animal usage of the Slaty Creek Wildlife Underpass in the Black Forest Section of the Calder Freeway, near Macedon, Victoria. The data collected through this contract has been used in this thesis.

The Black Forest Section of the Freeway now carries an average 7790 northbound vehicles per day, and an average 7706 southbound vehicles per day (VicRoads, internal data).
Figure 2: Land tenure of blocks surrounding the Black Forest.  
Source: Department of Natural Resources and Environment 2002
Figure 3: Map of Black Forest Section of Calder Freeway, study areas and surrounding landscape (Qasco Vic Image 2002)
1.3 Aims

1. (a) Is species cover and plant species richness similar between the underpass and forest sites?  
(b) Is there connectivity of vegetation structure between the underpass and forest on either side?  
2. Is the underpass being used by animals as a means of passage between the two forest sites or as habitat?  
   (a) Are there some species that are not detected within the underpass but are found in the forest sites either side?  
   (b) Is the Slaty Creek underpass more effective than smaller underpass alternatives at Blackwood Road and the culverts?  
3. Has the construction of the underpass and adjacent fencing eliminated road-kill?  
4. What are the most effective and efficient methods for determining the presence of different vertebrate species?

1.3.1 Constraints of the study

It is very difficult to replicate studies of crossing structures and to conduct a controlled, manipulated experiment with a crossing structure. The infrastructure expense and ethical justification of building another identical road with some variation is beyond the scope of this study, and unlikely to be within the realm of any other study. With few underpasses in existence in Victoria, and varying local geographic and variation in flora and fauna species composition surrounding the underpass, it is very difficult to accommodate for all factors in order to make comparison between the effectiveness of one structure over another.

The road and underpass were already built and opened before this study commenced. This limited the pre-construction information that was available and did not allow for base-line data of fauna presence in the Black Forest section study sites before the construction of the road.

This is a new road, and there is not opportunity for comparison of pre-underpass construction to post-underpass construction of fauna presence data.

Variation between vegetation type and habitat quality and availability, makes it very difficult to make true comparisons between the Slaty Creek Underpass and the Black Forest section of the Calder Freeway with other roads within the same region, because the surrounding
landscape matrix is quite variable and it is difficult to determine which factors would be responsible for the variation in results. For example, road kill rates on the Black Forest Section of the Calder Freeway may be higher than a nearby local road, but the cause may be due to the quality of habitat surrounding the local road being less than that surrounding the Freeway, or it could be that there is a higher traffic volume on the Freeway which puts the fauna at greater risk of being killed on the road. This study did not look at comparisons between fauna use of the Black Forest section of the Calder Freeway and other roads in the Macedon area.

The study focussed only on the presence and absence of species from the area, and did not look at:

- whether the same individuals were being trapped;
- population dynamics of the forest compared to the road or measurements of the road edge effect into the forest;
- distance that individuals travelled to use the underpass.

Resource constraints and choosing to study many species meant there were many methods over fewer sites, which limited the opportunity to study a single species (or group of animals) and monitor them more intensively over a larger area of the forest surrounding the road.

A 12-month study does not show the long-term effects of the road on local fauna populations, or the effectiveness of the underpass for generational dispersal of fauna.

1.4 Thesis outline
The next part of this study is a literature review of material on road ecology, particularly relating to fauna movements, from Australian and international scientific journals, university studies and theses, reports from Australian state and national road departments, conference proceedings and Internet resources. This provides an overview of the current understanding of the impacts of roads on vertebrate fauna and works conducted on fauna sensitive road design and mitigation measures. Work conducted overseas has also been reviewed, and contrasted to the Australian context, where different environmental conditions and fauna exist.

Chapter 3 outlines the methodology used in assessing the vegetation of the underpass and two study sites either side, along Slaty Creek. The monitoring methods used are described and the
methods for evaluating the use and effectiveness of the crossing structure and comparisons between the effectiveness and efficiency of monitoring methods are outlined.

In Chapter 4, the results and discussion section identifies the species use of the Slaty Creek Underpass and other under-crossings. Species more prominent within the surrounding forest sites, or within the underpass are identified and suggested possible reasons are given for this. The effectiveness and efficiency of monitoring methods is discussed.

The conclusions and recommendations section (Chapter 5) comment on the effectiveness of the Slaty Creek Underpass and make recommendations for improvements. Improvements to the management of roads and the surrounding land network by VicRoads are proposed, and the role of crossing structures in the environmental mitigation of roads is presented.
CHAPTER 2 – LITERATURE REVIEW

2.1 Chapter outline
After a general introduction, this chapter attempts to outline the positive and negative impacts that roads have on animals. It covers the methods tried and sometimes tested, within Australia and overseas, to reduce the impacts of roads and vehicles on the natural environment, and to enhance these areas for wildlife.

Particular focus is given to crossing structures and the use of these structures by various faunal groups is reviewed. The approaches to evaluating the effectiveness of these crossing structures is reviewed, and some conclusions drawn on the effectiveness or ineffectiveness of different road enhancement or deterrent methods.

2.2 The interaction of roads with wildlife
Roads are an integral part of the Australian landscape. Over 800,000 kilometres of roads transport people and goods across the continent (Australian Bureau of Statistics 2002). Roads cut across all of the bioregions of Australia, and have varied and widespread impacts upon the natural environment and wildlife. Each year, millions of animals become road killed carcasses. Other impacts are less obvious and more difficult to measure. Noise and pollution from vehicles permeates into the surrounding landscape. The pollution and runoff from roads can enter watercourses and may affect species for up to hundreds of metres away from the road (Forman, Sperling et al. 2003). More than 20 ecological impacts of roads have been identified through studies worldwide, with comprehensive reviews by Bennett (1991), Forman and Alexander (1998), Spellerberg (1998), Trombulak and Frissell (2000) and Forman, Sperling et al. (2003). Forman (2000) estimated that 1/5th of the United States of America was affected ecologically by roads.

Roads can form a barrier for movement, by fragmenting and isolating populations of animals (Mansergh and Scotts 1989; Goosem 1997; Goosem 2001; Goosem 2002). In agricultural landscapes, road reserves may provide the only remnant habitat and are an important resource for the conservation of native plants and animals (Bennett 1988; Bennett 1990; Bennett 1991; Forman and Alexander 1998; Bennett 1999; Bennett and van der Ree 2001; van der Ree and Bennett 2001; van der Ree, Soderquist et al. 2001; van der Ree 2002; van der Ree, Bennett et al. 2003).
In many European and North American countries, research and practical works have been carried out to mitigate, and compensate for, the negative effects of roads. A number of organisations have focussed on these issues, including the Infra Eco Network of Europe (IENE) (Infra Eco Network Europe (IENE) 2003), Federal Highway Administration (FHWA) in the United States of America (Federal Highway Administration 2003), Center for Transportation and Environment (CTE) in the United States of America (North Carolina State University 2003), Wildlands Center for Preventing Roads in the United States of America (Wildlands CPR 2003), Austroads in Australia (Austroads 2003), European Cooperation in the field of Scientific and Technical Research (COST Project 341 – Habitat Fragmentation due to Transportation Infrastructure) (Iuell, Bekker et al. 2003). Conferences such as the International Conference on Ecology and Transportation (ICOET) bring together people working in this field.

There are some limited research and mitigation works being carried out in developing countries such as Brazil (Fischer, Ramos-Neto et al. 2003), Nepal (Forman, Sperling et al. 2003), Kenya (Kirathe and Parry 2003) and India (Singh and Sharma 2001).

2.3 Road networks

Australia is the sixth largest country in the world (Geoscience Australia 2003) and has more kilometres of roads than most European countries, but spread over a larger area (Table 1). There is no 10-km² block of land in England that does not contain a road (Forman, Sperling et al. 2003). The ratio of population to kilometres of roads in Australia is smaller than in Denmark, Germany or the United States, and therefore Australia has smaller revenue for funding to devote to mitigation projects.

New roads are always being built, with approximately 80 km of new major roads constructed in Victoria between 2000 and 2004 (VicRoads 2001; VicRoads 2002; VicRoads 2003). These figures do not include the upgrading and widening of roads already in place, which can increase the adverse effects on the surrounding environment (Forman, Sperling et al. 2003). There were 3.6 million licensed drivers operating 3.8 million vehicles registered within Victoria in 2001-02 (VicRoads 2002).
Table 1: Comparisons in population size with land mass and total road kilometres.

<table>
<thead>
<tr>
<th>Country</th>
<th>Population</th>
<th>Road (km)</th>
<th>Land Mass (km²)</th>
<th>Land Mass: Population</th>
<th>Road: Land Mass Ratio</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>19,169,083</td>
<td>800,000</td>
<td>7,686,850</td>
<td>1:2.5</td>
<td>1:9.6</td>
<td>(Australian Bureau of Statistics 2002; Geoscience Australia 2003)</td>
</tr>
<tr>
<td>Denmark</td>
<td>5,352,815</td>
<td>70,000</td>
<td>43,094</td>
<td>1:124</td>
<td>1.6:1</td>
<td>(Trade Partners UK 2002; Geoscience Australia 2003)</td>
</tr>
<tr>
<td>Germany</td>
<td>82,797,408</td>
<td>226,000 (IENE, 1997 data)</td>
<td>357,021</td>
<td>1:232</td>
<td>1:1.58</td>
<td>(Geoscience Australia 2003; Georgii n.d.)</td>
</tr>
<tr>
<td>United States</td>
<td>275,562,673</td>
<td>6,200,000 (1997 data)</td>
<td>9,629,091</td>
<td>1:29</td>
<td>1:1.55</td>
<td>(Clevenger and Waltho 1999; Geoscience Australia 2003)</td>
</tr>
</tbody>
</table>

2.4 Wildlife threatened by roads

Road kill is the primary way that humans kill wildlife in the United States (Transact n.d.), and it is likely to be the same in Australia. The fragmenting of populations, and loss or injury of individuals can reduce fauna populations, even to the point of local extinction (Forman, Sperling et al. 2003), although this has rarely been quantified for Australia (Jones 2000). A conservative estimate suggests that 5 million frogs and reptiles are killed annually on Australian roads (Ehmann and Cogger as cited in Bennett 1991). Some studies have found the proportion of animals that die due to road kills compared to the overall population is not significant enough to warrant it being a cause for concern (Bennett 1991).

Accurate measures of road kill are not possible, as usually only carcasses found on the road or next to a road are recorded. This does not identify animals removed by scavengers, or those that move away from the road before they eventually die (Forman, Sperling et al. 2003).
2.5 Positive interactions of wildlife with roads

Wildlife interact with roads in different ways, depending on many variables. These variables include the surrounding environment of the road and the structural integrity of that environment; how long the road has been in place; the width of the road; volume and speed of traffic; and the type of animal (Forman, Sperling et al. 2003). Even individual animals of the same species may react differently to roads (Clevenger and Waltho 2003). The provision of crossing structures can make a big difference to how wildlife interacts with roads (Clevenger and Waltho 2000).

Road reserves often form continuous linear zones of vegetation, and in some landscapes, the road reserves remain one of the few remnant examples of the indigenous flora and sources of suitable habitat for wildlife (Bennett 1988; Bennett 1990; Bennett 1991; Forman and Alexander 1998; Bennett 1999; Bennett and van der Ree 2001; van der Ree and Bennett 2001; van der Ree, Soderquist et al. 2001; van der Ree 2002; van der Ree, Bennett et al. 2003). Victorian roadside reserves contain 25% of all endangered species and 45% of the remaining native grasslands (Harper-Lore 2002). These roadside reserves can be viewed as corridors in the landscape, particularly if they connect other patches of habitat and form an important element to the home ranges of reptiles, mammals and birds (Bennett 1999). The role of corridors in the landscape has been debated, but it is generally agreed that corridors are more beneficial than not (Beier and Loe 1992; McKenzie 1995; Wilson and Lindenmayer 1996; Beier and Noss 1998).

The roadside corridor linkages occur through coincidence or through managed landscape ecology design (Forman, Sperling et al. 2003; van der Ree, Bennett et al. 2003). The management of these road reserves varies across the landscape, with the effects of these management techniques influencing the quality of habitat (Spooner, Lunt et al. 2003 (in press)). The scale of connectivity required for species will vary, and can range from entire regional landscape over hundreds of kilometres, to the specific location of crossing structures for wildlife at intersections of roads (Bennett 1999).

Road reserves, and the road itself are used by a great variety of animals. A network of forested roadside strips in southwestern Victoria, ranging from five to 40 m in width were found to be used as habitat by eighteen species of non-flying mammals (78% of the local fauna) and at least seven species (70%) of bats (Bennett 1988). In the severely cleared and fragmented wheatbelt region of Western Australia, roadside reserves have proven very important habitat locations, with more than 80% of local bird species using this vegetation.
In the United States, meadow voles (*Microtus pennsylvanicus*) and pocket gophers (*Thomomys bottae*) have been found to use the road reserve to extend their territory (Forman, Sperling et al. 2003). Even invertebrates are able to travel over several kilometres along roadsides to expand their home range, as was the case over 12 years with the harvester ant (*Pogonomyrmex occidentalis*) in North Dakota, USA (Forman, Sperling et al. 2003).

Road reserves are not the only places associated with roads that can provide habitat. Bridges and culverts have proved to be very suitable for many bats and birds. These structures can be enhanced for use by wildlife with very little additional expense or structural modification.

As part of the American Bats in Bridges Project, Keeley and Tuttle (1999) covered 25 states of the United States, interviewing biologists and engineers, and monitoring 2,421 highway structures (bridges and culverts) from sea level to 10,000 feet. This study discovered approximately 4,250,000 bats of 24 species living in 211 highway structures. Keeley and Tuttle (1999) outline the characteristics preferred by bats when looking for a roost within a bridge or culvert, and opportunities to increase the amount of habitat available to bats. There has been no evidence that bats roosting in bridges or culverts jeopardises structural integrity.

Whilst the species of bats may be different within the Northern Hemisphere to those found within Australia, it is likely that bats would still roost within bridge and culvert structures that offered crevices and shelter (Duffy pers. comm., 2003). One example from eastern New South Wales involved the large-footed bat (*Myotis adversus*), a threatened species, discovered roosting in an old wooden bridge due for demolition (Hoye and Hoye 1999). Care was taken in plugging gaps after bats had left at dusk and the construction of the new bridge was able to retrofit the old wooden bridge structures into the new concrete bridge. The bats were found to return back to their old home again once construction was completed. A comprehensive document for the construction of artificial bat roosts within Victoria has been produced for the Gippsland region, but with relevance to other locations across Victoria (de Souza-Daw 2000). It provides dimensions and materials for constructing roosts, placement and directions for follow up monitoring. There is opportunity for further research and construction of bat roosts within Australian bridges and culverts.

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Some bird species such as swallows (*Hirundo* sp.) and peregrine falcons (*Falco peregrinus*) have successfully nested within road infrastructure (Carey 2003). Nesting boxes for these birds have been installed into bridge structures within New York, Connecticut, and Virginia in the United States of America, and have successfully raised fledglings year after year, often returning to the same nest. The Washington State Department of Transportation have found the bridges to be very popular with a variety of bird and mammal species, and have needed to re-schedule how they conduct maintenance work such as painting, to fit around the breeding seasons of some bird species such as cormorants (*Phalacrocorax* sp.). The Washington State Department of Transportation now trains all bridge inspectors in wildlife identification and provides information regarding the management of these species (Carey 2003).

Roads and their construction can create altered environments which can provide for an increased source of food for some animals, such as invertebrates or herbivores grazing on the grasses and herbs, or scavengers that come to feed on road killed animals (Jones 2000; Forman, Sperling et al. 2003).

A great many bird species have been recorded feeding on grain and insects along roads and roadsides. In the Sierra Imathaca in Venezuela, one hawk species has been named the ‘road hawk’, for it is absent from the adjacent dense rainforest (Forman, Sperling et al. 2003).

### 2.6 Negative interactions of wildlife with roads

The negative ecological effects of roads have been reviewed in several publications (Bennett 1991; Forman and Alexander 1998; Spellerberg 1998; Trombulak and Frissell 2000; Forman, Sperling et al. 2003). Fahrig (2001, p. 9) suggests that species’ response to a road will vary:

Animals with low reproductive rates, low density and high space requirements will be susceptible to all road effects. Animals that avoid roads and require several different kinds of habitats will be susceptible to the effects of habitat inaccessibility. Highly vagile animals that are habitat generalists and species that are attracted to roads (e.g., reptiles for basking) will be particularly susceptible to traffic mortality. Species with high road avoidance and forest interior specialists will be more susceptible to habitat loss and fragmentation effects.

Determination of the road effect zone requires mapping the location of the road, along with the various environment factors of the surrounding landscape, such as vegetation, contours of the land and hydrology. Using data collected in the field, or extrapolation from other studies, the area affected by the road can be plotted. This area includes the roadside (management areas, road-kill effects, microclimate changes), other areas affected by materials and
chemicals (air pollution, litter, heavy metals, erosion and sediment, rubber), areas which suffer from water pollution and runoff, areas in which organisms are affected by traffic disturbance (noise, vibration, light), and areas which suffer from habitat fragmentation (Forman, Sperling et al. 2003). This method allows for the road effect zone to be plotted, and through quantifying the distance and intensity of the measures outlined above, can provide a series of overlays that identify areas of high impact requiring mitigation. The road effect zone has been tested on a proposed Hume Freeway extension in Melbourne. Depending on the route option chosen, either through already highly altered and fragmented environments or native grasslands of better quality and size, it would impact upon 13% to 55% of the remaining native grasslands (Williams, Leary et al. 2001).

Figure 4 illustrates the many negative effects a road system can have on wildlife at an individual level. This can be through mortality, the creation of a behavioural or physical barrier, or through to a reduction in connectivity of the landscape, and reduction of the local population, which can in turn lead to a reduction of a viable population size, affecting the persistence of that species across the region (Forman, Sperling et al. 2003). As a direct influence, roads provide access for people, and this may lead to the animals being directly or indirectly fed by people (via rubbish disposal), which is not looked upon as a positive thing as it can create a reliance on humans for food (Gibeau and Herrero 1998).
2.6.1 Barriers to movement between suitable habitats

When a road is built through contiguous habitat, it creates a new element in that environment, which may be a hostile zone for an animal. A narrow gap of hostile or unsuitable habitat may be more of a barrier to animal movements than a broad expanse of low quality habitat (Bennett 1999). Figure 5 demonstrates the various positive and negative effects a road and the roadside habitat may provide (Bennett 1991).

Introduced species may take advantage of roads as dispersal corridors, as was the case in Australia with the cane toad (*Bufo marinus*) (Seabrook and Dettmann 1996). The use of road corridors by non-native species and their effects on native Australian fauna is not well understood (May and Norton 1996). Given the vast network of land that is managed under road reserves, there seems to be few researchers documenting the use of these road reserves for the movement of animals (Bennett 1988; Bennett 1990; Bennett 1991; Forman and Alexander 1998; Bennett 1999; Bennett and van der Ree 2001; van der Ree and Bennett 2001; van der Ree, Soderquist et al. 2001; van der Ree 2002; van der Ree, Bennett et al. 2003). This is an area that requires further research.

![Diagram](image)

**Figure 5:** Diagrammatic representation of the relationship between road systems and wildlife. Road reserves can provide habitat for wildlife, serve as a conduit for movement, create a barrier, be a source of mortality, and act as a source of biotic and abiotic effects on the surrounding environment (Bennett 1991).

2.6.2 Population sink through increased mortality

Roads and road verges can be attractive to a variety of animals, which can be a benefit on one hand, but can also increase the likelihood of collision with vehicles.

Road kill may or may not affect the ability of a population to maintain itself (Forman, Sperling et al. 2003). The death of an individual animal, whilst unfortunate, may not be a
major factor in the overall size of the population. On the other hand, if there are many wildlife-vehicle collisions, or if there are other factors impacting upon the size of a population of animals, then it is possible that the increased rate of mortality can create a population sink.

Road kill is a part of the Australian driving landscape, with signs of past accidents between animals and vehicles evident in the carcasses that remain at the side of the road. These accidents can have extremely detrimental effects on localised populations of animals, and can sometimes have a heavy human toll, particularly if a driver hits a large animal such as a kangaroo, or attempts to swerve to miss the animal on the road and, in turn, ends up off the road. The NRMA estimated the cost of animal/vehicle collisions, including property and injuries to humans, in 1998 to be $10 million in Australia (Cooper 1998; Bender 2001). Insurance companies have an interest in reducing the impacts of roads and vehicles on wildlife, as it may assist in reducing claims of this nature. This was evident in the cooperative funding by NRMA, Royal Automobile Club of Victoria (RACV), the RTA and Transport SA to look into the efficacy of Shu Roo whistles (Bender 2001) which are reviewed later in this chapter.

Coulson (1982; 1989; 1997) found that the majority of road killed macropods, mainly Eastern grey kangaroos (*Macropus giganteus*) and swamp wallabies (*Wallabia bicolor*), along a section of highway in North Central Victoria were male. Jungalwalla (2002) suggests that this could be due to males behavioural tendency to have larger home ranges, with increased likelihood of crossing roads; their rapid movements through their range; a greater preference for roadside habitat; or a tendency to be less alert or responsive to vehicles.

Road kill is a regular part of Tasmanian roads, with estimates of over four million animals killed by vehicles on Tasmanian roads every year (Mooney, as cited in Lazenby and Jones 1999). Data compiled by the Department of Infrastructure, Energy and Resources provide some useful information on the number and type of animals killed. It also provided information on ‘hot spots’ for road mortality, with one 50 m section of the Gordon River Road generating 58 road kills in one year. The study averaged 513 deaths per km for other roads in the same area, which may able to be more generally applicable (Jones 2000).

A road upgrade in the Cradle Mountain National Park created localised extinction of eastern quolls (*Dasyurus viverrinus*), and severely depleted the Tasmanian devil (*Sarcophilus harrisii*) population. This prompted mitigation works of signage, traffic calming through rumble bars, reduced speed limits, escape ramps over drainage lines next to the roads and the
use of Swarflex reflectors. These actions have resulted in some success in restoring the populations (Whiley 1997; Lovas 2002; Taylor and Goldingay 2003). There have been a number of other Australian road kill studies, particularly in New South Wales, demonstrating that a large variety of native and introduced animals become road kill (2003). Dique, Thompson et al. (2002) found that 1407 koalas (*Phascolarctos cinereus*) were hit by vehicles on the south-east Queensland coast over a five year period. Most of these were young healthy males, with a combination of high koala densities and high traffic volume combining to cause these collision rates. Speed sign alterations made little difference in the number of koalas hit by vehicles. Goosem (1997) monitored four 0.5 km sections of highway that traversed rainforest, and over a 38-month period found more than 4,000 vertebrate road killed animals comprising over 100 species, including 500 mammals, almost 90 birds, 450 reptiles and more than 3,000 amphibians. There are other examples such as the tammar wallaby (*Macropus eugenii*) on Garden Island in Western Australia, which has approximately 450 out of a total population of 2,000, killed by cars each year (Bencini, pers. comm., 2003). Lovas (2002) found road kills had a significant impact on the wombat (*Vombatus ursinus*) population in Kangaroo Valley, NSW.

Hels and Buchwald (2001) found that the probability of an individual amphibian getting killed on a road dramatically increased with an increase in the volume of traffic. Forest road impacts on amphibians was monitored by deMaynadier and Hunter (2000), who found that most frogs were not largely affected by either a lightly used 5 m track or the 12 m heavily used forestry road, when compared to control sites in the adjacent forest. However, salamanders were significantly impacted upon, with 2.3 times higher abundance away from the road, demonstrating a considerable barrier effect. During two separate two-year periods, Ashley and Robinson (1996) recorded 30,034 amphibians of seven species, and 864 reptiles comprising ten species, along a 3.6 km section of two-lane paved causeway adjacent to Big Creek National Wildlife Area, Ontario. Mortality rates of some amphibians and reptiles showed correlation to seasonal patterns consistent with life history. In Spain, Rosell, Parpal et al. (1995) found amphibians were one of the most susceptible fauna groups to fragmentation and found roads to be impermeable, sometimes even with crossing structures.

Whilst there is a lot of evidence of animals being killed by vehicles, studies need to be conducted within various bioregions of Australia to determine the impacts of these road kills on Australian fauna populations, and the effectiveness of treatments in minimising these impacts and in protecting species identified as being highly threatened by roads.
2.7 Species behavioural responses to roads and vehicles

There has been very little published work relating to the response of an individual species to roads, and the follow on impacts this could have on populations of these animals (Kuitunen, Rossi et al. 1998). For example, animals that are road shy will retreat away from areas of roads, and may be highly impacted upon by road densities (Forman, Sperling et al. 2003). Alternatively, there are some species, particularly birds, that appear to be attracted to roads, which may be a source of food, and they are then likely to settle close to roads perhaps generating a dependence on roads, or imbalances in particular wildlife populations of that ecosystem, favouring animals that are attracted to roads (Coulson 1997). Carnivores may be attracted to carcasses on the road and then killed. The response of animals to danger, particularly if they freeze, or are slow to react, may place them in situations in which they are more likely to have a collision with a vehicle. Alternatively, species that demonstrate reckless behaviour, or cover large areas in their home range that intersect with roads are also at threat (as cited in Forman, Sperling et al. 2003). Animal behavioural responses to roads is an area that requires further study.

2.8 Means for making roads more wildlife friendly

There are a variety of techniques that can be used to make roads and road reserves more wildlife friendly. This includes the education and alteration of driving styles of drivers, preventing access of animals to the roadway, and providing for alternative options for movement from one side of the road to the other.

2.8.1 Driver Warning and fauna exclusion

Heightening the awareness of drivers to the dangers and impacts of wildlife-vehicle collisions is thought to reduce the impact on wildlife. Romin and Bissonette (Bank, Irwin et al. 2002; Forman, Sperling et al. 2003) pointed out that attempts to modify human behaviour appear to be less successful than attempts to modify deer behaviour. This result occurred in spite of greater attempts to alter human behaviour than options such as wildlife fencing, overpasses and underpasses for wildlife.

The use of signs depicting animals have been used to warn drivers of the possibility of animals within the area; sometimes associated with extra information such as a ‘help for wildlife’ phone number (Plate 2). These signs induce mixed reactions from drivers, with some people believing drivers can become accustomed to seeing them and do not alter their speed accordingly (Eilerts). This has led to some very creative signage, sometimes involving input from local people into their design. One example from the Arizona Department of
Transportation involved local school children developing the slogan “Keep your eyes open and your speed slow. Watch out for elk as you go.” This slogan was split over four signs placed 500 m apart and has successfully reduced driver speed and the number of road kills on the State Route 260, which was an area with a high elk (*Cervus elephas*) population (Jones 2000).

Main Roads (Queensland) (2000) recommend signage that shows the animal, such as Koalas, walking along the ground as opposed to sitting in a tree. In Tasmania, drawings of animals smashing up cars aid in emphasising the impacts animals can have on cars (Grzelewski 2003).

Leaving carcasses on the side of the road (Plate 3) is a controversial option that can raise the awareness of drivers to the potential of hitting an animal and lead them to altering their driving style appropriately (A.C.T. Kangaroo Advisory Committee 1997). However, leaving animal carcasses can invite scavengers to feed on the carrion, which in turn puts these animals at risk. In Tasmania, road killed animals are collected by some tourism operators to feed to Tasmanian Devils (Tschudin 1998).

Plate 2 (left): The silhouette of the Kangaroo warns drivers animals may be in the area. The phone numbers provide emergency assistance if there is a collision with an animal.

Photo: Rodney Abson.

Plate 3 (right): When warning signs are not entirely effective at preventing animal-vehicle collisions, leaving the remains of animals, such as this swamp wallaby (*Wallabia biclor*), can be a sufficient deterrent to drivers to encourage them to slow down.

Photo: Rodney Abson.
Advanced technologies incorporate expensive motion detection or trigger systems that either warn oncoming drivers of the presence of animals within the nearby vicinity, or try to deter animals from the roadway if an oncoming vehicle is detected.

Huijser and McGowen (2003) identified 26 locations across North America and Europe where animal detection or animal warning systems are in place. These systems vary in the way the notification signs are triggered, but could include a 'break the beam' system when an animal crosses a laser of infrared beam between two fixed positions. Others include motion sensors, vibration sensors, video cameras, and even collaring some individual elk so that if they passed within 400 m of a set detection point, beacons and signs would be activated. There are options to fit in-car warning devices to warn drivers of the nearby presence of animals (McGowen and Carson 2000).

Swiss researchers have developed solar powered fibre-optical signage that is triggered by a heat sensor, detecting animals up to 30 m away. It displays a lighted sign with the shape of a jumping deer and 40 km/h. Of seven locations where these signs have been tested, three sites have had a complete cessation of road kill, with two showing some improvement and another two showing little difference. The difference between the response at the sites is likely to be due to drivers ignoring the warning signs as they become used to seeing warning signs (Tschudin 1998).

Many of these systems are solar powered, which can result in some issues of shading or battery malfunction. Other issues with these advanced systems can include theft of signs or equipment, false detections caused by overgrown vegetation, vehicles accessing the road verge, interference by people and electrical failure. At present these systems are only targeting large fauna (Huijser and McGowen 2003).

There could be opportunity for similar warning signs within Australia when detecting large fauna such as kangaroos and emus (Dromaius novaehollandiae), although the expense of such systems would limit these devices to specific locations of extreme importance.

Reducing the speed of traffic in key points of high animal populations, through means of adding structures that reduce speed, closing roads or channelling traffic onto specific roads is referred to as ‘traffic calming’ (Forman, Sperling et al. 2003). The Nepalese government placed a ban on driving at night (when most animal movements occurred) through the Royal
Bardia National Park during 1992-1995. This ban was lifted and in the following three years 1995-1998, annual road-kill mortality was six-times higher than when the night driving ban was in place (Forman, Sperling et al. 2003).

Jones (2000) arranged for rumble bars to be incorporated into the road at the entrance to the Cradle Mountain National Park that forced drivers to slow to 60 km per hour. This was accompanied by 60 km per hour signs and wildlife warning signs. There was a public educational release at the same time, with pamphlets and stickers of a Tasmanian Devil and the words ‘Don’t squash me. Drive slowly at night.’ which was readily taken up by Tasmanian drivers. There were many methods employed at one time during to reduce the impacts on wildlife, so it is difficult to judge which was the most effective.

2.8.2 Prevention of animal access to roads

The prevention of access can take a number of forms, but may incorporate physical barriers, such as fencing, or more subtle barriers such as scent or reflectors.

Fencing of roads provides an important role in keeping animals away from the road, and may be necessary along high speed, high traffic volume roads that are impassable by animals (Bank, Irwin et al. 2002; Forman, Sperling et al. 2003) (Plate 4). Many European countries incorporate fencing along their major roads, but they also incorporate many alternative crossing points, such as overpasses, underpasses or culverts, which are essential to avoid compounding the barrier effect of roads (ACO Polymer Products 2003; Austroads 2003; Federal Highway Administration 2003). Clevenger, Chruszcz et al. (2001) found that fencing within the Banff National Park, Canada, reduced accidents involving wildlife by 80%. They did find that areas most likely to involve wildlife vehicle collisions were associated with fence ends or gaps in the fence. Fencing designs often vary depending on the type of animal(s) that are to be deterred. This may vary
from low-level fencing for amphibians and reptiles (Hoffman 2003), to fencing of over two metres height for preventing deer and elk access (Danielson and Hubbard 1998). There are a variety of fencing styles, with some incorporating fine sized mesh at the base to prevent smaller animals from entering. Cheap and simple silt fencing (fine mesh) has proved effective in preventing amphibians (Hoffman 2003) and reptiles (Aresco 2003) from accessing roads, although they do require regular maintenance.

These fences sometimes have safety mechanisms built into them to allow for fauna that does access the road to return to the other side of the fence. The techniques include one-way gates that animals push up against, climbing poles for arboreal animals (Abson and Lawrence 2003) and one-way off ramps (Jones 2000; Bank, Irwin et al. 2002; Lovas 2002; Forman, Sperling et al. 2003). Fences can also have detrimental effects on wildlife if poorly designed. van der Ree (1999) found that barbed wire fencing can be the cause of death by entanglement of many animals and birds.

The Shu Roo is a device fitted to cars that is designed to emit an ultrasonic noise that can be detected up to 400 m away, and deters animals from entering the road when a car fitted with a Shu Roo device is in the area. However, Bender (2001) conducted studies in NSW and found the devices to be not purely ultrasonic, undetectable at 400 m, to not alter behaviour of eastern grey kangaroos (Macropus giganteus) or red kangaroos (Macropus rufus) and to make no difference to the number of kangaroos hit when fitted to vehicles. Whistles have been shown to be ineffective in reducing animal vehicle collisions in other States within Australia, and test in North America and Europe found them to be ineffective for deer (Tanner, pers. comm., 2002; Billon and Carsignol 2000; Forman, Sperling et al. 2003).

Hazing (a means of human physical deterrence of animals) is a very resource intensive means of deterring animals from a road, usually requiring the presence of people such as highway personnel (Forman, Sperling et al. 2003). A ‘bucket brigade’ of concerned citizens in Amherst, USA, collected salamanders from near roads to avoid them becoming road-kill (Jackson 1996). During seasonal migrations of red crabs (Gecarcoidea natalis) on Christmas Island, a person with a broom assists with directing these animals to underpasses (Forman, Sperling et al. 2003).

Swareflex Reflectors are a type of reflective post intended to bounce the light from vehicle headlights into the surrounding landscape, creating an optical illusion for animals within the road verge of a ‘moving fence’, and is supposed to stop the animals in their tracks. These
have had mixed reactions, with some studies showing reflectors to be effective (Pafko and Kovach 1996), some studies being inconclusive (Sielecki 2001), and others indicating that they are largely ineffective for preventing collisions with mammals such as deer and kangaroos, to whom they are primarily directed (Aspinall 1995; Billon and Carsignol 2000).

There have been some experimental approaches to the use of scent as a deterrent of animals to the road, by spraying a scent of human, predator and other unpleasant smells on the road and nearby structures (Bank, Irwin et al. 2002). These experiments provide some promising results, but Ramp and Croft (2002) found that, in controlled conditions, the chemical odour repellent Plant Plus was suitable for deterring parma wallabies (Macropus parma), but attracted red-necked pademelons (Macropus rufogriseus). Applying scent in the field can be a labour intensive method for deterring animals.

2.8.3 Building structures that allow animal passage
An underpass is a structure that allows for the movement of animals beneath a road, and may vary in size from an oversized culvert to an extended bridge. Underpasses may be specifically built for wildlife, or allow the passage of minor roads, pedestrians or streams in addition to animals.

Underpasses have been incorporated into roads across Australia (Hunt, Dickens et al. 1987; Mansergh and Scotts 1989; Ecologia 1995; AMBS 1997; Main Roads 2000; AMBS 2001b; AMBS 2001c; AMBS 2001d; AMBS 2001e; AMBS 2001f; AMBS 2001g; Goosem, Izumi et al. 2001; Goosem 2002; Abson and Lawrence 2003); and overseas (Bekker and Vastenhout 1995; Janssen, Lenders et al. 1995; Jackson 1996; Clevenger and Waltho 2000; Forman, Sperling et al. 2003; Ng, Dole et al. 2004) to make roads more permeable to wildlife.

The openness of structures such as an underpass or culvert can be calculated by using the following equation:

\[
\text{Openness measure} = \frac{\text{width} \times \text{height}}{\text{length}}
\]

This measure may be a possible determinant of use by some animals. If a structure is seen to be too small or dark, an animal may be unwilling to enter the passage (Clevenger, Chruszcz et al. 2001; Cain, Tuovila et al. 2003; Ng, Dole et al. 2004). Ng, Dole et al. (2004) show a direct correlation between the openness measure of culverts and their use by Bobcats. ACO Polymer Products (2003) found that frog passages needed to incorporate some natural light to
make them enticing. The substrate of the passage may affect how comfortable it is for an animal to move through. For example, ungulates have more difficulty moving through a corrugated underpass than one with a flat bottom, and amphibians prefer underpasses with some moisture (Forman, Sperling et al. 2003).

Main Roads (Queensland) (2000) suggested that arboreal mammals, such as the sugar glider (*Petaurus breviceps*), will not use underpasses, most likely because they do not provide for their favoured method of movement through trees.

The presence and activities of humans within crossing structures can impact upon their effectiveness for facilitating fauna movements by scaring animals away, although this has not been largely quantified and needs further study (Clevenger and Waltho 2000; Little, Harcourt et al. 2002; Forman, Sperling et al. 2003; Ng, Dole et al. 2004).

An overpass is similar to an underpass, except the road goes beneath the bridge constructed for wildlife, instead of the wildlife going beneath the road. They are sometimes referred to as 'green bridges' or 'ecoducts', and are often covered in soil and planted with indigenous vegetation or stumps to provide cover for animals (Forman, Sperling et al. 2003). Overpasses are considered a very attractive option for facilitating a wide variety of fauna to cross roads, from invertebrates to large fauna such as ungulates, bears (*Ursus* sp.) and wolves (*Canis lupus*) (Clevenger and Waltho 2000; Bank, Irwin et al. 2002; Forman, Sperling et al. 2003).

Overpasses have been used in many countries across Europe and North America. France was the first country to develop overpasses, stemming from an agreement with French hunters in the 1960s to allow for 'game bridges' to allow for game animals to cross highways. There are now 150 narrow (5-10 m) wide bridges in France that incorporated minor farming roads (Forman, Sperling et al. 2003). Bank, Irwin et al. (2002) reported France had over 125 overpasses in 1991, and Billon and Carsignol (2000) identified at least 260 overpass structures crossing roads, motor-ways and high speed railway lines.

Overpasses structures vary in design, such as an hourglass shape wider at entrance point, and tapering in toward the arch of the bridge, or they may be rectangular. Some are not fenced. However, most are, and include many forms of fencing. The type of structural covering of the overpass could include planted or seeded vegetation, ponds, logs and stump lines. The widths of overpass structures vary with one overpass 800 m wide spanning the Forest Hardelot in France (Bank, Irwin et al. 2002).
There appears to be a correlation between the width of the narrowest point of the overpass and the reaction to animals using the structure. As discussed by Bank, Irwin et al. (2002) and Forman, Sperling et al. (2003), there have been studies within Germany, the Netherlands, France and Switzerland indicating structures at least 60 m wide were more effective than structures narrower than 50 m.

There is only currently one known specific-built wildlife overpass in Australia, on the Yelgun to Chinderah section of the Pacific Highway, north of Sydney, New South Wales (Plate 5). No report has been released on the effectiveness of this structure in facilitating fauna movements (Dunstan, pers. comm., 2003). The use of overpasses to reduce the impacts of roads upon wildlife has not been thoroughly researched within Australia.

There is generally a higher expense associated with the construction of overpasses when compared with underpasses (Forman, Sperling et al. 2003). Another advantage of underpasses is that there is the opportunity for underpasses or open-span bridges to incorporate other functions, such as passing over drainage lines or gullies.

Wildlife reaction to underpasses and overpasses within the same geographic region have been compared by Clevenger and Waltho (2000) in North America. They found that grizzly bears (Ursus arctos), wolves and all ungulates (deer, elk, moose (Alces alces) and bighorn sheep (Ovis Canadensis)) have a preference for overpasses, whilst cougar (mountain lions) (Puma concolor) prefer underpasses. Black bears (Ursus americanus) do not appear to have a preference.
Single rope crossing structures have been used extensively in England, United States, Scotland, and Wales for facilitation of movement for animals such as squirrels and dormice (*Muscardinus arvellanarius*) (Weston in prep.). There has been very little work conducted within Australia on the use of rope canopy bridges to provide connectivity at tree height for arboreal fauna to cross a road. This type of structure can be useful for animals that tend to be arboreal or semi arboreal, such as possums, melomys (*Melomys sp.*) and gliders. Weston’s (in prep.) work in the Atherton Tablelands has proven this simple structure very successful for canopy dwelling mammals. There have also been some limited experiments with these structures near Hobart, Tasmania (Tanner, pers. comm. 2003). An experiment with a rope tunnel within a park in Sydney produced inconclusive results, but did provide evidence of ringtail possums (*Pseudocheirus peregrinus*) utilising the structure (Weston in prep.).

Kirathe and Parry (2003) point out that various monkeys have been known to use rope ladder crossing structures in Kenya called ‘colobridges’, named after the colobus monkey (*Colobus angolensis*) (Plate 6). These rope ladders have been used in Brazil, Belize, and Taiwan for various monkeys. A combination of branches lashed together with nylon rope was tested in Mexico, but were not utilised by the target spider monkeys (*Ateles fusciceps*) because it is suspected the monkeys did not trust the structure (Hull, cited in Weston in prep.).


When a road bisects an area inhabited by gliding possums, such as the greater glider \textit{(Petauroides volans)}, yellow-bellied glider \textit{(Petaurus australis)}, sugar glider \textit{(Petaurus breviceps)}, squirrel glider \textit{(Petaurus norfolcensis)} and feathertail glider \textit{(Acrobates pygmaeus)}, it is generally expected that these animals will not use culverts or underpasses (Main Roads 2000) and it is uncertain as to whether they would use bridge overpasses. An alternative that has been tried in NSW is the Glider Pole that allows the gliders to move in their preferred gliding movement, attaching themselves to poles placed within the median strip. Spotlighting and a fixed data logger to detect movement, as well as radio tracking of individual animals, were used to monitor the glider pole structure. There were no conclusive results that it was being utilised by gliding possums, as monitoring was not conducted for a sufficient duration (AMBS 2001a). Berra (1998) claimed the gliding distance of the sugar glider and squirrel glider is up to about 50 m. He suggests the feathertail glider can reach glides of 20 m or more. van der Ree, Bennett et al. (2003), studied fragmented woodland patches and individual isolated trees within an agricultural landscape near Euroa Victoria, and found \textit{Petaurus} species would not occupy patches greater than 75 m from known occupied territories, as this is outside of their gliding distance. These species are unlikely to spend much time moving along the ground.

Culverts are a regular part of many road constructions, primarily for the movement of water beneath the roads surface. There have been many studies demonstrating the use of these structures by wildlife, demonstrating there is some over-lap between ‘culverts’ and ‘underpasses’ (Hunt, Dickens et al. 1987; AMBS 2002a). There have been developments in modifying culverts to incorporate dry passage, and other options to make them more attractive for fauna as a safe passage to cross from one side of the road to the other. Armstrong and Francis (1997) produced a document ‘Culvert modifications to assist wildlife movements’ emphasising the need for these structures to incorporate as much light as possible and allow for ledges or internal piping which will remain dry. In Europe, these passages are sometimes referred to as ‘ecopipes’ and ‘ecoculverts’ (Bank, Irwin et al. 2002; Forman, Sperling et al. 2003). These modified culverts are becoming more widespread practice in new road designs, as road development incorporates the recommendations of wildlife biologists (Soderquist 2002).

One of the most celebrated success stories of a culvert being used to provide safe passage for fauna beneath a road is that of the ‘love tunnel’ at Mt. Higginbotham in Victoria, which allowed the mountain pygmy possum \textit{(Burramys parvus)} to maintain their natural dispersal routes and social organisation after the male and female populations habitat was dissected by
an alpine road (Mansergh and Scotts 1989). This culvert, filled with rocks to resemble the natural rock scree habitat of the mountain pygmy possum, had a grate fitted at either end to prevent larger animals and predators from accessing it. Within two weeks of its construction, the culvert was being utilised by the target species, mountain pygmy possum, as well as bush rats (*Rattus fuscipes*), and dusky antechinus (*Antechinus swainsonii*).

There have been several studies of fauna use of culverts within Australia (Plate 7 demonstrates a wombat within a culvert). Taylor and Goldingay (2003) studied the usage of 18 m long culverts in NSW, showing they were being utilised by a large variety of vertebrate mammals, from house mice (*Mus musculus*) to swamp wallabies. Culverts were not used by amphibians (other than the introduced cane toad (*Bufo marinus*)), sugar gliders or long-nosed potoroos (*Potorous tridactylus*). Koalas made sparing crossings through the culverts.

Goosem (2002), conducted a trapping regime around four sites within the Atherton Tablelands to monitor for small mammals. Having determined the presence of individuals within the vicinity and their crossing locations through culverts, she blocked some culverts off using fine wire mesh. All species showed an aversion to crossing the 12 m or 20 m roads, although individuals of all species did pass over the top of the roads. Platypus (*Ornithorhynchus anatinus*) have shown some unwillingness to pass through culverts in Tasmania, which Tanner (pers. comm., 2002) suspects may be due to the metal incorporated into the culvert interfering with electro receptors used for feeding; or an aversion developed after the platypus had a negative encounter with a culvert once (such as difficult passage due to blockages of the culvert, or environmental factors such as noise).

Clevenger, Chruscz et al. (2001) investigated several culverts within the Banff National Park in Canada. They studied how various attributes relating to a culvert, such as the dimensions, amount of traffic noise, road width and traffic speed, can influence whether a particular species of small to medium sized mammal would use a culvert. They obtained mixed results in terms of species preference and use, and concluded that traffic volume was the most significant factor in relation to

Plate 7: Wombat inside a culvert near Slaty Creek. Photo: Rodney Abson.
culvert use. They suggested that culverts play an important role in making the barrier of highways more permeable for animals, and that at least one culvert should be placed within the home range of an individual to ensure connectivity and gene-flow.

There have been a large variety of animals that will use culverts, providing they are appropriately constructed (Forman, Sperling et al. 2003). In Tasmania, Davies (2003) has developed bio-baffles that allow fish to move up stream through culverts adapted to resemble natural stream flow conditions. A number of studies have addressed the requirements of aquatic fauna, primarily fish, to move through crossing structures (Gubernick and Bates 2003; Gubernick, Clarkin et al. 2003; Jackson 2003; Johansen 2003; Moore 2003; Riley 2003; Sharma 2003; Stadler 2003). North America’s first salamander tunnels, which were essentially culverts, were created in 1987, which was some of the earliest work on crossing structures in North America (Jackson 1996).

Vegetation leading up to the culvert is widely recommended to provide protective cover, with fauna more likely to use vegetated culverts than those without vegetation (Main Roads 2000; Ng, Dole et al. 2004).

2.8.4 Habitat re-creation or modification
Modification of roadside reserves can alter the attractiveness of these areas for animals. Depending on the formation of roadside vegetation it can be managed to provide drivers with greater opportunity to see fauna on the side of the road through clearing vegetation or by providing movement-triggered lighting when an animal enters the road reserve (Forman, Sperling et al. 2003).

Sometimes the path of a proposed road will impact directly upon the habitat of a threatened species, which would require mitigation of some form. The destruction of habitat in one location can be sometimes re-created at another nearby location, although this method must be approached with caution, as some natural environments would be extremely difficult to attempt to recreate, such as rainforests, alpine areas or environments that take hundreds or thousands of years to be formed or repaired from damage. One of the most successful methods of habitat recreation is the development of wetlands and breeding ponds. These have been successfully installed for Green and Golden Bell Frog (Litoria aurea) in Sydney (Gillian 2002), and the Green-thighed Frog (Litoria brevipalmata) in Northern NSW (O’Connor pers. comm., 2002) where new road constructions would have threatened the breeding habitat of these frogs. Re-creation of wetlands and relocating 11,000 frogs also proved successful in
Cheshire, United Kingdom, when new road construction threatened the original wetlands and ponds of five species of amphibians (Marshall, Corner et al. 1995).

2.9 Determination of effectiveness

To determine the effectiveness of a crossing structure, it is usual to start with some form of monitoring to determine the use of the crossing structure. There have been a variety of techniques used to detect use of crossing structures, which are covered in Table 2. The monitoring methods chosen need to be tailored to the crossing structure being monitored, the species groups being targeted, the surrounding environment (for example cameras near a residential area may be likely to be stolen or vandalised), and the resources available for monitoring, including monetary and human resources to establish the equipment, collect the data and analyse it, and the amount of time available for the monitoring regime.

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
<th>Species Group</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Tray</td>
<td>A strip of sand is placed along the entrance or within an underpass, overpass or culvert to detect footprints of ground dwelling animals.</td>
<td>Large to medium animals. Can be small animals depending on the size of the sand and exposure to weather.</td>
<td>(AMBS 1997; Clevenger and Waltho 2000; AMBS 2001b; AMBS 2001c; AMBS 2001d; AMBS 2001e; AMBS 2001f; AMBS 2001g; AMBS 2002a; AMBS 2002b).</td>
</tr>
<tr>
<td>Marble dust</td>
<td>Similar to the sand tray, except a much finer material able to detect small animals such as amphibians and rodents.</td>
<td>Large, medium and small sized animals. Needs to be sited out of the weather.</td>
<td>(Mata 2003)</td>
</tr>
<tr>
<td>Inkpad and soot paper</td>
<td>A towel containing ink is placed at the entrance of an underpass or culvert and paper sheets on either side of the inkpad. As the animal passes over the inkpad on their way through the passage, their footprints are left on the paper. Replacing the inkpad with soot can provide a similar effect.</td>
<td>Large, medium and small sized animals. Provides a permanent record that can be later analysed.</td>
<td>(Hunt, Dickens et al. 1987; Ecologia 1995; Clevenger and Waltho 1999; Veenbaas and Brandjes 1999; Huijser and Bergers 2000)</td>
</tr>
<tr>
<td>Snow prints</td>
<td>Footprints in the snow surrounding a crossing structure can be read to provide information on species, quantities and direction of movement.</td>
<td>Large, medium and possibly small sized animals depending on the quality of the snow.</td>
<td>(Clevenger and Waltho 1999);</td>
</tr>
<tr>
<td>Method</td>
<td>Description</td>
<td>Species Group</td>
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<tr>
<td>Video Camera</td>
<td>Video cameras of varying capabilities are directed at the crossing structure, or surrounding environment to record the passage of animals. These may be trigger activated, or recorded throughout the day. Infrared video cameras are capable of recording at night.</td>
<td>Large, medium and possibly small animals, depending on the size of the animal, the size of the structure and substrate, and distance of the camera from the animal being monitored.</td>
<td>(Bank, Irwin et al. 2002; Dodd, Gagnon et al. 2003)</td>
</tr>
<tr>
<td>Still Camera</td>
<td>Trigger activated still cameras with a flash have been used to record movements through underpasses, culverts, overpasses and rope canopy bridges.</td>
<td>Large, medium and possibly small animals, depending on the size of the animal, the size of the structure and substrate, and distance of the camera from the animal being monitored.</td>
<td>(Mansergh and Scotts 1989; AMBS 1997; Clevenger and Waltho 2000; AMBS 2001b; AMBS 2001c; AMBS 2001d; AMBS 2001e; AMBS 2001f; AMBS 2001g; AMBS 2002a; AMBS 2002b)</td>
</tr>
<tr>
<td>Motion Sensor</td>
<td>An animal moving past a particular point at a crossing structure triggers the motion sensors. This movement could trigger a camera to record, or simply count, the number of movements made on the structure.</td>
<td>If attached to a camera the sensor could work for a variety of species; but can be deceptive if an animal is attracted to the sensor, giving false indications of species use of the structure.</td>
<td>(Ecologia 1995; AMBS 2001a; Brudin 2003; Weston in prep.)</td>
</tr>
<tr>
<td>Direct observations</td>
<td>An observer is present at the location of the crossing structure and records observations of species present; this could incorporate spotlighting equipment.</td>
<td>Any species group. Could potentially deter some animals from crossing if they detect the observer.</td>
<td>(Jones 2000; Weston in prep.)</td>
</tr>
<tr>
<td>Incidental observations</td>
<td>Collection of evidence of animals in a non-systematic way from general inspection of the crossing structure. This could include evidence such as footprints, scats, hair samples, or observations of an animal.</td>
<td>Limited to direct sightings, footprints from large or medium animals in soil, or possibly mammalian hair or scats.</td>
<td>(Hunt, Dickens et al. 1987; AMBS 1997; AMBS 2001b; AMBS 2001c; AMBS 2001d; AMBS 2001e; AMBS 2001f; AMBS 2001g; Goosem, Izumi et al. 2001; AMBS 2002a; AMBS 2002b)</td>
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<tr>
<td>Method</td>
<td>Description</td>
<td>Species Group</td>
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<tr>
<td>Scat collection</td>
<td>Incidental or systematic collection of scats from within the crossing structure or surrounding it.</td>
<td>Mammalian scats or raptor pellets.</td>
<td>(Hunt, Dickens et al. 1987; deMaynadier and Hunter 2000; Jones 2000; Goosem 2001; Goosem 2002)</td>
</tr>
<tr>
<td>Traps</td>
<td>Various traps could be used, including Elliott, cage, or pitfall traps, depending on the size of the animal targeted. Trapping could be carried out in the surrounds of the structure, or within, depending on the size of the structure.</td>
<td>Any size ground dwelling or arboreal animal, but usually mammals, reptiles or sometimes amphibians.</td>
<td>(Ecologia 1995; AMBS 1997; Clevenger and Waltho 2000; AMBS 2001b; AMBS 2001c; AMBS 2001d; AMBS 2001e; AMBS 2001f; AMBS 2001g; AMBS 2002a; AMBS 2002b; Weston in prep.)</td>
</tr>
<tr>
<td>Radio tagging</td>
<td>Trapping and tagging individual animals can provide information on the movement of animals through or surrounding the crossing structure.</td>
<td>Large, medium or small animals, although the smaller the animal, the more expense in fitting suitably sized transmitters.</td>
<td>(Rondinini and Doncaster 2002; Huijser and McGowen 2003)</td>
</tr>
<tr>
<td>Capture mark recapture</td>
<td>Trapping and marking individual animals can provide information on the movement of animals through or surrounding the crossing structure or road.</td>
<td>Large, medium or small sized animals.</td>
<td>(Ecologia 1995; Clark, Clark et al. 2001; Goosem 2001)</td>
</tr>
<tr>
<td>Hair sampling</td>
<td>A collection of hair from mammals can be taken from hair funnels, sticky tape, or barbed wire for larger animal, such as bear.</td>
<td>Large, medium or small sized mammals. Baits and method needs to be suited to the species group targeted.</td>
<td>(Ecologia 1995; Proctor 2003)</td>
</tr>
<tr>
<td>Nest boxes</td>
<td>Nest boxes for birds and bats may be fitted to bridge structures, as artificial habitat that may then be monitored for use.</td>
<td>Birds and bats. Can be used for arboreal hollow dwelling mammals.</td>
<td>(Keeley and Tuttle 1999; Carey 2003; Slesar, Morse et al. 2003)</td>
</tr>
</tbody>
</table>
2.9.1 Evaluation and measures of effectiveness

Forman, Sperling et al. (2003) explained “the overall objective of wildlife passages is to increase the permeability of a road corridor. Success reduces barrier effects and usually reduces road-kills (Table 3).” The points in Table 3 become increasingly more complex and difficult to assess, from comparison of road kill frequencies to measuring the reduction of barrier effects.

Table 3: Objectives and measures for evaluating the effectiveness of a crossing structure (As adapted from Forman, Sperling et al. 2003).

<table>
<thead>
<tr>
<th>Objective</th>
<th>Measure</th>
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<tbody>
<tr>
<td>4. Ensure biological requirements are met. Sufficient passage</td>
<td>Reproductive rates (short term and long term), sex ratios, survivorship and physical condition.</td>
</tr>
<tr>
<td>5. Allow for dispersal and recolonization. Juveniles are able to</td>
<td>Evidence of juvenile passage at structure; collateral study radio-monitoring movements of dispersing animals; detection of species returning to area after long absence.</td>
</tr>
<tr>
<td>6. Maintain metapopulation processes and ecosystem processes.</td>
<td>Distribution of herbivores and predators with respect to habitat quality; foraging intensities; and predation rates.</td>
</tr>
</tbody>
</table>

Crossing structures are rarely put to a rigorous monitoring test, and success is usually determined by the presence of an individual of a species or variety of species using the crossing structure (Forman, Sperling et al. 2003). It is rare for year round, comprehensive pre-construction data to be gathered so that a sound baseline of information can be used to evaluate the impacts of a new road (Clevenger and Waltho 2000). Baseline data can be useful for looking at questions of population changes over time in the remnant forest patches on either side of the crossing structure.
Where crossing structures are in place, and no pre-construction data is available, some work on radio-tagging of individuals, and an awareness of the response of individual species to a structure has been very useful to gauge the population changes over time as animals familiarise themselves with the structure (Clevenger and Waltho 2003).

2.9.2 Target species

Target species are sometimes used as the measure for evaluating the effectiveness of a crossing structure. If an individual of the particular target species, for example the Lumholtz's tree-kangaroo (*Dendrolagus lumholtzi*) as chosen by Goosem (2002), were to use an underpass, the project could be deemed successful, or a failure if no Lumholtz's tree-kangaroos moved through the underpass. However, this measurement alone does not look at whether there are sufficient numbers of the target species using the underpass or whether most of them are avoiding the underpass; it does not take into account other species that use the underpass, be they native or predators, and the impacts this could have on fauna populations. The selection of species as 'target species' for a crossing structure needs to take into account not only the species that are rare or threatened. Georgii (n.d., p.4), states that the target species should be 'all species which are significantly affected by the barrier effect of the respective road.'

2.9.3 Ineffectiveness evaluation

Another measure of effectiveness is the ineffectiveness of a structure, and this is less often looked at. Dodd, Gagnon et al. (2003) when monitoring two underpasses in Arizona, USA, used several cameras facing into and away from the underpass, and was able to detect that deer would move through the underpass. However moose would approach the entrance, but never move through.

As well as identifying which species never use a crossing structure, ineffectiveness can be measured by comparing the number of animals of a particular species to move through a crossing structure with the number of animals expected to cross through. To determine the expected number of animals to access a crossing structure, there may need to be ongoing monitoring to determine what is necessary to maintain long-term genetic interchange between divided populations. Expected measurements of movement for sufficient genetic interchange could be generated from monitoring the same species within 'healthy populations' in relatively undisturbed environments.
2.10 Functions of animals in relation to roads and crossing structures

2.10.1 Species Groups

Fleury and Brown (as cited in Billon and Carsignol n.d.), identified specific vegetation and structural habitat preferences of different guilds of animals, such as insects, birds, reptiles and amphibians, small fauna, medium sized mammals and large fauna. When deciding on the location of a crossing structure, or its design, this type of information is important.

When planning the location of crossing structures in Europe, the seasonal migration routes of animals is usually accommodated. These target species could be bears, deer or even amphibians. Australian fauna, with the exception of bird species, do not exhibit these high-volume seasonal migration patterns. Whilst some studies from overseas contain information relevant to Australian fauna, such as passage design for amphibians, other studies relating to accommodating carnivorous megafauna are not relevant to Australian conditions. Examples of studies conducted on different species groups are covered below.

2.10.2 Amphibians and Reptiles

There have been a variety of work from around the world showing the negative influence of roads on amphibians (Santolini, Sauli et al. 1995; Vos 1995; Hels and Buchwald 2001) and successful amphibian tunnels installed across Europe (Forman and Hersberger 1996; Bank, Irwin et al. 2002; Puky 2003) and North America (Jackson 1996). An example of a successful amphibian tunnel is shown in Plates 8 and 9 from Albany, New York. ACO Polymer Products (2003) have patented a number of plastic piping designs for facilitating effective movement of amphibians beneath roads.

Plates 8 and 9 show an amphibian underpass built into a road near Albany, USA showing the size of a passage that can be suitable for these taxa.

Rosell, Parpal et al. (1995) found the response of reptile species to drains was varied, with some species being comfortable using drains as permanent habitat, and others being very selective. Reptiles can be influenced by such factors as the existence of natural substratum or
whether the base of the drain and the location of the structure are at the same level as the surroundings. Giles (2001) studied the impacts of roads on the Oblong Turtle (*Chelodina oblonga*) in Western Australia, noting that some road structures were difficult for the turtles to climb over. The use of steps within culverts can be a hindrance to amphibians.

2.10.3 Mammals

Mammals have tended to be a major focus and reason for mitigation works and crossing structures associated with roads. This may be due to several reasons, including safety, the visibility of dead mammals on the road, and the role mammals play in an ecosystem. People often easily relate to mammals, which can be made into iconic species that can be easier to generate support for their protection than some other fauna groups.

2.10.3.1 Large mammals

The safety of motorists is more likely to be compromised by large mammals than any other species group that may access a road. Underpasses and overpasses have been constructed around the world, with their use by large mammals being key criteria to measure the effectiveness of these structures.

Some of the best work in long-term, year-round, rigorous monitoring of a variety of crossing structures has been conducted in Banff National Park, Canada (Clevenger and Waltho 2000). Over a 45-kilometre stretch of highway through the Banff National Park, 24 wildlife crossings, of 5 design types, were built over two periods: in 1985 and 1997 (Clevenger and Waltho 2003). Eleven of these underpasses were monitored to analyse their use by black bear, grizzly bear, cougar, wolf, deer, elk and moose (Clevenger and Waltho 2000). In another study by Clevenger, Chruszcz et al. (2001) the impacts of fencing on wildlife-vehicle collisions was examined, largely focussing on deer, elk, moose, bighorn sheep, coyote (*Canis latrans*), black bear, and wolf. Bears are a popular choice of animals to study in the Northern hemisphere, with results showing these animals are negatively affected by roads, which cause road kill, habitat fragmentation and isolation of populations (Demarchi 2001; Gibeau, Clevenger et al. 2001; Gilbert and Kawula 2001; Gore 2001; McCown and Eason 2001; van Manen, Jones et al. 2001; Wills and Vaughan 2001).

Singh and Sharma (2001) discussed the many man-made conflicts facing the Indian Elephants (*Elephas indicus*) in India, including roads and railway lines that reduce access to natural wood and water sources these animals have been able to freely access in the past. This can
cause frustration and confusion in the elephants, and cause aggressive or dangerous situations for both people and elephants.

2.10.3.2 Medium sized mammals

The presence of small mammals within road corridors, and the impacts of roads on these animals have been studied around the world with some interesting results. For example, Otter (*Lutra lutra*) have been found to live in industrialised areas in the United Kingdom, using road underpasses and culverts for movement, and even using these structures for holts (James 2002). Rondinini and Doncaster (2002) found that whilst hedgehogs (*Erinaceus europaeus*) were comfortable living in urban environments, they avoided roads and road verges. Huijser and Bergers (2000) found that roads and traffic are likely to reduce hedgehog density by about 30%, which could affect the long-term survival of a population.

Lindenmayer and Nix (1993), whilst studying corridors of vegetation retained within logging coupes in the alpine region of south-eastern Australia, found greater gliders and mountain brushtail possums (*Trichosurus caninus*) were regularly detected in corridors, and Leadbeater's possum (*Gymnobelideus leadbeateri*), sugar glider, yellow-bellied glider and feathertail glider were rarely detected within corridors. It should be noted that these corridors did not contain roads, which may affect the use of corridors by these species.

Clevenger and Waltho (1999), found that culverts beneath the Trans-Canada Highway in Banff National Park were used by a variety of medium and small-sized mammals, including weasels (*Mustela* sp.), martens (*Martes Americana*), hares (*Lepus americanus*), red squirrels (*Tamiasciurus hudsonicus*), mice, shrews (*Sorex* sp.) and coyotes, although the most important factors affecting their use of culverts varied between species.

2.10.3.3 Small-sized mammals

Small mammals, by nature of their size, can find roads to be a formidable barrier, and even the upgrading of a road can make a considerable difference in their ability to move across the landscape (Clevenger and Waltho 1999). On the other hand, some small solutions or alterations can have quite significant results that are beneficial for small mammals (Hunt, Dickens et al. 1987; Mansergh and Scotts 1989).

Native rodents of California, USA, were found to use median strip and roadside habitat (Bolger, Scott et al. 2001), however, Clark, Clark et al. (2001), found that rodents showed an
aversion to crossing roads voluntarily, unless they were displaced by humans, and were then likely to return to their original side of the road.

In the Netherlands, 25% of the badger \textit{(Meles meles)} population is killed each year by road traffic. The use of fencing and strategically planted vegetation to direct these animals to tunnels beneath the road are paying off, with these crossings being used by badgers and other animals, although it is uncertain of the effects these have had on the population (Bekker and Canters 1995). Janssen, Lenders et al. (1995) found that in order for badger tunnels to remain effective, they required appropriate construction, such as the placement of the tunnels with surrounding vegetation, and ongoing maintenance to ensure tunnels are clear and the surrounding area is fenced without gaps.

2.10.4 Birds
Of the fauna groups killed on roads, birds are one of the most regularly killed (Forman, Sperling et al. 2003), yet the effects of roads and vehicles on these animals have not been well documented. A study in Finland to determine whether highways influence the density of land birds found that the altered environment may favour the pied flycatcher \textit{(Ficedula hypoleuca)}, and can negatively impact upon others including the willow warbler \textit{(Phylloscopus trochilus)}, crossbills \textit{(Loxia spp.)} and tree pipit \textit{(Anthus trivialis)} (Kuitunen, Rossi et al. 1998). van der Zande, ter Keurs et al. (1980) identified that the lapwing \textit{(Vanellus vanellus)}, godwit \textit{(Limosa limosa)} and redshank \textit{(Tringa totanus)} are negatively affected by roads for distances of at least 750 metres.

2.10.5 Invertebrates
There have been very few studies on the impacts of roads on invertebrates, although it is recognised that roadside vegetation can be suitable for invertebrate populations (Vermeulen 1995; Forman, Sperling et al. 2003). Baur and Baur (1990) found that snails had difficulties crossing roads in Sweden, and were largely confined to roadsides. Mader (1984 as cited in Forman and Alexander 1998), found that roads as small as 2.5 m wide can be a barrier for carabid beetles and wolf spiders \textit{(Lycosa sp.)}. Haskell (2000) found that minor roads through continuous forests in the Southern Appalachian Mountains can have significant impacts on both the abundance and diversity of macroinvertebrates in the soil. Invertebrates have been found to use overpasses (Bank, Irwin et al. 2002), with butterflies and birds crossing more frequently at sites with overpasses than at sites without (Pfister et. al., in Forman, Sperling et al. 2003). Problems with Red Crabs \textit{(Gecarcoidea natalis)} on Christmas Island being killed
on roads have been effectively averted with some simple underpasses and fencing (Orchard, pers. comm.).

2.10.6 Fish

There have been a number of works around the world directed at reducing the barrier effect roads can have on fish passage and the flow-on ecological consequences of these barriers (Schroop and Simons 1995; Hegberg and Jacobs 2001; Pearson, Richmond et al. 2001; Spotts 2001; Gubernick and Bates 2003; Gubernick, Clarkin et al. 2003; Jackson 2003; Johansen 2003; Moore 2003; Riley 2003; Sharma 2003; Stadler 2003). The U.S. Fish & Wildlife Service (U.S. Fish and Wildlife Service 2003) established the ‘National Fish Passage Program’ which is working to identify man-made artificial barriers, such as roads, culverts, dams and dikes, and where possible are removing or adapting them for the benefit of fish and other aquatic organisms. The design of a culvert or the area surrounding it can be modified to provide ‘natural passage’ of organisms, and still maintain the structural integrity of the road (Davies 2003; Forman, Sperling et al. 2003).

2.11 Predator & prey relationships

There has been concern that crossing structures may be utilised by predator animals as a prey trap, thus negating the benefits of the structure. There is very little non-anecdotal evidence of predation occurring at crossing structure sites (Puky 2003). Little, Harcourt et al. (2002) looked at the question of wildlife passages as prey traps. In some cases, they found that the predators actually used different crossing structures to their prey.

The relationship between roads and introduced predators in Australia is poorly understood, and likely would differ from those conditions studied in North America and Europe where the predator and prey have co-evolved (May and Norton 1996; Little, Harcourt et al. 2002). The main introduced predators of native Australian animals are foxes, cats and dogs, which are relatively new predators to the Australian mainland, and many native fauna species have yet to develop sufficient survival mechanisms to handle these additional predators.

2.12 Summary

A review of the literature has shown there are many ecological impacts of roads on the ability of animals to live and function safely in their natural habitat. Studies of the main influences of animal mortality are being undertaken, with some measures of these impacts on the viability of populations being examined, although this is still little understood. The fragmentation of habitats by roads can compound already depleted environments, creating
impermeable barriers to fauna. It has also been shown that roads can provide benefits to fauna, particularly Australian road reserves in agricultural regions, where these areas make up a substantial proportion of the remaining native vegetation and habitat of fauna.

Today, there is a variety of crossing structures established around the world, and it is becoming more commonplace to integrate them in new road construction. The greatest amount of work in these developing fields has been conducted in Europe and North America. There are a lot of variables that interact to determine the effectiveness of fauna crossing structures. Australia has several good examples of crossing structures, but would further benefit from the construction of additional crossing structures, accompanied by comprehensive monitoring and evaluation of their effectiveness. This thesis provides an example of a crossing structure that has incorporated a comprehensive monitoring and evaluation program.
CHAPTER 3 - METHODOLOGY

3.1 Study sites and sampling times

The three sites used in the present study were:

- within the Slaty Creek Underpass,
- along Slaty Creek in the eastern forest block 100 metres to the east of the underpass, and
- in the western forest block 320 metres to the west of the underpass along Slaty Creek.

The east site was selected because it was the furthest location to the East, following Slaty Creek, which consisted of contiguous forest; before backing directly onto residential properties, which potentially could have influenced the fauna in that area. The West site was chosen at 320 m along Slaty Creek from the Calder Freeway, as this distance was half way between the Calder Freeway and a single lane gravel road. The size of each monitoring site was approximately 50 m x 50 m as this was consistent with roughly the same sized area being monitored within the Slaty Creek Underpass. The entire study area also included the section of the Calder Freeway between Alex Evans Bridge and Blackwood Road (Figure 1.).

3.1.1 Study site information

3.1.1.1 Dimensions of Slaty Creek Wildlife Underpass

The Slaty Creek Wildlife Underpass is approximately 70 metres wide at the base, and 100 metres wide at the abutment to the road carriageway. The dual lane split carriageways are each supported by two 12-metre piers. The distance between continuous forest on the West and East of the Underpass is approximately 100 metres. Some mature trees and middle storey shrubs have been retained between the carriageways and between the service road and Western edge of the carriageway, and post construction plantings undertaken (Plate 10). A settling pond for water runoff from the road is situated next to the Slaty Creek Underpass on the eastern side.
Plate 10: Slaty Creek Wildlife Underpass showing the distance between carriageways and mature Eucalypts that have been retained. Photo: Rodney Abson.

Figure 1 shows the locations of the West Forest site, Underpass, East Forest Site and Blackwood Road Underpass. The entire Black Forest Section of the Calder Freeway is fenced with chain wire and colorbond corrugated iron to prevent animals from accessing the freeway (Plate 4).
3.2 Data collection period

Data collection occurred for one week each month between July 2002 and June 2003. During that one-week per month, Rodney Abson and others conducted at least three days worth of data collection at each of the three monitoring sites along Slaty Creek. The dates of these data collection periods were as follows:

- 15 to 19 July,
- 19 to 23 August,
- 16 to 20 September,
- 14 to 18 October,
- 18 to 22 November,
- 16 to 20 December,
- 20 to 24 January,
- 17 to 21 February,
- 17 to 21 March,
- 7 to 11 April,
- 19 to 23 May, and
- 16 to 20 June.

An extensive data collection program was conducted each month. Table 4 outlines the methods used to detect animal species at the three sites along Slaty Creek. The data collection program included the use of apparatus in permanent position (traps, sand trays and nest boxes), as well as mobile techniques (spotlighting, audio recording, active searching and incidental observations).

Table 5 outlines the monitoring that was undertaken at Blackwood Road, and the culverts between Slaty Creek and Blackwood Road. Specific details of each method are provided in Section 3.4.
Table 4: Detection methods used at three sites along Slaty Creek

<table>
<thead>
<tr>
<th>Method</th>
<th>West Forest Site</th>
<th>Underpass</th>
<th>East Forest Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 Elliott traps</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>8 Pitfall traps</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>5 Hair funnels</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>2 Sugar Glider / Tuan Nest Boxes</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>1 Feathertail Glider Nest Box</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>1 Leadbeaters Possum Nest Box</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Sand tray</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Bird survey</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Harp trap</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Anabat survey</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Spotlighting / Nightscope</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Audio recordings</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>5 Scat &amp; sign quadrats</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Active search</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Incidental observations</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
</tbody>
</table>

Table 5: Detection methods used for road and culverts between Slaty Creek and Blackwood Road

<table>
<thead>
<tr>
<th>Site</th>
<th>Length of Culvert (metres)</th>
<th>Location (metres south east of Slaty Creek) (1)</th>
<th>Location (chainage from Melbourne) (1)</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culvert 1A &amp; 1B (2)</td>
<td>28</td>
<td>0</td>
<td>61315</td>
<td>Sand Tray</td>
</tr>
<tr>
<td>Culvert 2</td>
<td>92</td>
<td>305</td>
<td>61010</td>
<td>Sand Tray</td>
</tr>
<tr>
<td>Culvert 3</td>
<td>72</td>
<td>640</td>
<td>60675</td>
<td>Sand Tray &amp; Hair Funnel (3)</td>
</tr>
<tr>
<td>Culvert 4A &amp; 4B (2)</td>
<td>165</td>
<td>1205</td>
<td>60110</td>
<td>Sand Tray</td>
</tr>
<tr>
<td>Blackwood Road</td>
<td>1430</td>
<td>59885</td>
<td>61315</td>
<td>Sand Tray</td>
</tr>
<tr>
<td>Freeway: Melbourne bound traffic</td>
<td>0 - 1430</td>
<td>59885 - 61315</td>
<td>Road Walk</td>
<td></td>
</tr>
<tr>
<td>Freeway: median strip</td>
<td>0 - 1430</td>
<td>59885 - 61315</td>
<td>Road Walk</td>
<td></td>
</tr>
<tr>
<td>Freeway: Bendigo bound traffic</td>
<td>0 - 1430</td>
<td>59885 - 61315</td>
<td>Road Walk</td>
<td></td>
</tr>
</tbody>
</table>

(2) A & B refers to a double culvert running parallel at the same location.
(3) Hair funnel data collection between December 2002 & June 2003 only.

3.3 Vegetation monitoring techniques

3.3.1 Vegetation quadrats

The vegetation in both the forest sites and the underpass was surveyed to determine both species present and species cover at the three sites. The cover overlapping of all species was along a 50 m line transect (Brower, Zar et al. 1998), forming a 50 m x 2 m quadrat at each site. Each transects was aligned to run perpendicular to the Slaty Creek, which was incorporated into the line transects. The species cover along the line transects, and heights of
the tallest individuals of each species touching the transects were recorded. Species within the quadrat that did not touch the line transect were recorded, but their cover not measured. Biomass for the lower storey (plants less than 1 m) middle storey (plants 1 m to 4 m) and upper storey (plants 4 m and taller) was approximated by multiplying the cover of each species on the line transect by the height of the tallest individual of that species. Each species was categorised into lower, middle and upper storey and the overall biomass for each category calculated.

3.3.2 Vegetation mapping
In order to establish the exact distribution of vegetation in the underpass site, all the vegetation at the site was mapped through visual inspection and line drawing, measurements with tape measures and clinometers where necessary (Plate 11). This mapping provided a picture of the distribution and percentage cover of:

- mature trees,
- middle canopy vegetation cover (approximately 1 – 4 m height),
- ground vegetation cover, and
- logs and branches.

The mature tree and middle canopy vegetation cover were estimated through field surveys, hand drawing onto maps the approximate canopy cover of these plants. Logs and fallen branches were measured and mapped in the same way.

The ground vegetation cover was determined using a modified Braun-Blanquet cover code scale (Brower, Zar et al. 1998):

<table>
<thead>
<tr>
<th>Code</th>
<th>Cover</th>
<th>Number of Individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>cover &lt;5%</td>
<td>few individuals</td>
</tr>
<tr>
<td>1</td>
<td>cover &lt;5%</td>
<td>any number of individuals</td>
</tr>
<tr>
<td>2</td>
<td>cover 5-20%</td>
<td>any number of individuals</td>
</tr>
<tr>
<td>3</td>
<td>cover 20-50%</td>
<td>any number of individuals</td>
</tr>
<tr>
<td>4</td>
<td>cover 50-75%</td>
<td>any number of individuals</td>
</tr>
<tr>
<td>5</td>
<td>cover 75-100%</td>
<td>any number of individuals</td>
</tr>
</tbody>
</table>

3.3.3 Line distance survey
A line was taken from the western forest edge, across the underpass to the eastern forest edge incorporating the shortest distance between large trees. This was conducted by taking a series of tape measures and a clinometer and mapping by hand the distance between the stems of mature trees. This was undertaken to provide an insight into the distances required to be covered by gliders if they were to move between the eastern and western forest sites.
3.4 Fauna

3.4.1 Monitoring techniques

A variety of techniques have been used in studies of wildlife underpasses or crossing structures, including sand tray, marble dust, ink pad, soot paper, snow prints, video camera, still camera, motion sensor, direct observations, incidental observations, scat collection, traps, radio tagging, capture-mark-recapture, hair sampling and nest boxes (Hunt, Dickens et al. 1987; Mansergh and Scotts 1989; Ecologia 1995; AMBS 1997; Clevenger and Waltho 1999; Veenbaas and Brandjes 1999; Clevenger and Waltho 2000; deMaynadier and Hunter 2000; Huijser and Bergers 2000; AMBS 2001b; AMBS 2001c; AMBS 2001d; AMBS 2001r; AMBS 2001f; AMBS 2001g; Clark, Clark et al. 2001; Goosem, Izumi et al. 2001; Lindenmayer, Cunningham et al. 2001; AMBS 2002a; AMBS 2002b; Bank, Irwin et al. 2002; Goosem 2002; Brudin 2003; Dodd, Gagnon et al. 2003; Mata 2003; Proctor 2003; Weston in prep.). These methods were reviewed in Chapter Two.

Because this study required the monitoring of several types of animals, including terrestrial and arboreal mammals, bats, birds, amphibians and reptiles, some different monitoring techniques to those outlined above were employed, including active searching, the use of an Anabat, audio recording, bird surveying, harp traps, pitfall traps and spotlighting, which have
not been known to be used in other underpass studies. The large dimensions and retained vegetation in the underpass allowed for some of these techniques to be employed. This would not have been possible with underpasses of smaller dimensions.

In the present study it was not feasible to use cameras for several reasons: the large size of the underpass and retained vegetation would limit the size of the fauna that could be detected; the expense and difficulty of purchasing the cameras, powering them and securely fitting them was outside the budget of this project; and the close proximity to residential properties meant the cameras could be vandalised or stolen.

3.4.2 The methods used to monitor fauna in and around the underpass

Fourteen methods were used to monitor fauna in and around the underpass, with the frequencies of monitoring covered in Table 6. Specific details of each of the methods are outlined below.
<table>
<thead>
<tr>
<th>Site</th>
<th>Trap type/ Monitoring method</th>
<th>Trap days/nights</th>
<th>Detection hours</th>
<th>Number of months of data collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slaty Creek West site</td>
<td>Bird survey</td>
<td>12</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 x Elliott traps</td>
<td>504</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 x Hair funnels</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incidental observations</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 x Nest boxes</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 x Pitfall traps</td>
<td>576</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 x Scat &amp; sign quadrants</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Slaty Creek underpass</td>
<td>Anabat survey</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bird survey</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 x Elliott traps</td>
<td>504</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 x Hair funnels</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Harp trap</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incidental observations</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 x Nest boxes</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 x Pitfall traps</td>
<td>576</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sand Tray</td>
<td>48</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 x Scat &amp; sign quadrants</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Slaty Creek East site</td>
<td>Bird survey</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 x Elliott traps</td>
<td>504</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 x Hair funnels</td>
<td></td>
<td>12</td>
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<td></td>
<td>Harp trap</td>
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</tr>
<tr>
<td></td>
<td>Incidental observations</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 x Nest boxes</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 x Pitfall traps</td>
<td>576</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 x Scat &amp; sign quadrants</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>All sites &amp; surrounds</td>
<td>Active Search</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Audio Recordings</td>
<td>Incidental</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incidental Observations</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Spotlighting</td>
<td>41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culvert 1A &amp; 1B</td>
<td>Sand Tray</td>
<td>36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culvert 2</td>
<td>Sand Tray</td>
<td>36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culvert 3</td>
<td>1 x Hair funnel</td>
<td></td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sand Tray</td>
<td>36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culvert 4A &amp; 4B</td>
<td>Sand Tray</td>
<td>36</td>
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<td>Blackwood Road bridge</td>
<td>Sand Tray</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Freeway east side</td>
<td>Road walk</td>
<td></td>
<td>12</td>
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<tr>
<td>Freeway median strip</td>
<td>Road walk</td>
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<tr>
<td>Freeway west side</td>
<td>Road walk</td>
<td></td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>
3.4.2.1 Active Searches

Active searching involved the lifting of logs and rocks within the three sites to search for reptiles and amphibians. The three sites were searched thoroughly until it was ascertained all likely sites for reptiles and amphibians had been explored. Active searching was conducted in areas surrounding the underpass, and between the two forest sites, as well as along the service road adjacent to the freeway south to Blackwood Road (Figure 6). This was conducted once per three months, for four hours during the day.

3.4.2.2 Audio recordings

During bird surveys and the spotlighting walks, a note taker and sensitive directional microphone were used to record calls of birds, frogs, and nocturnal animals.

3.4.2.3 Bird Surveys

In the hour leading into dusk at each site, a 20-minute bird survey was conducted, starting at the West site, then underpass, followed by East site. The same order of sites for conducting the bird surveys was chosen out of practicality of checking traps and the sand tray in the hours of dusk. Sitting in a location with the sun to the back of the observer, and able to view the 50 x 50 metre quadrat, all birds sighted and identified were noted. This information included the species, location within structure of the forest, activity of the bird, and also whether they were detected within or outside the quadrat.

3.4.2.4 Elliott Traps

Elliott traps are metal, spring loaded treadle boxes 32cm long, with a 9cm x 10cm opening. They were baited with a mix of honey, oats and peanut butter. This bait mix and size of the trap are primarily aimed at detecting small mammals. The traps were covered with a plastic bag to keep any animals caught dry, and coconut fibre placed inside the traps for warmth and comfort of the animal. Seven Elliott traps were scattered over a 50m x 50m area, at each of the three sites, and were checked at dawn and dusk for three days of monitoring per month (See figure 7, 8 and 9 for the locations of Elliott traps).
Figure 6: Map of road walk, active search and spotlighting. Source: (Qasco Vic Image 2002)

- Approximate area covered in road walk
- Approximate area covered in spotlighting walk
- Approximate area covered in active search
Figure 7: West Site Trap and Nest box locations

- Nest Box
- Pitfall Trap
- Hair Funnel
- Elliott Trap
- Slaty Creek

FTG = Feathertail Glider
LBP = Leadbeater Possum
SG = Sugaar Glider
NUMBER = Site Number
Figure 8: Slaty Creek Underpass Site Trap and Nest box locations

- Nest Box
- Pitfall Trap
- Hair Funnel
- Elliott Trap
- Slaty Creek

FTG = Feathertail Glider
LBP = Leadbeater Possum
SG = Sugaar Glider
NUMBER = Site Number
3.4.2.5 Hair Funnels

Hair funnels are plastic half-funnels 24 cm long, with a 13 cm diameter aperture at the open end, narrowing down to a 4 cm diameter at the closed, baited end. The closed end of the hair funnel is baited with a mix of oats, honey and peanut butter to attract mammals. A sticky wafer is placed on the top arc of the funnel to collect a small sample of hair from the animals investigating the scent of the bait. Five hair funnels were placed at each of the three sites: three funnels on the ground and two in trees. From December to June a hair funnel was placed inside the centre of culvert 3 and was accessed from the freeway central median strip. The hair funnels were checked monthly, with the bait and wafer replaced, and the wafer sent to Barbara Triggs, an expert for identification of mammalian hair (See figure 7, 8 and 9 for the locations of hair funnels).
3.4.2.6 Harp Trap & Anabat

Five Harp traps were set up within the underpass and nearby forest, from late afternoon to early morning in late November, which is a prime time for detecting bats (Holsworth, pers. comm., 2003). These were checked twice during the night, and once more at dawn.

An Anabat was used to detect the audio frequency of bat calls, and this is then projected onto a computer and later sent to an expert, Angela Duffy, for analysis. This equipment was used in November, January and April during the first four hours after dusk.

3.4.2.7 Incidental Observations

Incidental observations of animals outside of the regular monitoring methods were noted.

3.4.2.8 Nest Boxes

At each site, four nest boxes were set up to detect arboreal mammals or birds in the area. There were three designs to the nest boxes depending on the target mammals. Each site had one Leadbeaters possum box (600 mm tall, 300 mm deep, 300 mm wide with an oval aperture hole of 60 mm height and 40 mm width), one feathertail glider box (400 mm tall, 235 mm deep, 235 mm wide with two aperture holes of 25 mm diameter), and two sugar glider/tuan boxes (400 mm tall, 235 mm deep, 235 mm wide with an aperture hole of 35 mm diameter) attached to trees four to five metres above ground. These were checked once per month for any evidence of animal use (See figure 7, 8 and 9 for the locations of nest boxes).

3.4.2.9 Pitfall Traps

PVC pipe 15 cm in diameter and 30 cm deep were placed into holes in the ground of the same dimensions, with fly wire across the bottom to allow drainage of water, but stop animals from digging through. A 16 cm high, four m long, fence was placed over the hole to direct animals into the pit. These were intended to capture small mammals, reptiles and amphibians. Eight pitfall traps were placed at each of the three sites, scattered across a 50 m x 50 m area. Pitfall traps were checked at dawn and dusk for three days of monitoring per month and capped when not in use (See figure 7, 8 and 9 for the locations of pitfall traps).

3.4.2.10 Road Walk

A road walk was conducted along the freeway from Blackwood Road (approximately 1 km South of Slaty Creek Underpass) to Slaty Creek, and to Alex Evans Bridge (approximately 1 km North of Slaty Creek Underpass), encompassing both sides of the road, and the centre
median strip to look for any road kill animals, or signs of animals (See Figure 6). This was conducted once per month.

3.4.2.11 Sand Tray
Sand was placed for 80 metres along the west service road that runs the total length of the underpass, parallel with the freeway (Plate 12). Two cubic metres of washed sand were laid each month on the service road when required, to ensure fresh sand. This was approximately 2 metres wide and 5cm deep. This was used to detect medium to large animals and human footprints, and was checked at dawn and dusk for a three-day period, and raked smooth after each observation time. The species, length of footprint, and direction of movement were recorded from one print of a set of prints made from one animal in each crossing of the sand tray. Plaster casts were made of representative footprints found.

Each month, sand was also placed at the western entrance of the culverts between Slaty Creek and Blackwood Road. Many of the culverts at the eastern side of the freeway were wet, and would not make effective sand trays. The western end of the culverts allowed for ease of access, as they were adjacent to vehicular access. A sand tray 0.5 m wide was placed along the 15 m width of tanbark mulch along Blackwood Road to detect footprints of animals or humans. The Blackwood Road sand tray and culvert sand trays were checked after each of the three day monitoring periods.

Plate 12: Sand Tray at Slaty Creek Underpass. Photo: Rodney Abson.

3.4.2.12 Scat analysis
Five 1 m² quadrats were randomly placed within a 50 m x 50 m area at each of the three sites, and checked for scats or other signs of animals which were collected. It was expected that mammal scats, hair and bones would be collected. This was conducted once per month. Random plots were determined from a central point of each site, by generating a random
number on a calculator, dividing it by four to give the distance from the central point. A stick was then spun to give direction, and the distance was measured with a tape measure.

3.4.2.13 Spotlighting
Red filtered spotlights and a nightscope (device that can detect infra-red and ultra-violet light, allowing a person to see in the dark) were used in an attempt to detect arboreal mammals using the underpass and forest on either side. Spotlighting started from 200 m north of the west site, and the area was scanned with the spotlight whilst slowly walking. This covered the west site, and walked along the creek line through the underpass, and across to the east site, and back up the west side service road to the starting point (Figure 6). With each animal that was detected, the data collected included the time of sighting, the location and position of the animal within the forest structure, the activity of the animal, and any further notes or photographs where possible. This was conducted three nights per month for around one hour, within the first two hours of darkness, which is an optimal time for detecting nocturnal animals (Lindenmayer, Cunningham et al. 2001). Audio recordings were taken of any animals detected during the walk, where possible.

3.5 Methods used for evaluation of the effectiveness of the Underpass
3.5.1 Statistical analysis
Chi-squared was used to test:

Is there an equal distribution of individual taxa across each of the three sites or is there significantly more or less than expected in each of the three sampling sites?

The observed value was the number of monthly presences of a taxon, using the techniques that were applied to each site in each month. Thus, if a taxon was recorded using bird survey in February and March and in a nest box in February in the underpass, the observed value for the underpass would be 3. The predicted value for each site for each species was the total number of monthly observations for all sites divided by 3. It is realized that individual observations may not be independent, and that the statistical outcomes are relative and indicative rather than confirmatory. The limitation of this method is that the close proximity of sites and traps within sites means there is not an independence of counts, and it is possible that one animal could be responsible for most of the scats collected, or infecting all hair funnels within a site, or it is the same individuals of one population being trapped many times. It is also possible that wide ranging animals, such as Eastern grey kangaroos could be detected at each of the three sites, making them not entirely independent of each other. This could be particularly likely with the underpass and east site, as they are 100 m apart.
Any species with fewer than 15 records was not analysed, as the expected value was less than 5. The analysis was done independently for scat types.

3.5.2 Direction of movement
From the footprints detected on the sand tray, the directions of prints were recorded. Prints refers to the set of prints made by an individual animal in one direction, and does not mean each print recorded on the sand tray. This information can determine the percentage of fauna moving in a Westerly, Easterly, Southerly or Northerly direction, to determine if there is a high proportion of fauna moving in any particular direction.

3.5.3 Diurnal animal activity
The use of the underpass during day and night was determined through analysis of the monitoring methods that were checked once, or twice (dawn and dusk) in a 24-hour period. This includes the Sand Tray (only within the Underpass), Elliott traps and Pitfall traps.

A second level of diurnal animal activity is determined by those methods which recorded an animal at a location during the day or night, but was not consistently measured through the surveying period to show day or night variation (Anabat, audio recordings, bird surveys and spotlighting).

3.5.4 Comparison of effectiveness between Slaty Creek, Blackwood Road and culverts
Whilst there were a variety of techniques used within the Slaty Creek Underpass to determine the species use of the Underpass, some methods were also employed at the culverts and Blackwood Road and can be used for comparison. This limits comparative analysis to sand trays, although comment is made on scats, bones or hair samples also collected within the Blackwood Road corridor.

3.5.5 Road kill
Animals killed on the Freeway between Blackwood Road and Alex Evans Bridge have failed to make safe passage from one side of the freeway to the other (Plate 13).

Plate 13: Road killed Koala. Photo: Rodney Abson.
3.6 Effectiveness of methods

The effectiveness of a technique for detecting fauna could be assessed in a number of ways, including the quantity of animals detected, variety of species, the costs involved in using the technique, or the time involved in using the technique. Because this monitoring study was primarily only concerned with detecting the presence or absence of a species from a location, this is the basis for evaluating the effectiveness of the methods. This evaluation looks at the number of species detected during each month, and the effectiveness of each method for detecting species.

3.6.1 Month

The most effective months for monitoring are assessed by comparing the number of species that are detected within each month. In this way, species that are only recorded once will be identified, and it will be obvious as to whether all 12 months of monitoring were necessary in order to detect all species. A species accumulation curve is generated to present how long it would take before the methods used have exhausted the total number of species they are likely to detect.

3.6.2 Method

Comparisons are made on the effectiveness of each method for detecting species. The accumulation of most effective methods can be used to generate a table that demonstrates the most effective to least effective methods as a percentage of the total vertebrate fauna collected.

3.7 Efficiency of methods

Efficiency of methods is based around how quickly the methods are able to detect vertebrate fauna, and what is the expense involved in these methods.

3.7.1 Time

The number of hours required for the preparation of equipment, installation, monitoring and cleaning of equipment is calculated and assessed against the number of species detected by that method. This demonstrates the most efficient methods for detecting vertebrate species, based on time invested.

3.7.2 Expense

The expense of each method is determined by calculating the costs involved in the purchasing or hiring of equipment and the estimated time involved in collection of data is costed at an
hourly rate of $20 per hour. Each method’s total expense is divided by the number of species detected through that method to determine the most efficient method for detecting species, based on monetary expense.
CHAPTER 4 – RESULTS & DISCUSSION

This study is intended to give a comprehensive description of the presence of vertebrate fauna species within the Slaty Creek Underpass compared to sites in the surrounding Black Forest. The underpass has been studied for its connectivity of vegetation and species composition with the two adjacent forest sites. The results and discussion have been combined in order to provide for coherent analysis of the results, which address the questions as outlined in Chapter One.

4.1 Plant species comparison between sites

This section looks at the species composition of the three sites. It addresses question 1 (a):

1. (a) Is species cover and plant species richness similar between the underpass and forest sites?

A plant species list comparing the Slaty Creek Underpass with the East and West forest sites is shown in table 7.

The main tree species in the Black Forest sites are:

- Blackwood (*Acacia melanoxylon*),
- Broad leaved Peppermint (*Eucalyptus dives*),
- Manna Gum (*Eucalyptus viminalis*),
- Messmate Stringybark (*Eucalyptus obliqua*), and
- Narrow leaved Peppermint (*Eucalyptus radiata*).

The only mature trees to occur in the underpass site are the Manna Gum and Messmate Stringybark.

The middle storey vegetation occurring in the Black Forest comprises:

- Clustered Pomaderris (*Pomaderris racemosa*),
- Hazel Pomaderris (*Pomaderris aspera*),
- Narrow-leaved Wattle (*Acacia cognata*),
- Prickly Moses (*Acacia verticillata*), and
- Victorian Christmas Bush (*Prostanthera lasianthos*).

The only middle storey vegetation occurring in the underpass, as detected by the line transect were two acacias, one of which was Prickly Mimosa, although there is a remnant patch of Clustered Pomaderris and Hazel Pomaderris.
Ground storey vegetation in the forest sites consisted of a mosaic of *Clematis* sp., *Carex* sp., *Poa* sp., *Lomandra* sp., *Tetrarrhena juncea*, *Adiantum aethiopicum*, *Pteridium esculentum*, and weeds. There were many more ground storey plant species within the underpass, including species belonging to the following genera: *Agrostis*, *Carex*, *Clematis*, *Deyeuxia*, *Dianella*, *Geranium*, *Gonocarpus*, *Goodenia*, *Juncus*, *Oxalis*, *Plantago*, *Poa*, *Senecio*, and *Vulpia*, in addition to bracken, plantain, and dandelions. Eight understorey plant species were common to both the forest and underpass sites. There appears to be greater species richness within the underpass, possibly due to the presence of many small grasses and herbs.

4.1.1 Vegetation Biomass

The underpass has a different structure to the forest sites (Table 8). The upper storey biomass of the Underpass measured about 450 m$^3$ per 100m$^2$, compared to 4,300 m$^3$ per 100m$^2$ and 3,200 m$^3$ per 100m$^2$ for the West site and East site respectively. Middle storey biomass indices were about 500 m$^3$ per 100m$^2$ in the West site, 260 m$^3$ per 100m$^2$ in the East site, and only 5 m$^3$ per 100m$^2$ within the underpass. The biomass of ground story vegetation of the Black Forest sites was estimated to be about 2 m$^3$ per 100m$^2$ for the West site, and 9 m$^3$ per 100m$^2$ for the East site. The biomass of ground story vegetation of the underpass site was estimated to be about 33 m$^3$ per 100m$^2$. 
Table 7: Vegetation Species list for the Black Forest and Slaty Creek Underpass.

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Black Forest East Site</th>
<th>Slaty Creek Underpass</th>
<th>Black Forest West Site</th>
</tr>
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<tr>
<td><strong>FERNS</strong></td>
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<td>ADIANTACEA</td>
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<td>DENNSTAEDTIACEAE</td>
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<tr>
<td><strong>MONOCOTYLEDONS</strong></td>
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<td></td>
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</tr>
<tr>
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<td>Tall Sedge</td>
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<tr>
<td>JUNCACEA</td>
<td><em>Juncus sp.</em></td>
<td>Rush</td>
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<tr>
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<tr>
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<td>Black-anther Flax-lily</td>
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<td><em>Deyeuxia quadrirista</em></td>
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<td><strong>DICOTYLEDONS</strong></td>
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<td><em>Acacia melanoxylon</em></td>
<td>Blackwood</td>
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<td><em>Acacia mucronata</em></td>
<td>Narrow-leaf Wattle</td>
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<td><em>Eucalyptus obliqua</em></td>
<td>Messmate</td>
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<tr>
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<td><em>Eucalyptus radiata</em></td>
<td>Narrow-leaf Peppermint</td>
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<td></td>
<td><em>Eucalyptus viminalis</em></td>
<td>Manna Gum</td>
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<td><em>Oxalis perennans</em></td>
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<td><em>Rubus discolor</em></td>
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<td><em>Pinus radiata</em></td>
<td>Monterey Pine</td>
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* Introduced species
Table 8: Comparisons of biomass.

<table>
<thead>
<tr>
<th>Site</th>
<th>Trees (m$^3$ per 100m$^2$)</th>
<th>Middle storey (m$^3$ per 100m$^2$)</th>
<th>Grasses &amp; lower storey (m$^3$ per 100m$^2$)</th>
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</thead>
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<td>West</td>
<td>4318.13</td>
<td>506.83</td>
<td>1.79</td>
</tr>
<tr>
<td>Underpass</td>
<td>446.91</td>
<td>4.758</td>
<td>33.49</td>
</tr>
<tr>
<td>East</td>
<td>3222.86</td>
<td>261.98</td>
<td>8.92</td>
</tr>
</tbody>
</table>

4.1.2 Connectivity and composition of vegetation

The structure and connectivity of the vegetation within the underpass assessed in this section addresses question 1 (b) in Section 1.3:

1. (b) *Is there connectivity of vegetation structure between the underpass and forest on either side?*

There is contiguous vegetation cover throughout the forest to the West and East of the Slaty Creek Underpass (Figure 10). Figure 10 shows the large mature trees that have been retained adjacent to and within the two carriageways and middle storey patches within this vicinity. This map clearly illustrates the gaps in the canopy and middle storey through the underpass. Comparing Figure 6 with the cross sectional transect view of the Underpass shown in Figure 11, highlights the gaps of 12 to 17 metres at the closest intervals of mature trees.

Figure 12 illustrates the density of vegetation, highlighting the dense lower-storey vegetation connectivity along the creek-line, and relatively patchy vegetation in the remaining area.

The vegetation composition and fallen timber could be a very important element in allowing for movement through or habitat within the underpass. Small animals, particularly amphibians and skinks were regularly found beneath the rocks and logs within the underpass, as they were using them for shelter and feeding on invertebrates. It would be expected that over time, the middle storey and upper storey vegetation species would mature and provide for greater connectivity.

Figure 13 maps the fallen logs and tree stumps which are dispersed throughout the entire Underpass. This is a very important feature of the underpass, providing shelter for small animals, and an organic base that can assist with the long-term nutrient cycling on the site, which can assist in natural regeneration.
Figure 10: The distribution of upper and middle story vegetation in the Slaty Creek Underpass.
Figure 11: A cross-section depicting slope and upper storey vegetation in the Slaty Creek Underpass.
Figure 12: The distribution of ground story vegetation in the Slaty Creek Underpass.
Figure 13: The distribution of logs and stumps in the Slaty Creek Underpass.
4.1.3 Rainfall for Macedon Region

The rainfall data for Mt Macedon Station (88061) has been compiled into a five year moving average (with data correlating with the study year July to June) as shown in Figure 14, (Department of Sustainability and Environment 2002) (Note: Mt. Macedon September 2001 and June 2002 data was missing and interchanged with Gisborne Station (87026) data for the same period). This indicates that during the study period, the Macedon Region was experiencing a drought, of similar magnitude experienced in other years. This could have potentially impacted upon some fauna species with limited food supply available from vegetation, or aquatic dependent fauna if the Slaty Creek was drier than would be expected in years when the region was not in drought.

Figure 14: Rainfall for Macedon Region
4.2 Fauna use of the Slaty Creek Wildlife Underpass

The presence of animals within the underpass reflects that they are either using the underpass as a means of passage beneath the freeway, from one side of the forest to the other, or they are using this area as habitat. Alternatively if species are detected away from the underpass, and not within it, then this could demonstrate limitations to the effectiveness of the underpass.

This section addresses questions:

2. Is the underpass being used by animals as a means of passage between the two forest sites or as habitat?
   (a) Are there some species that are not detected within the underpass but are found in the forest sites on either side?

4.2.1 Mammals

A total of 24 confirmed and seven unconfirmed mammal species were detected within the Slaty Creek Underpass (Table 9) out of a total of 28 confirmed and nine unconfirmed mammal species detected during the study across all sites.

Between July 2002 and June 2003, just over half of the total number of mammal species detected occurred in both the underpass and forest sites. They were:

- Agile Antechinus (*Antechinus agilis*),
- Brushtail Possum (*Trichosurus sp.*) (species indeterminable),
- Bush Rat (*Rattus fuscipes*),
- *Cat (*Felis catus*),
- Common Brushtail Possum (*Trichosurus vulpecula*),
- *Dog (*Canis lupus familiaris*),
- Eastern Grey Kangaroo (*Macropus giganteus*),
- Echidna (*Tachyglossus aculeatus*),
- *European Rabbit (*Oryctolagus cuniculus*),
- *Fox (*Vulpes vulpes*),
- *Horse (*Equus caballus*),
- *House Mouse (*Mus musculus*),
- Koala (*Phascolarctos cinereus*),
- Ringtail Possum (*Pseudocheirus peregrinus*),
- Sugar Glider (*Petaurus breviceps*),
- Swamp Wallaby (*Wallabia bicolor*), and
- Wombat (*Vombatus ursinus*).

*Introduced
Six of the ubiquitous species were introduced. The introduced species detected within the underpass included the black rat, brown hare, cat, dog, European rabbit, fox, horse and house mouse. The only other introduced species detected, which were not within the underpass, were the cow and sheep (Table 9).

Up to twelve species of bats were recorded using an Anabat, only within the underpass, as this is the only place this monitoring method was employed (Table 9). The hair found in the hair funnel within the underpass could have been of the squirrel glider, but this could not be confirmed and is more likely to be that of the sugar glider which is known to inhabit this region, and was seen during this survey. The brown hare (*Lepus capensis*) was the only other mammal detected only within the underpass and not in any other location.

Some species were detected within the forest surrounding the underpass, but never within the underpass. Two species of gliding possums, the feathertail glider (*Acrobates pygmaeus*) and greater glider (*Petauroides volans*), were recorded from the surrounding forest. The feathertail glider was viewed by spotlighting at night over three months at or near the West site. A scat collected at the East site resembled that of a greater glider, but could not be confirmed.

The hair of a swamp rat (*Rattus lutreolus*) was recorded in May 2003 on the East site. This is the only record of this species recorded throughout the entire monitoring period.
Table 9: Mammals species list for Slaty Creek and the Black Forest.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>West Forest Site</th>
<th>Underpass</th>
<th>East Forest Site</th>
<th>Other location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agile Antechinus</td>
<td>Antechinus agilis</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>*Black Rat</td>
<td>Rattus rattus</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Brown Hare</td>
<td>Lepus capensis</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brushtail Possum</td>
<td>Trichosurus sp.</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Bush Rat</td>
<td>Rattus fuscipes</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>*Cat</td>
<td>Felis catus</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Chocolate Wattled Bat</td>
<td>Chalinolobus morio</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Brushtail Possum</td>
<td>Trichosurus vulpecula</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Cow (2)</td>
<td>Bos taurus</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Dog</td>
<td>Canis lupus familiaris</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Eastern False Pipistrelle</td>
<td>Falsistrellus tasmaniensis</td>
<td>•</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Eastern Freetail Bat (3)</td>
<td>Mormopterus sp.</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eastern Grey Kangaroo</td>
<td>Macropus giganteus</td>
<td>•</td>
<td>•</td>
<td>•</td>
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</tr>
<tr>
<td>Echidna (short-beaked)</td>
<td>Tachyglossus aculeatus</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>*European Rabbit</td>
<td>Oryctolagus cuniculus</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Feathertail Glider</td>
<td>Acrobates pygmaeus</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Fox</td>
<td>Vulpes vulpes</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Gould's Long-eared Bat (3)</td>
<td>Nyctophilus gouldi</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gould's Wattled Bat (3)</td>
<td>Chalinolobus gouldii</td>
<td>•</td>
<td></td>
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<tr>
<td>Greater Glider (3)</td>
<td>Petauroidea volans</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Horse</td>
<td>Equus caballus</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*House Mouse</td>
<td>Mus musculus</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Koala</td>
<td>Phascolarctos cinereus</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Large Forest Bat</td>
<td>Vespadelus darlingtoni</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lesser Long-eared Bat (3)</td>
<td>Nyctophilus geoffroyi</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Little Forest Bat</td>
<td>Vespadelus vultinus</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mountain Brushtail Possum (2)</td>
<td>Trichosurus caninus</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ringtail Possum</td>
<td>Pseudocheirus peregrinus</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>*Sheep (2)</td>
<td>Ovis aries</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Southern Forest Bat (3)</td>
<td>Vespadelus regulus</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southern Freetail Bat (3)</td>
<td>Mormopterus sp.</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Squirrel Glider (4)</td>
<td>Petaurus norfolcensis</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugar Glider</td>
<td>Petaurus breviceps</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swamp Rat</td>
<td>Rattus lutreolus</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swamp Wallaby</td>
<td>Wallabia bicolor</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unidentified long-eared Bat</td>
<td>Nyctophilus sp.</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-striped Freetail Bat</td>
<td>Tadarida australis</td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wombat</td>
<td>Vombatus ursinus</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
</tbody>
</table>

* Introduced species
(1) Other location includes culverts and road verges
(2) Evidence of animal does not necessarily mean the animal was physically present: i.e. a hair of the animal was found in a predator scat
(3) Identity could not be confirmed
(4) The identity of the Squirrel Glider is uncertain, as it is not possible to discriminate between the hairs of a Squirrel Glider and a Sugar Glider
4.2.2 Reptiles and Amphibians

Four of the seven reptile species detected during this survey were found within the Slaty Creek Underpass, being Coventry’s skink (*Niveoscincus coventryii*), the garden skink (*Lampropholis guichenoti*), McCoy’s skink (*Nannoscincus maccoyi*) and a snake (Table 10). Active searching detected all skink species, and tracks within the underpass sand tray resembled those of a snake.

Three species of reptiles, the Boulengers skink (*Morethia boulengeri*), southern water skink (*Eualamprus tympanum*) and White’s skink (*Egernia whitii*) were all detected at locations away from the Slaty Creek Underpass and not within.

Seven amphibian species were detected during this survey, with six species detected within the underpass, these being the brown toadlet (*Pseudophryne bibronii*), common froglet (*Crinia signifera*), plains brown tree frog (*Litoria paraewingi*), southern brown tree frog (*Litoria ewingii*) (Plate 14), southern bullfrog (*Limnodynastes dumerilii*) and Victorian smooth froglet (*Geocrinia victoriana*) (Table 11). The Slaty Creek and settling dam adjacent to the underpass provided a suitable habitat for frogs with permanent water, and semi-submerged vegetation surrounding the dam.

The whistling tree frog (*Litoria verreauxii vereauxii*) was detected at night in the East site and another site away from the Slaty Creek Underpass, but never within the Underpass.

The Boulengers skink (*Morethia boulengeri*) and the brown toadlet (*Pseudophryne bibronii*) had not previously been recorded within the Black Forest region and were not on the D.S.E. database of the Atlas for Victorian Wildlife (Department of Sustainability and Environment 2002).

Plate 14: Southern Brown Tree Frog within the Slaty Creek Underpass. Photo: Rodney Abson
Given that there were few individual reptiles or amphibians detected, it is difficult to draw conclusions as to whether there is variation within species response to the underpass. However, it is evident that some species were using the underpass as habitat. This habitat for reptiles and amphibians could be enhanced through the use of fallen timber and rocks within the sections of the underpass that are unlikely to be covered in vegetation, such as the areas immediately beneath the carriageway, and within the creek line.

Table 10: Reptiles species list for Slaty Creek and the Black Forest.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>West Forest Site</th>
<th>Underpass</th>
<th>East Forest Site</th>
<th>Other location (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulengers Skink</td>
<td>Morethia boulengeri</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coventry's Skink</td>
<td>Niveoscincus coventryii</td>
<td>•</td>
<td>•</td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>Garden Skink</td>
<td>Lampropholis guichenoti</td>
<td></td>
<td></td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>McCoy's Skink</td>
<td>Nannoscincus maccoyi</td>
<td>•</td>
<td></td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Snake sp.</td>
<td></td>
<td></td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southern Water Skink</td>
<td>Eulamprus tympanum</td>
<td></td>
<td></td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>White's Skink</td>
<td>Egernia whitii</td>
<td></td>
<td>•</td>
<td></td>
<td>•</td>
</tr>
</tbody>
</table>

(1) Other location includes culverts and road verges

Table 11: Amphibians species list for Slaty Creek and the Black Forest.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>West Forest Site</th>
<th>Underpass</th>
<th>East Forest Site</th>
<th>Other location (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown Toadlet</td>
<td>Pseudophryne bibronii</td>
<td></td>
<td></td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Common Froglet</td>
<td>Crinia signifera</td>
<td>•</td>
<td></td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Plains Brown Tree Frog</td>
<td>Litoria paraewingi</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southern Brown Tree Frog</td>
<td>Litoria ewingii</td>
<td>•</td>
<td></td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Southern Bullfrog</td>
<td>Limnodynastes dumerilii</td>
<td>•</td>
<td></td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Victorian Smooth Froglet</td>
<td>Geocrinia victoriana</td>
<td></td>
<td></td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Whistling Tree Frog</td>
<td>Litoria verreauxii verreauxii</td>
<td></td>
<td></td>
<td>•</td>
<td>•</td>
</tr>
</tbody>
</table>

(1) Other location includes culverts and road verges

4.2.3 Birds

Between July 2002 and June 2003 a total of 63 bird species were recorded within the Black Forest, encompassing the Slaty Creek Underpass (Table 12). Thirty-seven bird species were recorded within or above the Slaty Creek Underpass. Only two species of birds sighted were introduced.

Most birds were detected few times, which meant most were unable to be statistically analysed for their distribution throughout the forest and underpass. However, of the following 26 bird species listed below, that were detected away from the underpass and never within or above, there are several birds that were detected more than 10 times, which may give an indication of some unwillingness to use the underpass. Those birds include the Grey
Currawong (*Strepera versicolor*), detected twelve times; Satin Flycatcher (*Myiagra cyanoleuca*), detected fourteen times; and Scarlet Robin (*Petroica multicolor*), detected ten times. The number of times each bird species was detected is recorded in brackets after the name:

- Australian Wood Duck (*Chenonetta jubata*) (1);
- Bassian Thrush (*Zoothera lunulata*) (6);
- Black-faced Cuckoo-shrike (*Coracina novaehollandiae*) (2);
- Common Myna (*Acridotheres tristis*) (1)
- Galah (*Cacatua roseicapilla*) (2);
- Great Egret (*Ardea alba*) (1);
- Grey Currawong (*Strepera versicolor*) (12);
- Horsfield’s Bronze-Cuckoo (*Chrysococcyx basalis*) (1);
- Leaden Flycatcher (*Myiagra rubecula*) (2);
- Long-billed Corella (*Cacatua tenuirostris*) (4);
- Magpie-lark (*Grallina cyanoleuca*) (1);
- Masked Lapwing (*Vanellus miles*) (4);
- New Holland Honeyeater (*Phylidonyris novaehollandiae*) (1);
- Pied Cormorant (*Phalacrocorax varius*) (1);
- Powerful Owl (*Ninox strenua*) (1);
- Raptor sp. (1);
- Rose Robin (*Petroica rosea*) (1);
- Rufous Whistler (*Pachycephala rufiventris*) (5);
- Sacred Kingfisher (*Todiramphus sanctus*) (1);
- Satin Flycatcher (*Myiagra cyanoleuca*) (14);
- Scarlet Robin (*Petroica multicolor*) (10);
- Southern Boobook (*Ninox novaeseelandiae*) (4);
- Spotted Pardalote (*Pardalotus punctatus*) (1);
- Tawny Frogmouth (*Podargus strigoides*) (1);
- Wedge-tailed Eagle (*Aquila audax*) (2); and
- White-plumed Honey Eater (*Lichenostomus penicillatus*) (1).
Table 12: Bird species list for Slaty Creek and the Black Forest.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>West Forest Site</th>
<th>Underpass</th>
<th>East Forest Site</th>
<th>Other location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian Raven</td>
<td>Corvus coronoides</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Australian Wood Duck</td>
<td>Chenonetta jubata</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Bassian Thrush</td>
<td>Zoothera lunulata</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Black-faced Cuckoo-shrike</td>
<td>Coracina novahollandiae</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Brown Throated</td>
<td>Acanthiza apicalis</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Buff-rumped Thrush</td>
<td>Acanthiza reguloides</td>
<td>•</td>
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<td>•</td>
<td></td>
</tr>
<tr>
<td>Common Blackbird</td>
<td>Turdus merula</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Common Myna</td>
<td>Acroderes tristis</td>
<td>•</td>
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</tr>
<tr>
<td>Crested Shrike-tit</td>
<td>Felicunculus frontatus</td>
<td>•</td>
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<td></td>
</tr>
<tr>
<td>Crimson Rosella</td>
<td>Platycercus elegans</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Eastern Spinebill</td>
<td>Acanthorhynchus tenuirostris</td>
<td>•</td>
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<td></td>
</tr>
<tr>
<td>Eastern Yellow Robin</td>
<td>Eopsaltria australis</td>
<td>•</td>
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</tr>
<tr>
<td>Galah</td>
<td>Cacatua roseicapilla</td>
<td>•</td>
<td>•</td>
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<td></td>
</tr>
<tr>
<td>Gang-Gang Cockatoo</td>
<td>Callocephalina fimbriatun</td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Golden Whistler</td>
<td>Pachycephala pectoralis</td>
<td>•</td>
<td>•</td>
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* Introduced species; (1) Identification not certain
4.3 Faunal site preferences

There was a great deal of variation between the number of times each species was detected, and variations in the locations the species were detected. Many species were detected in low numbers, with only 20 of the 77 taxa obtaining 15 records or more. Nine of the 20 taxa (antechinus sp., crimson rosella, currawong, eastern yellow robin, grey fantail, rat sp., sugar glider, white throated tree creeper and wombat) presented no significant variation between the Underpass, East and West sites (Table 13).

There are two main reasons why species would be detected more often within the underpass than within the surrounding forest: funnelling of animals through the underpass as they move throughout the forest; the preferential use of the underpass as habitat. Two introduced rodent species were detected regularly within the underpass and rarely within the surrounding forest. The black rat (*Rattus rattus*) was detected 11 times, all only within the underpass, and whilst this is noteworthy, there were insufficient number of recordings to include this in statistical analysis. The house mouse (*Mus musculus*) was detected a total of 45 times, 39 of which were within the underpass. These results suggest that individuals or groups are taking residence with the underpass and using it as habitat (Table 13). The acquisition of the underpass as part of an animal’s home range may become an issue if other animals are deterred from entering the underpass because of the presence of these individuals. Whilst the dimensions and design of the underpass may be structurally suitable for animal movement, these resident animals may be causing a biological barrier to other animals. Several species of amphibians, appeared to be utilising the underpass and adjacent dam as habitat, with the southern brown tree frog showing a statistically significant association with the underpass (P <0.05) (Table 13).

The superb fairy wren, which is an open habitat dweller – such as that of the underpass, demonstrated a statistically significant association to the underpass (P <0.001), as did to a lesser extent the eastern grey kangaroo (P <0.01), and swamp wallaby (P <0.05) (Table 13). This would appear to be a funnelling effect.

Three species showed a statistically significant rarity of detection within the underpass, namely the agile antechinus (P <0.001), ringtail possum (P <0.001) and the restless flycatcher (P <0.05) (Table 13). It could be possible that the house mouse is occupying the territory of the underpass and competing with the agile antechinus for food and habitat resources, although antechinus have been shown to attack and eat mice on occasion. Antechinus may be agoraphobic, and find the sparse cover and trees within the underpass to be unsuitable for movement. The disturbed environment, and close proximity to residential areas may assist
the house mouse in its occupancy of the underpass, although the Eastern site is close to residential properties also. The lack of suitable habitat or potential territoriality could be the reasons for the rarity of ringtail possums within the underpass.

There were other species that either demonstrated a statistically significant preference for the West site or the East site, although further comment as to the cause of these results cannot be made. Those species were the bush rat (P < 0.01 rarity of observations at West site), and magpie (P < 0.01 observed preference to East site), red wattlebird (P < 0.01 observed preference to East site) and the sulphur-crested cockatoo (P < 0.001 observed preference to East site), which are birds, open places and woodlands (Table 13). The East site was the last location for the bird survey at dusk, which may have resulted in recording birds as they become active at this time of day.

**Table 13: Chi-squared analyses of species observed preferences within the Black Forest and Slaty Creek Underpass.**

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<tr>
<th>Species</th>
<th>No. of Records for West Side</th>
<th>No. of Records for Underpass</th>
<th>No. of Records for East Side</th>
<th>Total No. of Records</th>
<th>Chi²</th>
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<td>5</td>
<td>15</td>
<td>8</td>
<td>23</td>
<td>21.74</td>
</tr>
<tr>
<td>Red-browed finch</td>
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<td>5</td>
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<tr>
<td>Restless flycatcher</td>
<td>15</td>
<td>3</td>
<td>14</td>
<td>11</td>
<td>32</td>
<td>8.06</td>
</tr>
<tr>
<td>Ringtail Possum</td>
<td>41</td>
<td>14</td>
<td>39</td>
<td>31</td>
<td>94</td>
<td>34.34</td>
</tr>
<tr>
<td>Rose Robin</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<td></td>
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<tr>
<td>Rufous Fantail</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Satin Flycatcher</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>7</td>
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<tr>
<td>Scarlet Robin</td>
<td>1</td>
<td>0</td>
<td>0</td>
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<td>Silveryeye</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
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<td>Southern Brown Tree Frog</td>
<td>1</td>
<td>10</td>
<td>4</td>
<td>5</td>
<td>15</td>
<td>8.4</td>
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<tr>
<td>Southern Bullfrog</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Striated Pardalote</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>3</td>
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<td></td>
</tr>
<tr>
<td>Sugar Glider</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>16</td>
<td>2.2</td>
</tr>
<tr>
<td>Sulphur Crested Cockatoo</td>
<td>5</td>
<td>8</td>
<td>22</td>
<td>12</td>
<td>35</td>
<td>13.68</td>
</tr>
<tr>
<td>Superb Fairy-Wren</td>
<td>4</td>
<td>17</td>
<td>0</td>
<td>7</td>
<td>21</td>
<td>22.48</td>
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<tr>
<td>Swamp Rat</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Swamp Wallaby</td>
<td>28</td>
<td>39</td>
<td>18</td>
<td>28</td>
<td>85</td>
<td>7.89</td>
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<td>4</td>
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<td>2</td>
<td>2</td>
<td>1</td>
<td>5</td>
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<td></td>
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<tr>
<td>Wedge-tailed Eagle</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
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<td></td>
</tr>
<tr>
<td>Welcome Swallow</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
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</tr>
<tr>
<td>White Eared Honey Eater</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
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<tr>
<td>White Naped Honey Eater</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2</td>
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<td>White Throated Tree Creeper</td>
<td>35</td>
<td>27</td>
<td>31</td>
<td>31</td>
<td>93</td>
<td>1.02</td>
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<td>White-browed Scrubwren</td>
<td>1</td>
<td>8</td>
<td>2</td>
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<tr>
<td>White-faced Heron</td>
<td>0</td>
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<td>1</td>
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<td></td>
</tr>
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<td>Wombat</td>
<td>6</td>
<td>7</td>
<td>4</td>
<td>6</td>
<td>17</td>
<td>0.82</td>
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<tr>
<td>Yellow Tailed Black Cockatoo</td>
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<td>0</td>
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<td>1</td>
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</tr>
<tr>
<td>Yellow-tufted Honeyeater</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>All</strong></td>
<td><strong>401</strong></td>
<td><strong>441</strong></td>
<td><strong>510</strong></td>
<td><strong>1353</strong></td>
<td></td>
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</tr>
</tbody>
</table>

NS = Not significant
*** = Probability of <0.001 of it occurring by chance
** = Probability of <0.01 of it occurring by chance
* = Probability of <0.05 of it occurring by chance
4.3.1 Scats

Macropods and all terrestrial animals were preferentially recorded in the underpass, but the groupings of possums and all arboreal animals preferentially occurred outside the underpass (Table 14).

<table>
<thead>
<tr>
<th>Taxon</th>
<th>West</th>
<th>Underpass</th>
<th>East</th>
<th>Chi-squared</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macropods</td>
<td>17</td>
<td>43</td>
<td>24</td>
<td>12.94</td>
<td>***</td>
</tr>
<tr>
<td>Possums</td>
<td>31</td>
<td>2</td>
<td>34</td>
<td>28.41</td>
<td>***</td>
</tr>
<tr>
<td>All arboreal</td>
<td>38</td>
<td>2</td>
<td>38</td>
<td>33.23</td>
<td>***</td>
</tr>
<tr>
<td>All terrestrial</td>
<td>23</td>
<td>52</td>
<td>29</td>
<td>13.40</td>
<td>***</td>
</tr>
</tbody>
</table>

NS = Not significant  
*** = Probability of <0.001 of it occurring by chance  
** = Probability of <0.01 of it occurring by chance  
* = Probability of <0.05 of it occurring by chance
<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Underpass common/ rare</th>
<th>Native/ Introduced</th>
<th>Habitat Preference</th>
<th>Feeds on</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agile Antechinus</td>
<td>Antechinus agilis</td>
<td>Rare</td>
<td>Native</td>
<td>Dense undergrowth and litter in wetter environments.</td>
<td>Insects, occasionally flowers, fruit or small animals, such as house mice.</td>
<td>Menkhorst et. al. (1995)</td>
</tr>
<tr>
<td>Eastern Grey Kangaroo</td>
<td>Macropus giganteus</td>
<td>Common</td>
<td>Native</td>
<td>High level of grass cover with lateral cover from trees and shrubs.</td>
<td>Predominantly grasses</td>
<td>Menkhorst et. al. (1995)</td>
</tr>
<tr>
<td>House Mouse</td>
<td>Mus musculus</td>
<td>Common</td>
<td>Introduced</td>
<td>Disturbed environments, near residential areas.</td>
<td>Insects, grains, seed, fungi</td>
<td>Menkhorst et. al. (1995)</td>
</tr>
<tr>
<td>Ringtail Possum</td>
<td>Pseudocheirus peregrinus</td>
<td>Rare</td>
<td>Native</td>
<td>Dense tree and shrub layer that allows for movement without descending to ground.</td>
<td>Leaves, flowers, fruits and buds.</td>
<td>Menkhorst et. al. (1995)</td>
</tr>
<tr>
<td>Restless Flycatcher</td>
<td>Myiagra inquieta</td>
<td>Rare</td>
<td>Native</td>
<td>Open forests and farmland</td>
<td>Insects</td>
<td>Simpson &amp; Day (1996)</td>
</tr>
<tr>
<td>Swamp Wallaby</td>
<td>Wallabia bicolor</td>
<td>Common</td>
<td>Native</td>
<td>Wet forest or riparian vegetation, with dense understorey.</td>
<td>Forbs, ferns, shrubs, grasses, sedges and rushes and fungi.</td>
<td>Menkhorst et. al. (1995)</td>
</tr>
</tbody>
</table>
The reason for some species being rarely recorded within the underpass and others being commonly recorded within the underpass is likely to be due to habitat and structural composition of the vegetation (Table 15). Arboreal animals and most birds are unlikely to be regularly recorded within the underpass because the local environment does not allow for places to perch or climb through without being forced to come to ground. Birds are likely to fly over the top of the freeway, and not be as greatly impacted upon by the barrier of the road, as other taxa.

It is likely that the dense lower storey vegetation, creek line and settling dam have produced favourable habitat conditions for amphibians (Bennett, Kimber et al. 2000). The more open spaces in comparison to the forest would allow for easy movement and feeding sights for macropods. These conditions may also provide for favourable areas for bats to forage on insects (Holsworth, pers. comm., 2003).

Factors relating directly to the road, including noise, light, or pollution may be a limiting factor in use of the Underpass (2002), but cannot be assessed from the data collected.

4.3.2 Direction of movement
The direction of movement of ground dwelling large to medium-sized animals can be quantified from the sand tray data. Figure 15 shows there was almost equal quantity of prints recorded going in a West and East direction (through the underpass), and almost equal quantity of prints recorded in a North and South direction (parallel to the underpass). This demonstrates that there was an equal abundance of fauna moving in either direction through the Underpass, indicating that it is being used for passage by fauna.
Figure 15: Direction of animal movement detected from Sand Tray

<table>
<thead>
<tr>
<th>Direction</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>North</td>
<td>8.07%</td>
</tr>
<tr>
<td>West</td>
<td>8.49%</td>
</tr>
<tr>
<td>South</td>
<td>40.49%</td>
</tr>
<tr>
<td>East</td>
<td>42.68%</td>
</tr>
</tbody>
</table>

East: 312 prints
North: 59 prints
South: 64 prints
West: 296 prints
TOTAL = 731 sets of prints (individual animals)

4.4 Diurnal animal activity

The use of the underpass during day and night was determined through analysis of the monitoring methods that were checked once, or twice (dawn and dusk) in a 24-hour period. Table 16 outlines the animals that were recorded during the day or night using methods that were checked consistently at dawn and dusk within a 24-hour period, for three days per month (Elliott traps, pitfall traps and underpass sand tray). Note that the sand tray was only used in the underpass, and not at the two forest sites. Table 17 comprises information gathered which recorded the presence of animals at a particular location at a time of the day or night, but was not consistently measured through the surveying period to show day or night variation (Anabat, audio recordings, bird surveys and spotlighting).

The majority of animals were detected by Elliott traps, pitfall traps, and sand tray within the underpass at night (Table 16). The inclusion of the additional four methods used to compile Table 17, incorporates birds, which has resulted in a shift in favour of more animals being active during the day.

There were many animals that only used the underpass during either daytime or night-time (Tables 16 and 17). The following animals were only encountered in the underpass during the day: one introduced mammal (a horse, most likely with rider), two skinks, two amphibians and 33 birds.
Of the many animals that were only encountered at night, twelve were found to be bats (Table 17), seven were found to be mammals other than bats, two were reptiles (McCoys Skink and an unidentified snake) and two were amphibians (southern bullfrog and Victorian smooth froglet). Of the seven mammals other than bats, three were native and four were introduced. The following three native mammals only used the underpass at night:

- Koala (*Phascolarctos cinereus*),
- Ringtail Possum (*Pseudocheirus peregrinus*), and
- Wombat (*Vombatus ursinus*).

The following four introduced mammals only used the underpass at night:

- Brown Hare (*Lepus capensis*),
- Cat (*Felis catus*),
- European Rabbit (*Oryctolagus cuniculus*), and
- Fox (*Vulpes vulpes*).

In general, birds were found to use the underpass solely during the day, and non-domestic mammals were found to use the underpass solely at night. More introduced mammals used the underpass at night than native mammals.

Of those species that were only observed at night, there were two fauna groups that were only found in the forest setting and not in the underpass. The following two arboreal mammals are both nocturnal and were only found in the Black Forest sites and never in the Slaty Creek Underpass, through the methods used to compile Tables 16 and 17:

- Feathertail glider (*Acrobates pygmaeus*), and
- Sugar glider (*Petaurus breviceps*).

The following three nocturnal predatory birds were also detected only in the Black Forest sites at night rather than the underpass:

- Powerful owl (*Ninox strenua*),
- Southern boobook (*Ninox novaeseelandiae*) and
- Tawny frogmouth *Podargus strigoides*. 


Table 16: Diurnal animal activity for the underpass and forest areas as-detected by Elliott Traps, Pitfall Traps and Sand Tray.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Underpass Day</th>
<th>Underpass Night</th>
<th>Forest Day</th>
<th>Forest Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agile Antechinus</td>
<td>Antechinus agilis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Black Rat</td>
<td>Rattus rattus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bush Rat</td>
<td>Rattus fuscipes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Cat</td>
<td>Felis catus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coventry's Skink</td>
<td>Niveoscincus coventryii</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Dog</td>
<td>Canis lupus familiaris</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eastern Grey Kangaroo</td>
<td>Macropus giganteus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Echidna (short-beaked)</td>
<td>Tachyglossus aculeatus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*European Rabbit</td>
<td>Oryctolagus cuniculus</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Fox</td>
<td>Vulpes vulpes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Garden Skink</td>
<td>Lampropholis guichenoti</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*House Mouse</td>
<td>Mus musculus</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Koala</td>
<td>Phascolarctos cinereus</td>
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</tr>
<tr>
<td>McCoy's Skink</td>
<td>Nannoscincus maccocy</td>
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<tr>
<td>Snake sp.</td>
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<tr>
<td>Southern Brown Tree Frog</td>
<td>Litoria ewingii</td>
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</tr>
<tr>
<td>Southern Bullfrog</td>
<td>Limnodynastes dumerlii</td>
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<tr>
<td>Sugar Glider</td>
<td>Petaurus breviceps</td>
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</tr>
<tr>
<td>Swamp Wallaby</td>
<td>Wallabia bicolor</td>
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</tr>
<tr>
<td>White-browed Scrubwren</td>
<td>Sericornis frontalis</td>
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</tr>
<tr>
<td>Wombat</td>
<td>Vombatus ursinus</td>
<td></td>
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</tr>
</tbody>
</table>

* Introduced animal

Table 17: Diurnal animal activity for the underpass and forest areas (Anabat, Audio, Bird Survey, Incidental Observations, and Spotlighting).

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Underpass Day</th>
<th>Underpass Night</th>
<th>Forest Day</th>
<th>Forest Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agile Antechinus</td>
<td>Antechinus agilis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australian Raven</td>
<td>Corvus coronoides</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australian Wood Duck</td>
<td>Chenonetta jubata</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bassian Thrush</td>
<td>Zoothera lunulata</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black-faced Cuckoo-shrike</td>
<td>Corecina novaehollandiae</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Brown Hare</td>
<td>Lepus capensis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brown Thornbill</td>
<td>Acanthiza apicalis</td>
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<td></td>
</tr>
<tr>
<td>Brown toadlet</td>
<td>Pseudophynxibronii</td>
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</tr>
<tr>
<td>Buff-rumped Thornbill</td>
<td>Acanthiza reguioides</td>
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<tr>
<td>Bush Rat</td>
<td>Rattus fuscipes</td>
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<td></td>
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<tr>
<td>*Cat</td>
<td>Felis catus</td>
<td></td>
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</tr>
<tr>
<td>Chocolate Wattled Bat</td>
<td>Chalinotobus morio</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>*Common Blackbird</td>
<td>Turdus merula</td>
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</tr>
<tr>
<td>Common Brushtail Possum</td>
<td>Trichosurus vulpecula</td>
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</tr>
<tr>
<td>Common Froglet</td>
<td>Cinia signifera</td>
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</tr>
<tr>
<td>*Common Myna</td>
<td>Acridotheres tristis</td>
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</tr>
<tr>
<td>Crested Shrike-lit</td>
<td>Falcunculus frontatus</td>
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<td></td>
</tr>
<tr>
<td>Crimson Rosella</td>
<td>Platycerus elegans</td>
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<td></td>
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</tr>
<tr>
<td>*Dog</td>
<td>Canis lupus familiaris</td>
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<tr>
<td>Eastern False Pipistrelle</td>
<td>Falistrellus tasmaniensis</td>
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</tr>
<tr>
<td>Eastern Freetail Bat</td>
<td>Mormopterus sp.</td>
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</tr>
<tr>
<td>Eastern Grey Kangaroo</td>
<td>Macropus giganteus</td>
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<tr>
<td>Eastern Spinebill</td>
<td>Acanthorhynchus tenuirostris</td>
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</tr>
<tr>
<td>Eastern Yellow Robin</td>
<td>Eopsaltria australis</td>
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<tr>
<td>Echidna (short-beaked)</td>
<td>Tachyglossus aculeatus</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>*European Rabbit</td>
<td>Oryctolagus cuniculus</td>
<td></td>
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<tr>
<td>Feathertail Glider</td>
<td>Acrobatus pygmaeus</td>
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</tr>
<tr>
<td>*Fox</td>
<td>Vulpes vulpes</td>
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<tr>
<td>Galah</td>
<td>Cacatua roseicapilla</td>
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</tr>
<tr>
<td>Common Name</td>
<td>Scientific Name</td>
<td>Underpass Day</td>
<td>Underpass Night</td>
<td>Forest Day</td>
<td>Forest Night</td>
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<td>Gang-Gang Cockatoo</td>
<td>Callocephalon fimbriatum</td>
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<tr>
<td>Garden Skink</td>
<td>Lampropholis guichenoti</td>
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<tr>
<td>Golden Whistler</td>
<td>Pachycepha1 pectoralis</td>
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</tr>
<tr>
<td>Gould’s Long-eared Bat</td>
<td>Nyctophilus gouldi</td>
<td></td>
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<tr>
<td>Gould’s Wattled Bat</td>
<td>Chalinolobus gouldi</td>
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<tr>
<td>Great Egret</td>
<td>Ardea alba</td>
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<tr>
<td>Grey Currawong</td>
<td>Strepera versicolor</td>
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<tr>
<td>Grey Fantail</td>
<td>Rhipidura fuliginosa</td>
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<tr>
<td>Grey Shrike-thrush</td>
<td>Colluricincla harmonica</td>
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<tr>
<td>*Horse</td>
<td>Equus caballus</td>
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<tr>
<td>Horsfield’s Bronze-Cuckoo</td>
<td>Chrysococcyx basalis</td>
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<td>Phascolarctos cinereus</td>
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<td>Kookaburra</td>
<td>Dacelo novaeguineae</td>
<td></td>
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<tr>
<td>Large Forest Bat</td>
<td>Vespadelus darlingtoni</td>
<td></td>
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<tr>
<td>Leaden Flycatcher</td>
<td>Myiagra rubecula</td>
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<tr>
<td>Lesser Long-eared Bat</td>
<td>Nyctophilus geoffroyi</td>
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<tr>
<td>Little Forest Bat</td>
<td>Vespadelus vulturinus</td>
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<td>Little Raven</td>
<td>Corvus melilj</td>
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<tr>
<td>Long-billed Corella</td>
<td>Cacatua tenuirostris</td>
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<td>Magpie</td>
<td>Gymnorhina tibicen</td>
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<tr>
<td>Magpie-lark</td>
<td>Grallina cyanoleuca</td>
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<td>Masked Lapwing</td>
<td>Vanelius miles</td>
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<td>New Holland Honeyeater</td>
<td>Phylidonyris novaehollandiae</td>
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<td>Anas superciliosa</td>
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<td>Painted Honeyeater</td>
<td>Granitella picta</td>
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<tr>
<td>Pied Cormorant</td>
<td>Phalacrocorax varius</td>
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<tr>
<td>Pied Currawong</td>
<td>Strepera graculina</td>
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<tr>
<td>Plains Brown Tree Frog</td>
<td>Litoria paraewingi</td>
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<tr>
<td>Powerful Owl #</td>
<td>Ninox strenua</td>
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<td>Red Wattlebird</td>
<td>Anthochaera carunculata</td>
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<td>Red-browed Finch (Firetail)</td>
<td>Neochmia temporalis</td>
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<tr>
<td>Restless Flycatcher</td>
<td>Myiagra inquieta</td>
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<tr>
<td>Ringtail Possum</td>
<td>Pseudocheirus paregrinus</td>
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<tr>
<td>Rose Robin</td>
<td>Petroica roses</td>
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</tr>
<tr>
<td>Rufous Fantail</td>
<td>Rhipidura rufifrons</td>
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<tr>
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<td>Pachycepha1 rufiventris</td>
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<td>Todiramphus sanctus</td>
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<tr>
<td>Satin Flycatcher</td>
<td>Myiagra cyanoleuca</td>
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<td>Scarlet Robin</td>
<td>Petroica multicolor</td>
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<tr>
<td>Silvereye</td>
<td>Zosterops lateralis</td>
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<tr>
<td>Southern Boobook</td>
<td>Ninox novaesexualiae</td>
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<td></td>
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<tr>
<td>Southern Brown Tree Frog</td>
<td>Litoria ewingii</td>
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<tr>
<td>Southern Bullfrog</td>
<td>Limnodynastes dumerilei</td>
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<tr>
<td>Southern Forest Bat</td>
<td>Vespadelus regulus</td>
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<tr>
<td>Southern Freetail Bat</td>
<td>Mormopterus sp.</td>
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<td>Spotted Pardalote</td>
<td>Pardalolus punctatus</td>
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<td>Striated Thornbill</td>
<td>Acanthiza lineata</td>
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<td>Petaurus brevipes</td>
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<td>Sulphur Crested Cockatoo</td>
<td>Cacatus galera</td>
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<td>Superb Fairy-Wren</td>
<td>Malurus cyaneus</td>
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<tr>
<td>Swamp Wallaby</td>
<td>Wallabia bicolor</td>
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<tr>
<td>Tawny Frogmouth</td>
<td>Podargus strigoides</td>
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<tr>
<td>Thornbill sp.</td>
<td>Acanthiza sp.</td>
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<tr>
<td>Unidentified long-eared Bat</td>
<td>Nyctophilus sp.</td>
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<tr>
<td>Victorian Smoot Froglet</td>
<td>Geocrinia victoriae</td>
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<tr>
<td>Wedge-tailed Eagle</td>
<td>Aquila audax</td>
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<tr>
<td>Welcome Swallow</td>
<td>Hirundo neoxena</td>
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<tr>
<td>Whistling Tree Frog</td>
<td>Litoria verreauxii verreauxii</td>
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<tr>
<td>White Eared Honey Eater</td>
<td>Lichenostomus leucotis</td>
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<tr>
<td>White-faced Heron</td>
<td>Eretta novaehollandiae</td>
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<tr>
<td>White Naped Honey Eater</td>
<td>Melithreptus albogularis</td>
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<tr>
<td>White-plumed Honey Eater</td>
<td>Lichenostomus penicillatus</td>
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<tr>
<td>White-striped Freetail Bat</td>
<td>Tadarida australis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common Name</td>
<td>Scientific Name</td>
<td>Underpass Day</td>
<td>Underpass Night</td>
<td>Forest Day</td>
<td>Forest Night</td>
</tr>
<tr>
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<tr>
<td>White Throated Tree Creeper.</td>
<td>Cercobates leucophaeus</td>
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<tr>
<td>White-browed Scrubwren</td>
<td>Sericornis frontalis</td>
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<tr>
<td>White-winged Chough</td>
<td>Corcorax melanorhamphos</td>
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<tr>
<td>Wombat</td>
<td>Vombatus Ursinus</td>
<td>•</td>
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</tr>
<tr>
<td>Yellow-faced Honey Eater</td>
<td>Lichenostomus chrysops</td>
<td>•</td>
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</tr>
<tr>
<td>Yellow-tailed Black Cockatoo</td>
<td>Calyptorhynchus funerius</td>
<td>•</td>
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<td></td>
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</tr>
<tr>
<td>Yellow-tufted Honeyeater</td>
<td>Lichenostomus melanops</td>
<td>•</td>
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</tbody>
</table>

4.5 Comparison of effectiveness for Slaty Creek, Blackwood Road and culverts

The comparison between the faunal use of Slaty Creek, Blackwood Road, and the culverts beneath the freeway are assessed, addressing question 2 (b):

(b) Is the Slaty Creek underpass more effective than smaller underpass alternatives at Blackwood Road and the culverts?

The detection methods used at Slaty Creek were not all used at Blackwood Road and the culverts between these two locations. Whilst it is recognised that many species moved through the Slaty Creek Underpass, it is only possible to make comparisons on those methods that were consistent across each location. Limited time and resources meant the culverts were best monitored via sand trays. These were placed at the upper, drier side to the West. Culvert 3 could be accessed from the median strip of the freeway, and a hair funnel was placed inside the culvert during the months of December 2002 and July 2003, detecting hair from a bush rat and brushtail possum. Blackwood Road was monitored with a sand tray and scat collection.

Evidence of animal presence at the entrance to the culverts and Blackwood Road are shown in Table 18. It must be noted that some species such as the eastern grey kangaroo and swamp wallaby provided scats at the entrance to the culverts, but it is more likely they were browsing on the grass than moving through the culverts. The skinks and amphibians found at the entrance to the culverts were most likely taking advantage of the rocky habitat than moving through the culverts.

The species that appeared to use multiple culverts as access routes were:
- Cat (*Felis catus*);
- Dog (*Canis lupus familiaris*);
- Wombat (*Vombatus ursinus*);
- Fox (*Vulpes vulpes*); and
- An unidentified reptile.
Table 18: Animals found to be utilising culverts and the Blackwood Road corridor.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>BR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brushtail Possum sp. (1)</td>
<td>Trichosorus sp.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Bush Rat (1)</td>
<td>Rattus Fuscipes</td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>*Cat</td>
<td>Felis catus</td>
<td></td>
<td>•</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Dog</td>
<td>Canis lupus familiaris</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Eastern Grey Kangaroo</td>
<td>Macropus giganteus</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>*European Rabbit</td>
<td>Oryctolagus cuniculus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>*Fox</td>
<td>Vulpes vulpes</td>
<td></td>
<td>•</td>
<td>•</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>*Horse</td>
<td>Equus caballus</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Possum sp.</td>
<td></td>
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<tr>
<td>Southern Brown Tree Frog</td>
<td>Litoria ewingii</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Southern Water Skink</td>
<td>Eulamprus tympanum</td>
<td></td>
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<td></td>
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<tr>
<td>Swamp Wallaby</td>
<td>Wallabia bicolor</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>White’s Skink</td>
<td>Egemia whitii</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Wombat</td>
<td>Vombatus ursinus</td>
<td></td>
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</tr>
<tr>
<td>Unidentified bird ?</td>
<td></td>
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<tr>
<td>Unidentified mammal ?</td>
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<tr>
<td>Unidentified reptile ?</td>
<td></td>
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</tr>
</tbody>
</table>

C1 - Culvert 1; C2 - Culvert 2; C3 - Culvert 3; C4 - Culvert 4; BR - Blackwood Road

* Introduced species

(1) The Brushtail Possum and Bush Rat were detected by a hair funnel that was placed in the median strip of Culvert 3. Hair funnels were not used in any other culvert or at Blackwood Rd.

(2) Scats or animals were found at culvert entrances: this does not necessarily mean the animal entered the culvert.

When comparing the sand tray data of the Slaty Creek Underpass, culverts and Blackwood Road underpass (Table 19), it is evident that the Slaty Creek Underpass is more effective than the smaller alternatives, giving support for the openness measure of culverts and underpasses, indicating that ‘bigger is better’ for facilitating fauna movements. The Blackwood Road underpass has a two lane road adjacent, is more sparsely vegetated and the surrounding environment is not the quality of that at Slaty Creek. All of these variables could play a part in the reduced effectiveness of the crossing structure. The sand tray at Blackwood Road was not as wide as the sand tray at Slaty Creek and could have impacted upon the number of animals detected if larger animals were able to jump over the sand tray.
Table 19: A comparison of the animal use of the Slaty Creek Underpass, culverts and the Blackwood Road corridor as detected by sand tray analysis.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Slaty Creek</th>
<th>All culverts</th>
<th>Blackwood Road</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Cat</td>
<td>Felis catus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Dog</td>
<td>Canis lupus familiaris</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eastern Grey Kangaroo</td>
<td>Macropus giganteus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Echidna (short-beaked)</td>
<td>Tachyglossus aculeatus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*European Rabbit</td>
<td>Oryctolagus cuniculus</td>
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<td></td>
<td></td>
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<tr>
<td>*Fox</td>
<td>Vulpes vulpes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Koala</td>
<td>Phascolarctos cinereus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Possum</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Snake</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swamp Wallaby</td>
<td>Wallabia bicolor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wombat</td>
<td>Vombatus ursinus</td>
<td></td>
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</tr>
</tbody>
</table>

* Introduced

The collection of scats and hair samples recorded from the Slaty Creek Underpass and at Blackwood Road are shown in Table 20. These also indicate support that the Slaty Creek Underpass is more effective than the smaller underpass at Blackwood Road, with more than twice as many species detected at Slaty Creek.

There are several variables which are likely to have further negative impacts upon the effectiveness of the Blackwood Road corridor, such as the road running parallel to this underpass, the lack of vegetation through the underpass and the fenced and cleared farmland adjacent to the underpass.

Table 20: Animal traces found within Slaty Creek Underpass, and Blackwood Road corridor.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Slaty Creek</th>
<th>Blackwood Road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brushtail Possum</td>
<td>Trichosorus sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Cat</td>
<td>Felis catus</td>
<td></td>
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<tr>
<td>*Dog</td>
<td>Canis lupus familiaris</td>
<td></td>
<td></td>
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<tr>
<td>Eastern Grey Kangaroo</td>
<td>Macropus giganteus</td>
<td></td>
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<tr>
<td>Echidna (short-beaked)</td>
<td>Tachyglossus aculeatus</td>
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<tr>
<td>*European Rabbit</td>
<td>Oryctolagus cuniculus</td>
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<tr>
<td>*Fox</td>
<td>Vulpes vulpes</td>
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<tr>
<td>*Horse</td>
<td>Equus caballus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*House Mouse</td>
<td>Mus musculus</td>
<td></td>
<td></td>
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<tr>
<td>Koala</td>
<td>Phascolarctos cinereus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Possum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Rat sp.</td>
<td>Rattus sp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ringtail Possum</td>
<td>Pseudocheirus peregrinus</td>
<td></td>
<td></td>
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<tr>
<td>Snake sp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swamp Wallaby</td>
<td>Wallabia bicolor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wombat</td>
<td>Vombatus ursinus</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Introduced
4.5.1 Road kill

The construction of the underpass, and the adjacent fencing was primarily designed to provide safe passage for fauna beneath the freeway. One of the measures for assessing the effectiveness of the underpass is the elimination of road kill. This section addresses question 3:

3. Has the construction of the underpass and adjacent fencing eliminated road kill?

Table 21 shows the species of animals that were detected on the freeway and road reserve between Blackwood Road and Alex Evans Bridge. Passing trucks dropping fragments of hair and bone are the most likely causes of the cow and sheep being discovered on the road walk, but evidence of all others is believed to have been from the animal accessing the roadway and being killed by passing traffic (Plate 15).

The exclusion fence designed to keep animals from the freeway required ongoing maintenance to ensure gaps were blocked to prevent access of animals onto the freeway. In August 2002, the gaps at the junction of the fence edge and concrete of the bridge at Slaty Creek and Blackwood Road were closed. A skirt was added to the bottom of the fence in May 2003 to block the holes beneath the fence and prevent access for burrowing animals, such as wombats, which can then allow access to other fauna. The impact of this maintenance cannot be measured by the data collected during this monitoring period.

Plate 15: Truck running over a dead animal on the Calder Freeway next to Slaty Creek Underpass. Photo: Rodney Abson.

The construction of the underpass and adjacent fencing has not eliminated road kill, but the improvements to the fencing design may further decrease the number of animals accessing the road and becoming road kill. The fencing alterations were made too late into the study for comment to be made on the impact of this modification.
TABLE 21: Species detected from evidence found on the Calder Freeway between Blackwood Road and Alex Evans Bridge.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agile Antechinus</td>
<td>Antechinus agilis</td>
</tr>
<tr>
<td>Australian Wood Duck</td>
<td>Chenonetta jubata</td>
</tr>
<tr>
<td>Bat sp.</td>
<td></td>
</tr>
<tr>
<td>Brown Thornbill</td>
<td>Acanthiza apicalis</td>
</tr>
<tr>
<td>*Cat</td>
<td>Felis cattus</td>
</tr>
<tr>
<td>*Cow</td>
<td>Bos Taurus</td>
</tr>
<tr>
<td>Crimson Rosella</td>
<td>Platycerus elegans</td>
</tr>
<tr>
<td>*Dog</td>
<td>Canis lupis familiaris</td>
</tr>
<tr>
<td>Eastern Grey Kangaroo</td>
<td>Macropus giganteus</td>
</tr>
<tr>
<td>Echidna (short-beaked)</td>
<td>Tachyglossus aculeatus</td>
</tr>
<tr>
<td>*European Rabbit</td>
<td>Oryctolagus cuniculus</td>
</tr>
<tr>
<td>*Fox</td>
<td>Vulpes vulpes</td>
</tr>
<tr>
<td>Koala</td>
<td>Phascolarctos cinereus</td>
</tr>
<tr>
<td>Kookaburra</td>
<td>Dacelo novaeguineae</td>
</tr>
<tr>
<td>Magpie</td>
<td>Gymnorhina tibicen</td>
</tr>
<tr>
<td>Magpie Lark</td>
<td>Grallina cyanoleuca</td>
</tr>
<tr>
<td>Masked Lapwing</td>
<td>Vanellus miles</td>
</tr>
<tr>
<td>Raven sp.</td>
<td></td>
</tr>
<tr>
<td>Ringtail Possum</td>
<td>Pseudocheirus peregrinus</td>
</tr>
<tr>
<td>*Sheep</td>
<td>Ovis aries</td>
</tr>
<tr>
<td>Southern Bullfrog</td>
<td>Limnodynastes dumerilii</td>
</tr>
<tr>
<td>Sulphur Crested Cockatoo</td>
<td>Cacatua galerita</td>
</tr>
<tr>
<td>Swamp Wallaby</td>
<td>Wallabia bicolor</td>
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<tr>
<td>Unidentifiable Bird sp.</td>
<td></td>
</tr>
<tr>
<td>Wombat</td>
<td>Vombatus Ursinus</td>
</tr>
<tr>
<td>Yellow Thornbill</td>
<td>Acanthiza nana</td>
</tr>
</tbody>
</table>

* Introduced species

4.6 Effectiveness and efficiency of data collection methods

A large variety of techniques were employed to detect the vertebrate fauna of the Black Forest, and those species using the Slaty Creek Underpass. The most effective and efficient methods can be analysed a number of ways, as this section outlines in addressing question 4:

4. What are the most effective and efficient methods for determining the presence of different vertebrate species?

The effectiveness and efficiency of monitoring methods can be assessed in a number of ways depending on what is trying to be measured. Effectiveness can be measured as either the number of species that a method is able to detect, or how effective that method is for detecting particular taxa. The aims of a study will value methods differently, so that intrusive methods (which capture an animal) may be required, or non-intrusive methods (which measure that a species is or has been present in the area) may also be suitable. This study regime used both
intrusive and non-intrusive methods and assessment of the effectiveness of methods was based purely on a species presence/absence.

Efficiency can be measured on the basis of resources (time, money, human resources) required for to implement the method, and the corresponding number of species it detected. Efficiency of data collection could be measured on the best time of year for sampling. If a methodology can be formulated that is still capable of detecting the same number of species, but with fewer monitoring techniques, this is a more effective study design.

Carter (2002), looked at the efficiency and effectiveness of non-intrusive monitoring techniques for detecting arboreal marsupials in Box-Ironbark forests. He determined that there is no single method that suits all conditions, and resource constraints and localised environmental conditions need to be taken into account when monitoring fauna.

4.6.1 Effectiveness and efficiency by months of monitoring
Figure 11 indicates the number of new species detected per month of data collection. This species accumulation curve indicates that over the 12-month period, the number of new species detected steadily dropped, until there was only one new species of bird and one new reptile species detected in the final month of monitoring. It can be assumed these monitoring methods had exhausted the sampling of all vertebrate species they were likely to detect within those sites in that year.
Figure 16: New species per month.

The number of species detected each month varied, as can be seen for mammals in Table 22. If the monitoring were to be limited to only some months, the likelihood of detecting all species is reduced, but a high proportion of the total number of species from the full 12-months will still be detected. Testing has been limited to mammals for effectiveness and therefore efficiency of months, because they were detected with a variety of methods, each month, throughout the year; except for bats that were all detected by an Anabat during November, January and April, but this is accounted for in the equations below. It could be possible to assess reptiles, amphibians and birds, however there were some problems in regard to active searching being responsible for detecting most reptiles and amphibians, but was not conducted every month. The migratory nature of some birds meant seasonal differences can play a major part in influencing the number of species detected in any given month.
Monitoring conducted in January detected 26 out of 37 mammal species (70%) and, excluding bats, detected 19 out of 25 species (76%). If monitoring were only conducted in April, then 25 out of 37 species would have been detected (68%), and excluding bats, 17 out of 25 species would have been detected (68%). Combining monitoring over January and April produced 33 out of 37 species detected (89%), including all 12-bat species. Excluding bats, these combined months recorded 21 out of 25 species (84%). No other combination of single months could provide more species, and five more months would need to be included to record the remaining five species to attain 100% of all mammal species detected during this 12-month study (as can be seen by the shaded boxes in Table 22).
Table 22: Mammal species detected each month in the Slaty Creek Underpass (+) & Black Forest region (•). Shaded boxes indicate species detected once or not detected within January and April.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
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<td>Agile Antechinus</td>
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<tr>
<td>*Black Rat</td>
<td>Rattus rattus</td>
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<tr>
<td>Brushtail Possum</td>
<td>Trichosurus sp.</td>
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<tr>
<td>*Brown Hare</td>
<td>Lepus capensis</td>
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<tr>
<td>Bush Rat</td>
<td>Rattus fuscipes</td>
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<tr>
<td>*Cat</td>
<td>Felis catus</td>
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<td>Common Brushtail Possum</td>
<td>Trichosurus vulpecula</td>
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<td>*Cow</td>
<td>Bos Taurus</td>
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<tr>
<td>*Dog</td>
<td>Canis lupus familiaris</td>
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<td>Eastern False Pipistrelle</td>
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<tr>
<td>Eastern Freetail Bat</td>
<td>Mormopterus sp.</td>
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<td>Eastern Grey Kangaroo</td>
<td>Macropus giganteus</td>
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<tr>
<td>Echidna (short-beaked)</td>
<td>Tachyglossus aculeatus</td>
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<tr>
<td>*European Rabbit</td>
<td>Oryctolagus cuniculus</td>
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<td>Feathertail Glider</td>
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<td>*Fox</td>
<td>Vulpes vulpes</td>
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<tr>
<td>Gould's Long-eared Bat</td>
<td>Nyctophilus gouldi</td>
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<td>Greater Glider #</td>
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<tr>
<td>*Horse</td>
<td>Equus caballus</td>
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<tr>
<td>*House Mouse</td>
<td>Mus musculus</td>
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<tr>
<td>Koala</td>
<td>Phascolarctos cinereus</td>
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<td>Mountain Brushtail Possum 3</td>
<td>Trichosurus caninus</td>
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<tr>
<td>Ringtail Possum</td>
<td>Pseudocheirus perspicinus</td>
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<tr>
<td>*Sheep</td>
<td>Ovis aries</td>
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<tr>
<td>Southern Forest Bat</td>
<td>Vespadelus regulus</td>
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<tr>
<td>Southern Freetail Bat #</td>
<td>Mormopterus sp.</td>
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<td>Squirrel Glider #</td>
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<tr>
<td>Sugar Glider</td>
<td>Petaurus breviceps</td>
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<tr>
<td>Swamp Rat</td>
<td>Rattus lutreolus</td>
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<tr>
<td>Swamp Wallaby</td>
<td>Wallabia bicolor</td>
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</tr>
<tr>
<td>Unidentified long-eared Bat</td>
<td>Nyctophilus sp.</td>
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</tr>
<tr>
<td>White-striped Freetail Bat</td>
<td>Tadarida australis</td>
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<tr>
<td>Wombat</td>
<td>Vombatus ursinus</td>
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</tbody>
</table>

* Introduced species # Identity is not confirmed  3 Fur found in predator scat only
4.6.2 Effectiveness of methods

Tables 23, 24, 25 and 26 show the methods by which species were detected.

Table 23: Detection methods successful in identifying mammal species in the Slaty Creek Underpass & Black Forest.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>AN</th>
<th>AS</th>
<th>AU</th>
<th>BS</th>
<th>BT</th>
<th>HT</th>
<th>IT</th>
<th>NP</th>
<th>PW</th>
<th>SW</th>
<th>SC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agile Antechinus</td>
<td>Antechinus agilis</td>
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<td>*Black Rat</td>
<td>Rattus rattus</td>
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<td>*Brown Hare</td>
<td>Lepus capensis</td>
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<td>Brushtail Possum</td>
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<td>Bush Rat</td>
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<tr>
<td>Chocolate Wattled Bat</td>
<td>Chalinolobus morio</td>
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<td>Common Brushtail Possum</td>
<td>Trichosurus vulpecula</td>
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<td>*Cow</td>
<td>Bos taurus</td>
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<td>Eastern False Pipistrelle</td>
<td>Falsistrellus tasmaniensis</td>
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<td>Eastern Freetail Bat #</td>
<td>Mormopterus sp.</td>
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<td>Echidna (short-beaked)</td>
<td>Tachyglossus aculeatus</td>
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<td>*European Rabbit</td>
<td>Oryctolagus cuniculus</td>
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<td>Feather tail Glider</td>
<td>Acerobates pygmaeus</td>
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<td>*Fox</td>
<td>Vulpes vulpes</td>
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<td>Gould’s Long-eared Bat #</td>
<td>Nyctophilus gouldi</td>
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<td>Chalinolobus gouldii</td>
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<td>Greater Glider #</td>
<td>Petauroidea volans</td>
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<tr>
<td>*Horse</td>
<td>Equus caballus</td>
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<td>*House Mouse</td>
<td>Mus Musculus</td>
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<td>Koala</td>
<td>Phascolarctos cinereus</td>
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<tr>
<td>Large Forest Bat</td>
<td>Vespadelus darlingtoni</td>
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<td>Lesser Long-eared Bat #</td>
<td>Nyctophilus geoffroyi</td>
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<tr>
<td>Little Forest Bat</td>
<td>Vespadelus vulturum</td>
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<td>Mountain Brushtail Possum</td>
<td>Trichosurus caninus</td>
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<td>Ringtail Possum</td>
<td>Pseudocheirus peregrinus</td>
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<td>*Sheep</td>
<td>Ovis aries</td>
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<td>Southern Forest Bat #</td>
<td>Vespadelus regulus</td>
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<tr>
<td>Southern Freetail Bat #</td>
<td>Mormopterus sp.</td>
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<td>Squirrel Glider #</td>
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<td>Sugar Glider</td>
<td>Petaurus breviceps</td>
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<tr>
<td>Swamp Rat</td>
<td>Rattus lutreolus</td>
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<tr>
<td>Swamp Wallaby</td>
<td>Wallabia bicolor</td>
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<tr>
<td>Unidentified long-eared Bat</td>
<td>Nyctophilus sp.</td>
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<tr>
<td>White-striped Freetail Bat</td>
<td>Tadarida australis</td>
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<tr>
<td>Wombat</td>
<td>Vombatus ursinus</td>
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</table>

* Introduced species
# Identity uncertain

AN – Anabat
AS – Active Search
AU – Audio
BS – Bird Survey
ET – Elliott Trap
HF – Hair Funnel
HT – Harp Trap
IO – Incidental Observation
NB – Nest Box
PT – Pitfall Trap
RW – Road Walk
SC – Scat analysis
SP – Spotlighting
ST – Sand tray
Table 24: Reptiles species list for the Slaty Creek Underpass and the Black Forest by detection method.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>AN</th>
<th>AS</th>
<th>SU</th>
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<th>RW</th>
<th>SC</th>
<th>SP</th>
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<tbody>
<tr>
<td>Blotched Blue-tongued Lizard</td>
<td><em>Tiliqua nigrolutea</em></td>
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<tr>
<td>Boulengers Skink</td>
<td><em>Morethia boulengeri</em></td>
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<tr>
<td>Coventry's Skink</td>
<td><em>Niveauoscincus coventryii</em></td>
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<tr>
<td>Garden Skink</td>
<td><em>Lampropholis guichenoti</em></td>
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<tr>
<td>McCoy's Skink</td>
<td><em>Nannoscincus maccoyi</em></td>
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<td>Snake</td>
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<tr>
<td>Southern Water Skink</td>
<td><em>Eulamprus tympanum</em></td>
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<tr>
<td>White's Skink</td>
<td><em>Egernia whitii</em></td>
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</table>

AN — Anabat, AS — Active Search, AU — Audio, BS — Bird Survey, ET — Elliott Trap, HF — Hair Funnel, HT — Harp Trap, IO — Incidental Observation, NB — Nest Box, PT — Pitfall Trap, RW — Road Walk, SC — Scat analysis, SP — Spotlighting, ST — Sand tray

Table 25: Amphibians species list for the Slaty Creek Underpass and the Black Forest by detection method.

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<th>Common Name</th>
<th>Scientific Name</th>
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<th>SC</th>
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<tbody>
<tr>
<td>Brown Toadlet</td>
<td><em>Pseudeophryne bibronii</em></td>
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<tr>
<td>Common Froglet</td>
<td><em>Crinia Signifera</em></td>
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<tr>
<td>Plains Brown Tree Frog</td>
<td><em>Litoria paraewingi</em></td>
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<tr>
<td>Southern Brown Tree Frog</td>
<td><em>Litoria ewingii</em></td>
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<tr>
<td>Southern Bullfrog</td>
<td><em>Limnodynastes dumerilli</em></td>
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<tr>
<td>Victorian Smooth Froglet</td>
<td><em>Geocrinia victoriana</em></td>
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<tr>
<td>Whistling Tree Frog</td>
<td><em>Litoria verreauxii verreauxii</em></td>
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AN — Anabat, AS — Active Search, AU — Audio, BS — Bird Survey, ET — Elliott Trap, HF — Hair Funnel, HT — Harp Trap, IO — Incidental Observation, NB — Nest Box, PT — Pitfall Trap, RW — Road Walk, SC — Scat analysis, SP — Spotlighting, ST — Sand tray
Table 26: Bird list for Black Forest and Slaty Creek by detection method.

<table>
<thead>
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<th>Scientific Name</th>
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<th>PRT</th>
<th>WRC</th>
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<td>Australian Raven</td>
<td>Corvus coronoides</td>
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<tr>
<td>Australian Wood Duck</td>
<td>Chenorhynchus jubata</td>
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<td>Bassian Thrush</td>
<td>Zosteria lunulata</td>
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<tr>
<td>Black-faced Cuckoo-shrike</td>
<td>Coracina novaehollandiae</td>
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<tr>
<td>Brown Thornbill</td>
<td>Acanthiza apicalis</td>
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<tr>
<td>Buff-rumped Thornbill</td>
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The species accumulation across all methods (Table 27 and Figure 12) demonstrate that through this system of analysis of the effectiveness of methods for detecting species, that with only incidental observations, bird survey, Anabat and audio recordings, 81% of the species detected during the study are included. Based only on this method of accumulated new species, Elliott traps, pitfall traps, nest boxes and harp traps could be eliminated altogether, because the combined aggregate of 13 species these methods detected, were all accounted for by other techniques.

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</table>
4.7 Efficiency of data collection methods

For each monitoring method, there are several variables, such as the equipment required to undertake the activity, or specialist knowledge required in the analysis of results. These variations between methods are not directly transferable and relevant to all methods, but some comparisons can be made in regard to the overall effectiveness and efficiency of methods for recording the total number of species detected during this survey. In kind support in terms of borrowed equipment, volunteer labour and advice cannot be easily priced into expenses, and have been left out of Table 28 (Table 29 outlines how the hours were calculated for each method). Other general project expenses such as travel have not been included in these results. The final column has given a cost on the basis of the total expenses of equipment, and an hourly rate, based on $20 per hour for each method.

In ranking the efficiency of species detection to the amount of time devoted to that method, the most efficient methods were the Anabat (1.33 species/hour), Bird Survey (1.19 species/hour), Audio Recordings (0.83 species/hour) and Active Searching (0.64 species/hour). The three least efficient methods were the Elliott Traps (0.05 species/hour), Nest Boxes (0.05 species/hour) and Harp Traps (0 species/hour).
Alternatively, if monetary cost is the most important variable, then the most efficient methods were Bird Survey ($16.74/ species), Audio Recordings ($28.50/ species), Active Searching ($30.90/ species) and Road Walk ($35.55/ species). Anabat was ranked as the most efficient monitoring method by time and ranked sixth for cost efficiency, at $46.16/ species. Given that the most efficient methods found in this study are the methods primarily detecting birds, as these are an abundant and varied taxa, it is worth noting that Spotlighting was not biased by the detection of birds, and was the fifth most efficient by time (0.56 species/ hour) and expense ($35.65/ species).

If this survey were to be conducted again, it is likely the same number of species could be obtained with a more time and cost efficient methodology.
<table>
<thead>
<tr>
<th>Method</th>
<th>Amount of time for set up &amp; data collection</th>
<th>Total hourly expense ($20 per hour)</th>
<th>Cost</th>
<th>No. of species detected</th>
<th>No. of species uniquely detected</th>
<th>Rank Time/Species</th>
<th>Rank Cost/Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Searching</td>
<td>17 hours</td>
<td>$340</td>
<td>Nothing. Expert's time donated.</td>
<td>11</td>
<td>4</td>
<td>(4) 0.64 species per hour</td>
<td>(3) $30.90/ species</td>
</tr>
<tr>
<td>Anabat</td>
<td>9 hours</td>
<td>$180</td>
<td>Equipment donated.</td>
<td>12</td>
<td>12</td>
<td>(1) 1.33 species per hour</td>
<td>(6) $46.16/ species</td>
</tr>
<tr>
<td>Audio Recordings</td>
<td>48 hours</td>
<td>$960</td>
<td>$150 equipment.</td>
<td>40</td>
<td>9</td>
<td>(3) 0.83 species per hour</td>
<td>(2) $28.50/ species</td>
</tr>
<tr>
<td>Bird Survey</td>
<td>36 hours</td>
<td>$720</td>
<td>Nothing. Borrowed equipment.</td>
<td>43</td>
<td>7</td>
<td>(2) 1.19 species per hour</td>
<td>(1) $16.74/ species</td>
</tr>
<tr>
<td>Elliott Trap</td>
<td>1,512 trap days/nights; 120 hours</td>
<td>$2,400</td>
<td>$500 hire of traps. $30 Bait</td>
<td>6</td>
<td>0</td>
<td>(12) 0.05 species per hour</td>
<td>(12) $48.33/ species</td>
</tr>
<tr>
<td>Hair Funnel</td>
<td>12 months continuous; 54 hours</td>
<td>$1,080</td>
<td>$655.40 equipment (incl. bait). $330 analysis of collections.</td>
<td>10</td>
<td>2</td>
<td>(8) 0.18 species per hour</td>
<td>(10) $266.54/ species</td>
</tr>
<tr>
<td>Harp Trap</td>
<td>8 hours</td>
<td>$160</td>
<td>Nothing. Borrowed equipment.</td>
<td>0</td>
<td>0</td>
<td>(14) 0.00 species per hour</td>
<td>(14) $160/ 0 species</td>
</tr>
<tr>
<td>Incidental Observations</td>
<td>60 days field data collection (~960 hours)</td>
<td>$19,200</td>
<td>Nothing.</td>
<td>51</td>
<td>6</td>
<td>(11) 0.06 species per hour</td>
<td>(11) $376.47/ species</td>
</tr>
<tr>
<td>Nest Box</td>
<td>36 hours</td>
<td>$720</td>
<td>$387.80</td>
<td>2</td>
<td>0</td>
<td>(13) 0.05 species per hour</td>
<td>(13) $583.90/ species</td>
</tr>
<tr>
<td>Pitfall Trap</td>
<td>1728 trap days/nights; 52 hours</td>
<td>$1,040</td>
<td>$200</td>
<td>5</td>
<td>0</td>
<td>(10) 0.09 species per hour</td>
<td>(8) $248/ species</td>
</tr>
<tr>
<td>Road Walk</td>
<td>48 hours</td>
<td>$960</td>
<td>Nothing.</td>
<td>27</td>
<td>2</td>
<td>(6) 0.56 species per hour</td>
<td>(4) $35.55/ species</td>
</tr>
<tr>
<td>Sand Tray</td>
<td>84 hours</td>
<td>$1,680</td>
<td>$753.50 Sand &amp; $54.30 equipment</td>
<td>10</td>
<td>1</td>
<td>(9) 0.11 species per hour</td>
<td>(9) $248.78/ species</td>
</tr>
<tr>
<td>Scat Collection</td>
<td>54 hours</td>
<td>$1,080</td>
<td>$35 equipment &amp; $1,280 analysis of collections.</td>
<td>20</td>
<td>2</td>
<td>(7) 0.37 species per hour</td>
<td>(7) $118.75/ species</td>
</tr>
<tr>
<td>Spotlighting</td>
<td>41 hours</td>
<td>$820</td>
<td>Nothing. Borrowed equipment.</td>
<td>23</td>
<td>3</td>
<td>(5) 0.56 species per hour</td>
<td>(5) $35.65/ species</td>
</tr>
<tr>
<td><strong>Total/ Average</strong></td>
<td><strong>1,567 hours</strong></td>
<td><strong>$31,340</strong></td>
<td><strong>$5,360</strong></td>
<td><strong>18.5</strong></td>
<td><strong>3.4</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Method</td>
<td>Calculations</td>
<td>Total time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active Searching</td>
<td>One day per three months, for around four hours. Times spent searching were recorded</td>
<td>17 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anabat</td>
<td>Three nights used, for three hours per night. Recordings sent to an expert for examination</td>
<td>9 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Audio Recording</td>
<td>Available during bird surveying, 20 minutes per site, for three afternoons per month, for 12 months = 36 hours. Additional one hour per month for recordings during spotlighting = 12 hours</td>
<td>48 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elliott Traps</td>
<td>Seven traps, dawn &amp; dusk for three days, per month for 12 months = 72 hours in the field to set and check traps. Two hours to set up traps and bait each month = 24 hours. Two hours per month to clean all traps = 24 hours</td>
<td>120 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hair Funnels</td>
<td>Five funnels per site, active all month, changed once per month for 12 months. 1.5 hours per site, for three sites, for 12 months. Samples sent to expert for examination.</td>
<td>54 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harp Traps</td>
<td>Five Harp Traps. Used on one night only. Eight hours for checking, setting up and packing of equipment</td>
<td>8 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incidental Observations</td>
<td>Five days per month in the field doing data collection</td>
<td>60 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pitfall Traps</td>
<td>Eight traps, dawn &amp; dusk for three days, per month for 12 months = 36 hours in the field to set and check traps. 16 hours to make and dig pitfall traps</td>
<td>52 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nest Boxes</td>
<td>Four nest boxes per site, approximately Three hours to check all boxes, per month for 12 months</td>
<td>36 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road Walk</td>
<td>Four hours per month, for 12 months</td>
<td>48 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand Tray</td>
<td>Two hours per day for reading and recording prints and raking sand, dawn &amp; dusk for three days, per month for 12 months = 72 hours in the field to prepare and read sand. Sand placed at culverts and Blackwood Road at start of sampling period, and checked at end of week, taking one hour each month for 12 months = 12 hours</td>
<td>84 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scat Collection</td>
<td>1.5 hours per site, for three sites, once per month for 12 months. Samples sent to expert for examination</td>
<td>54 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spotlighting</td>
<td>Three nights per month for all sites and in between, for 12 months. Averaged about one hour per month. The exact times for spotlighting were recorded each night</td>
<td>41 hours</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER 5 – CONCLUSIONS & RECOMMENDATIONS

The conclusions and recommendations made in this chapter relate to the Slaty Creek Wildlife Underpass, Blackwood Road Underpass and culverts under the following headings;

- the key themes and results that have come from this study are identified, and their contribution to the field of road ecology highlighted;
- recommendations relating to the local community of the Black Forest, and methods for the involvement of the community in the environmental management of roads are made;
- recommendations to VicRoads on wildlife and habitat management and present gaps within this area of road management;
- general comment is made on the role of underpasses and necessities for monitoring these crossing structures; and
- areas that require further research and development.

5.1 Results of the study

Compared to the other sites reviewed in Chapter 2, the design of the Slaty Creek Wildlife Underpass, in its large dimensions, and the retention of remnant vegetation within the underpass appears to be a unique design. These attributes are likely to have contributed to the use of the underpass by the variety of species, including the arboreal animals, and small ground dwelling animals that were provided with habitat and movement opportunities that in some way reflect those preferred within the forest environment.

The ability of the Underpass to accommodate many species of birds and bats demonstrates the importance of its large dimensions. The monitoring methods employed to assess the use of this structure by bats was very important, as this has rarely been assessed in other crossing structures (Hoye and Hoye 1999; Keeley and Tuttle 1999; Forman, Sperling et al. 2003).

With at least four species of reptile, six species of amphibian, 24 confirmed and seven unconfirmed mammal species and 37 bird species within or above the underpass, this has been shown to be one of the most diversely populated underpasses ever studied.
The culverts and Blackwood Road both showed evidence of use by native and introduced animals, however at much lower rates than Slaty Creek.

There were some species that were detected within the surrounding forest, but never detected within the underpass. Further studies examining individual fauna movements throughout the underpass and surrounding forest would be beneficial to give greater depth to the assessment of effectiveness of the Slaty Creek Underpass.

5.2 Slaty Creek Improvements

5.2.1 The design of the Slaty Creek Wildlife Underpass, Blackwood Road Underpass and culverts

5.2.1.1 Tree cover

The remnant and planted vegetation beneath and between the road carriageways is an important element of the Slaty Creek Underpass. However, the present differences between the biomass of the Black Forest and the Slaty Creek Underpass suggests that work needs to be done to further enhance the vegetation cover of the underpass. The existing vegetation will mature with time but more planting could be carried out to provide a continuous corridor of vegetation connecting the forest on either side. The vegetation cover through the Blackwood Road Underpass is quite sparse. It is speculated that both underpasses could be further enhanced with additional overstorey trees and middle storey species. When revegetating an area, it is best to use the same species found within the adjacent forest, to assist in replicating the species composition and structure of the surrounding forest (Buchanan 1989; Bennett, Kimber et al. 2000). Species that would be suitable to plant include:

- Blackwood (*Acacia melanoxylon*),
- Broad leaved Peppermint (*Eucalyptus dives*),
- Clustered Pomaderris (*Pomaderris racemosa*),
- Hazel Pomaderris (*Pomaderris aspera*),
- Manna Gum (*Eucalyptus viminalis*),
- Messmate Stringybark (*Eucalyptus obliqua*),
- Narrow leaved Peppermint (*Eucalyptus radiata*),
- Narrow-leaved Wattle (*Acacia cognata*),
- Prickly Mimosa (*Acacia verticillata*), and
- Victorian Christmas Bush (*Prostanthera lasianthos*).
Trees and shrubs should be planted throughout the Slaty Creek Underpass site, but particularly in the following locations (Figure 10):

- in the north-western sector of the underpass between the access track, creek line and western carriageway; and
- in the southern sector of the underpass between the two carriageways.

5.2.1.2 Ground cover of the underpass

Whilst the remnant vegetation and natural materials on the floor of the underpass are very good compared to most other underpasses, there is opportunity to further enhance this cover. The methods used in treating the ground cover of the underpass should be through rehabilitation techniques, making use of natural regeneration where possible. For future road works, during construction of the road, the vegetation and soil removed could be stockpiled in such a way that once the bridge sections are constructed, this soil and associated indigenous seed bank already built in, could be spread over the ground of the underpass. Brush matting with branches of eucalypts can provide further seeds to generate new plant growth, and mulching material that is sparse enough to still allow light to penetrate to the soil (Buchanan 1989). The current tanbark mulch and landscaped planting appears to be smothering any new growth and not providing a good opportunity for young plants. The placement of large loose rocks within the creek and in the areas without vegetation can provide habitat suitable for amphibians, reptile and invertebrates (Bennett, Kimber et al. 2000). As the vegetation within the underpass matures, the volume and depth of leaf litter and fallen timber should increase, providing better habitat for invertebrates, reptiles and amphibians than present (Buchanan 1989). Securing the logs to the ground in a way that will prevent them from being removed is probably necessary.

5.2.1.3 Bridge piers

One method of encouraging animals to use the underpass is to enhance the bridge piers to make them more attractive to animals. It is speculated that this could be achieved by painting the piers with a gripping paint, such as paint mixed with sand, or concrete rendering of these surfaces, thus allowing animals to climb the sides of the pylons to a designated height and avoid predators if necessary. Invertebrate cocoons were noted to attach themselves to the bridge piers (Plate 16). Attractive surfaces on the bridge piers could encourage further invertebrates to live within the underpass,
increasing the amount of life within the area, and potentially attracting animals that prey upon invertebrates. Arboreal mammals may also find the surfaces suitable for climbing. It is believed this approach has not been tested before. So long as the paint is not applied to the main carriageway it is not expected that animals would be able to access the road through this avenue. For general aesthetics, green paint would better camouflage the piers than the current blue paint, although this is unlikely to make much difference to fauna usage.

Plate 16: Cocoon from insect attached to a bridge pier in Slaty Creek Underpass. Photo: Rodney Abson.

5.2.1.4 Bat Roosts
Bat roosts have been successfully retrofitted to many bridges, creating habitat for these creatures with little extra expense (Hoye and Hoye 1999; Keeley and Tuttle 1999). These roosts or the presence of bats has not been found to jeopardise the structural integrity of the bridge. It is expected that Australian bats would use the roost structures within bridges in the same way the Northern Hemisphere bats do. A useful guide to the construction of species-specific bat roosts has been compiled for the Gippsland Region (de Souza-Daw 2000), and would most likely be transferable to species of the Macedon Region. These structures can be monitored for their effectiveness through using Anabat detection and through direct inspection.

5.2.1.5 Rope Canopy Bridges and Glider Poles
Given the number of arboreal mammals detected within the Black Forest Region and not in the underpass, there is scope for immediate improvements to the Slaty Creek Underpass to encourage safe passage for arboreal mammals between forest blocks. Whilst the retained vegetation is beneficial, it may be too sparse for animals such as gliders to safely traverse the underpass. At present, gaps of fifteen metres and more exist between the eastern and western edges of the Black Forest and the isolated stands of eucalypts in the underpass (Figures 10 and 11). It is uncertain if some species such as the feathertail glider (Acrobates pygmaeus) will ever come to ground, as they prefer to glide between trees or climb along branches. Before the new vegetation comes to maturity, it is recommended that glider poles or rope canopy
bridges be installed to minimise the distance required for passage between trees by gliders.

Other studies conducted within Australia (AMBS 2001a; Weston in prep.), and overseas (Kirathe and Parry 2003) have shown that arboreal mammals will use rope canopy bridges and may use glider poles as a means of moving through infrastructure-altered environments. These structures can enhance habitat connectivity and simulate a similar passage of movement to their natural preference through the forest. Installation of rope canopy bridges and glider poles could assist the passage of animals such as the common ringtail possum (Pseudocheirus peregrinus), common brushtail possum (Trichosorus vulpecula), mountain brushtail possum (Trichosorus caninus), sugar glider (Petaurus breviceps), feathertail glider (Acrobates pygmaeus), greater glider (Petauroides volans), and squirrel glider (Petaurus norfolcensis). These structures could also potentially be utilised by agile antechinus (Antechinus agilis), bush rat (Rattus fuscipes) and koala (Phascolarctos cinereus). This would keep the animals elevated from the threat of ground predators such as foxes, dogs and cats.

In accommodating favourable movement of the smallest glider (feathertail glider), which has a gliding distance of around 20 m (Berra 1998), it is recommended that glider poles should be placed at half of this distance from existing trees to allow for easy gliding movements. If these poles were to be utilised, a network of trees or poles every 10m in the vicinity of the underpass would allow for options for the direction of movement within the underpass. It is suggested that about ten poles be installed in the northeastern sector of the underpass, and another ten be installed under and between the two carriageways (Figure 11). Rope canopies could be attached to trees or to poles placed within the underpass. These structures can be monitored for their effectiveness by a variety of techniques including cameras, scat collection, hair collection, and direct observations.

5.2.1.6 Rubbish

Rubbish may cause pollution to the area of the underpass, Slaty Creek and adjacent dam. So as not to encourage people to use this area as a rubbish dump, it should be routinely cleared of rubbish. Whilst it is possible for fauna to use the rubbish as habitat (Low 2002), there are better alternatives for providing habitat opportunities.
5.2.1.7 Fencing along the Calder Freeway

The value of the 'animal-resistant' fencing of the Black Forest along the Calder Freeway is uncertain. The numbers of species identified as road kill appears to be high, but no comparative studies of fenced vs. unfenced or freeway vs. road scenarios were undertaken. Throughout the course of this study, gaps in fencing were identified as occurring both within the fences next to the concrete bridges and sporadically along the fences. By the end of the study, both fencing issues had been addressed: the gaps near bridges were plugged, and a skirt was placed along the entire length of the animal-proof fence to eliminate gaps made by burrowing animals (Plate 4). Eucalypt regrowth adjacent to the fence was also removed, as this was seen as a potential way for arboreal animals to access the freeway. On-going maintenance of fences should continue to prevent unnecessary animal deaths on the freeway.

5.2.2 Optimal dimensions and design for underpasses

It is difficult to make generalisations about the optimal dimensions of underpasses to effectively facilitate the movement of fauna. All that can be stated from this study is that a vegetated wildlife corridor that is 70 metres wide, which links two continuous forest patches 100 metres apart, has been effective for the passage of most ground-moving animals. Whilst some birds utilised the wildlife corridor, other arboreal mammals did not. It is not certain what the optimal height of the bridge above ground level should be. Whilst studies overseas have demonstrated different fauna preferences for crossing structures (Clevenger and Waltho 1999; Clevenger, Chrusczcz et al. 2001), there have been no rigorous studies to identify Australian fauna preferences. Therefore the precautionary principle should be employed, and until scientific evidence proves otherwise, the 'bigger the better' principle is generally appropriate when designing and building fauna crossing structures in Australia.

Other factors that may be more important than size for fauna to move through an underpass could be the noise and light levels, or familiarity over time with the crossing structure (Opdam 1995; Clevenger and Waltho 1999; Forman, Sperling et al. 2003). There is a need to look beyond what people see as being suitable for people to move through an underpass, and to interpret what Australian fauna would see as being suitable for moving through an underpass. A balance of cleared areas, and dense
vegetation or logs should be present within underpasses so as to allow for the variety of favoured movement preferences of fauna. Experiments could be carried out with wild populations, as well as animals in captivity, such as those kept at zoos and sanctuaries to test movement preferences and acceptance of crossing structures of varying dimensions.

5.2.3 Box Culverts
Although there were no box culverts within this study area, it has been shown through other studies (Clevenger and Waltho 2003) that these are more likely to be accessed by fauna than smaller round culverts. It is therefore recommended that where possible, box culverts should be used instead of round culverts, as they have tended to show greater use by fauna than round culverts, and are able to be adapted more readily to provide for dry passage when the culverts are built primarily for water flow. It would not be expected that the culverts in these locations would be replaced with box culverts, but is a recommendation for future road projects.

5.3 Ongoing monitoring
Should VicRoads approve the recommended new structures suggested in section 5.2.1, it is recommended these be monitored to evaluate both their effectiveness at Slaty Creek and potential opportunities for use at other locations across Victoria.

The focus of this study was to determine which animals were present in the underpass and the two forest sites, and to a lesser extent at the culverts and Blackwood Road. This study has not addressed questions of the population dynamics of animals interacting with, or avoiding, the underpass. For example, from this study it could not be determined if the same wombat was present in both the underpass and the forest sites every month of monitoring, or if there was a family of wombats. A series of tag and recapture studies or radio tagging and tracking of individual animals would be required in order to address some of the questions regarding population dynamics. Population analysis can be used as another measure of the effectiveness of the underpass. It is recommended that population studies be undertaken to gain a further understanding of the animal communities of the forest and underpass.
The twelve nest boxes within the underpass and forest either side should continue to be monitored for the presence of animals, and the removal of unwanted invaders such as bees or wasps. A colony of sugar gliders had moved into a nest box on the West Forest Site, and another colony had moved into a box on the East Forest Site towards the end of this study (Plate 17). It is expected that feathertail gliders may use the nest boxes in the future, as they have been found to readily do so in the nearby Wombat State Forest (Ward 2000). A local environmental group such as the Macedon Conservation Society could undertake next box monitoring in conjunction with checking their own boxes established in the local area.

Plate 17: Sugar Gliders inside a nest box in the West Site. Photo: Rodney Abson.

5.4 Further approaches to gauging the effectiveness of a Wildlife Underpass
When conducting a study of a wildlife underpass or crossing structure there are several points that would be valuable to cover based on experience gained in this study:

1. Ensure clear aims are established early, and to what degree the information being collected is able to gauge the effectiveness of a crossing structure. When assessing a wildlife crossing structure, the use of ‘target species’ as the means of evaluation of effectiveness should be approached with caution. By simply using target species, a structure could be deemed ineffective because none of the target species are detected within the underpass, although many other species may be
detected. Alternatively, crossing structure design may be only capable of accommodating the target species, ignoring other local fauna to the detriment of the ecosystem. The monitoring efforts should be broadly aimed at addressing these two questions:

- Does this structure allow for favourable movement of animals from one side of the road to the other? and
- Are the monitoring techniques employed going to detect all species which are to be monitored for use of this passage, including target species (if any)?

2. Conduct pre-construction monitoring to gauge the presence and quantities of species over a broad area covering the forest that is to be separated by the road. Genetic sampling would be useful.

3. Conduct monitoring during construction of the road.

4. Have ongoing monitoring on a regular (for example once per month) and systematic basis (set locations, times and methods used each month) spanning several years after the road and crossing structure has been established.

5. Use suitable techniques to thoroughly detect the presence of species within the vicinity. Ideally, a variety of animals should be thoroughly studied, such as arboreal animals, reptiles, amphibians and aquatic fauna for their response to the crossing structure.

6. Engage in capture mark and recapture studies to assess whether it is the same individual using the crossing structure, or whether it is a number of individuals. This method can provide information on the distance animals travel to access the crossing structure.

7. Assess the genetic mixing of fauna on either side of the road barrier, to determine whether the crossing structure is allowing for dispersal of animals. This is a very expensive, long-term and resource-intensive method, but would provide valuable information for the field of landscape ecology.

8. Maintain records of any modifications to the road environment during the time of monitoring which could influence the effectiveness of the crossing structure, such as the construction of a fence along the entire stretch of road, and assess whether this influences the use of the underpass.

9. Ensure reports and publications are widely distributed to add to the pool of information on the monitoring and effectiveness evaluation of crossing structures.
5.5 Black Forest community

5.5.1 Private ownership of Black Forest

The Black Forest has been shown to be a valuable habitat area for a variety of mammals, reptiles, amphibians and birds, some of which are not known in other local forest patches. This section of the Black Forest forms a stepping-stone patch between Mt. Macedon in the north, and the Wombat State Forest to the Southwest. With the importance of this patch of forest identified (VicRoads 1995; VicRoads 1995; Abson and Lawrence 2003) and the fact that it is largely privately owned, steps should be taken to see that it is maintained as a permanent Nature Reserve. VicRoads could initiate this by ensuring the land status of the Black Forest blocks belonging to VicRoads be deeded for permanent nature conservation. This land could be deeded to Parks Victoria, or the Department of Sustainability and Environment, or put under the trust of a community environmental group. In either case, an active management strategy should be written and implemented to ensure the integrity of the forest block is maintained. This could be carried out in consultation with local environment groups.

Figure 2 indicates that most of the forest collectively known as the Black Forest is privately owned. The long-term success and value of the underpass will ultimately depend on the quality and size of the surrounding forest. If the forest adjacent to the underpass is divided into smaller and smaller blocks, and the land cleared or invaded by weeds such as Monterey Pine (*Pinus radiata*), the type and diversity of animal species in the Black Forest may diminish. This is something that should be brought to the attention of the Macedon Shire Council. It is in the best interests of VicRoads to ensure that the financial investment they made to the wildlife of the Black Forest be maintained in perpetuity. Accordingly, VicRoads could request that the Macedon Shire Council curtail any further subdivision of existing forest blocks. VicRoads could also encourage local residents to place conservation covenants on remnant forest blocks that are privately owned. Trust for Nature (Trust for Nature 2003), and Land For Wildlife (Department of Sustainability and Environment 2003) can assist in enhancing the conservation and protection of these blocks of land.
5.5.2 Community involvement
During this study, the local community were noted to use the Slaty Creek Underpass and surrounding tracks for passive recreation. It would be useful for VicRoads to establish formal links between interested local individuals and/or groups to assist in the notification of any maintenance works needed, such as gaps in fencing that need repair or rubbish dumped in the area that needs to be removed. An action group such as the ‘Friends of the Black Forest’ could be formalised in the same way many friends groups are formed for various parks in Victoria. It is suggested that the local community, the Macedon Conservation Society, local schools and other residents could be involved in the ongoing monitoring of nest boxes or other structures established during this study within the underpass or surrounding forest. The local community may have more suggestions for VicRoads on how wildlife habitat can be enhanced in the region, and how the impacts of fragmentation by roads could be reduced. It is recommended that VicRoads actively engage in regular consultation with local people.

Motorcycles were often sighted riding throughout the underpass and surrounding tracks during the course of this study. Whilst signage indicated motorcycle riding in the area was prohibited, it persisted, and may be detrimental to the effectiveness of the wildlife underpass. Local residents could be encouraged to discourage this activity.

5.6 VicRoads
5.6.1 Internal awareness of environmental road issues and mitigation options
VicRoads have developed a number of processes and guidelines for the protection and enhancement of environmental factors as influenced by roads (VicRoads 1995; VicRoads 1999; VicRoads 2000; VicRoads 2000). The use of the road effect zone as a method of mapping the impacts of current and proposed roads could be a very useful tool for identifying impacts and site specific solutions required to mitigate those impacts (Forman 2000; Trombulak and Frissell 2000; Forman, Sperling et al. 2003). As yet, the road effect zone does not appear to have been used by any Australian road management authority.
It is essential that all levels of management within VicRoads are aware of the environmental impacts of roads and that sufficient funding resources and suitable, accurate information be provided for the environmental management of road systems.

5.6.2 Community awareness of road impacts and mitigation options

It is important that information relating to positive examples of environmental road management be distributed to the wider public. Crossing structures are a proven successful option for mitigating the impacts of roads on the environment, and are more likely to be put into place if there is an informed community advocating for them. There are a variety of ways that this information can become available, and that the wider public can be involved in the protection and enhancement of road environments.

5.6.3 Education

There are some very good examples of proactive community environmental educational programs based on roads developed in the United States (The Humane Society of the United States 2002; White and Ernst). Education relating to road ecology in Australia could come in many forms, including the formulation of brochures or stickers relating to care for injured wildlife, or driving with care through dusk to dawn to avoid colliding with wildlife. Information could be available on the VicRoads web page about how they are working towards better environmental management of roads, and tips for drivers.

The creation of a reference library of studies, reports and works relating to fauna sensitive road design, from within Victoria, Australia and overseas should be compiled. This information is currently spread largely within the ‘grey literature’ of roads departments, councils, universities, and other community organisations. Sharing of information and resources between states and overseas will be beneficial for the development of environmental management systems. Reports and relevant information should be available to the general public.

5.6.4 Roadside reserve management

Habitat enhancement of roadside reserves is very important, particularly throughout areas of few remnant patches of vegetation. Strategic planning could identify
opportunities for the roadside reserves to form wildlife corridors with other important patches across the landscape. The management of the roadside reserves should be incorporated into other environmental networks in the region, so that local level environmental groups (such as Landcare) activities can be incorporated into the roadside reserves. The land purchased by VicRoads to offset the negative impacts of new road developments, through the net gain principle could be offered to community groups for the purpose of locally managed nature reserves. These would require appropriate supervision of activities from another government department that specialises in environmental management, but would ensure the land is maintained.

5.6.5 Fauna management
Local community knowledge of fauna trends within the region should be involved in management plans. People who are residents of the area for a long time may be sensitive to localised extinctions or dropping number of animals, which could be due to road impacts (Lunney, O'Neill et al. 2000). Jones (2000) identified localised extinctions caused by roads, and proved that mitigation works can allow for the reintroduction of species that have become locally extinct.

Dead animals should be removed from the road to prevent death of scavengers. Funding for minor connectivity projects along roadsides should be available including the installation of rope canopy bridges, amphibian tunnels and 'Biobaffles' (Davies 2003) within culverts that accommodate stream crossings.

5.7 Fauna Reference Database
It would be useful if there were the creation of a database which identifies groups of animals, and their distribution, habitat requirements, preferred movement options, and mitigation measures which are likely to be best suited to their needs, which can be used in the assessment of new roads or the development of mitigation options for existing roads. This could incorporate existing databases, such as the Victorian Wildlife Atlas (Department of Sustainability and Environment 2002) and similar databases for vegetation or hydrological issues. This information can be accessed when developing habitat management plans for road reserves.
It is important that priority areas of high impacts on wildlife be identified, so that efforts to mitigate these impacts can be systematically handled and scarce resources be not wasted. These ‘hot spots’ may be identified by a variety of methods, including modelling programs, field research or communities identifying areas of high biodiversity importance (Opdam 1995; Barnum 2003; Neal, Gilbert et al. 2003; Ruediger, Lloyd et al. 2003).

5.8 Costs benefits analysis for mitigation options

Bennett (1999) posed the question as to whether corridors are a cost-effective option in comparison with other ways of using scarce conservation resources. In determining the best options for spending money on environmental mitigation projects, it would be beneficial to develop a cost benefit analysis of options which can be used as a decision making tool. Given that underpasses are relatively expensive structures, would the money be better spent on strategically purchasing important blocks of land or revegetating creek lines away from the road so that they form wildlife corridors within the landscape? Supporting local environmental groups on a 50/50 in-kind contribution to environmental works and assisting them in the management of the land could provide worthwhile dividends.

Predator reduction measures, the removal of invasive weeds within surrounding forest patches and the installation of nest boxes may be better for the long term conservation of the native fauna than to put an underpass into a freeway that runs through relatively low quality habitat. Perhaps a selection of smaller crossing structures, including several box culverts and rope canopy bridges spread over a larger area would be better for the conservation of the local species than pooling all of the money into one structure. This approach is beginning to take place within Victoria, as VicRoads develop habitat management plans, in conjunction with the Department of Sustainability and Environment (through the native vegetation management plan and net gain principles), local government and local level environmental groups.

5.9 Victoria, Australia, International

5.9.1 Areas requiring further research and development

There have been many issues raised throughout this thesis, identifying the need for further research and development in the field of road ecology, and specifically the use
of crossing structures. The most pressing need for further work is in ensuring there are thorough scientific monitoring regimes developed for crossing structures. Assessment of the optimal design, dimensions and quantity of crossing structures are required in order to maintain the integrity of fauna populations segregated by the construction of roads. The behavioural responses of Australian fauna to crossing structures, and roads in general, need to be understood. This includes recognising those species that find roads a barrier to movement, and identifying the cause of that barrier.

Measurements of distance that noise, light, air and water pollution impacts away from a road should be carried out, so that baseline measurements of the road effect zone can be established. This information can become a useful tool in conducting environmental impact assessments for roads.

There needs to be a comprehensive analysis of mitigation methods, as addressed in Chapter Two, to assess their effectiveness, affordability, practicality of installation and maintenance. Opportunities for small industry development should be encouraged, such as the ‘Biobaffles’ established in Tasmania to facilitate fish passage through culverts where roads cross a stream (Davies 2003).

The sharing of information and resources between states and involving Australia in international road ecology research is essential in keeping up to date, and aspiring to reach the benchmark (this may be considered to be currently being set by France, and Europe in general through cooperative management) in environmental management of roads.

5.9.2 The need for underpasses and crossing structures
Underpasses and crossing structures have proven that they do have an important role to play in mitigating the impacts of roads on the environment. It needs to be clear that underpasses are a mitigation tool, not a compensation for the loss and fragmentation of habitat. The success of the Slaty Creek Underpass for wildlife passage should not be seen as a reason to bisect forest patches in any future road-planning scheme. In real terms, there is very little remnant forest remaining in Australia. The priority for remaining forest patches in Australia should be to ensure their integrity is preserved.
as large forest blocks. Underpasses (or other structures) should not be encouraged if they provide credence to new road construction that ultimately result in further fragmentation of remnant forest patches.

The place for wildlife structures within the VicRoads policy should be associated with the ‘net gain’ policy (Parkes, Newell et al. 2003). As VicRoads develop their program of ensuring there is always a net environmental gain for every construction project undertaken, wildlife corridors should be developed in places where remnant forest patches can be linked. For example, if there are two good-sized remnant forest patches either side of a present or future roadway, there may be a suitable place for the construction of a wildlife crossing structure and associated vegetation. In this way, the net gain principle is applied and forest patch connectivity is enhanced, and VicRoads is seen as proactive rather than reactive in their environmental program.

The optimal design, locations and frequency of crossing structures for Australian fauna and landscape conditions need to be further studied; incorporating ecologists, road planners and engineers, all levels of government and local community. Crossing structures and underpasses are a useful tool that can be incorporated into other landscape rehabilitation programs to reduce the barriers to fauna movements across the landscape.
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123
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134


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### Appendix 1. Fauna List referred to in thesis

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<th>Scientific Name</th>
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<td><em>Pachycephala rufiventris</em></td>
</tr>
<tr>
<td>Sacred Kingfisher</td>
<td><em>Todiramphus sanctus</em></td>
</tr>
<tr>
<td>Satin Flycatcher</td>
<td><em>Myiagra cyanoleuca</em></td>
</tr>
<tr>
<td>Scarlet Robin</td>
<td><em>Petroica multicolor</em></td>
</tr>
<tr>
<td>Sheep</td>
<td><em>Ovis aries</em></td>
</tr>
<tr>
<td>Shrew</td>
<td><em>Sorex sp.</em></td>
</tr>
<tr>
<td>Silvereye</td>
<td><em>Zosterops lateralis</em></td>
</tr>
<tr>
<td>Snake sp.</td>
<td></td>
</tr>
<tr>
<td>Southern Boobook</td>
<td><em>Ninox novaeseelandiae</em></td>
</tr>
<tr>
<td>Southern Brown Tree Frog</td>
<td><em>Litoria ewingii</em></td>
</tr>
<tr>
<td>Southern Bullfrog</td>
<td><em>Limnodynastes dumerilii</em></td>
</tr>
<tr>
<td>Southern Forest Bat</td>
<td><em>Vespadelus regulus</em></td>
</tr>
<tr>
<td>Southern Freetail Bat</td>
<td><em>Mormopterus sp.</em></td>
</tr>
<tr>
<td>Southern Water Skink</td>
<td><em>Eulamprus tympanum</em></td>
</tr>
<tr>
<td>Spider Monkey</td>
<td><em>Ateles fusciceps</em></td>
</tr>
<tr>
<td>Spotted Pardalote</td>
<td><em>Pardalotus punctatus</em></td>
</tr>
<tr>
<td>Squirrel Glider</td>
<td><em>Petaurus norfolcensis</em></td>
</tr>
<tr>
<td>Striated Thornbill</td>
<td><em>Acanthiza lineata</em></td>
</tr>
<tr>
<td>Sugar Glider</td>
<td><em>Petaurus breviceps</em></td>
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<tr>
<td>Sulphur Crested Cockatoo</td>
<td><em>Cacatua galerita</em></td>
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<tr>
<td>Superb Fairy-Wren</td>
<td><em>Malurus cyaneus</em></td>
</tr>
<tr>
<td>Swallow</td>
<td><em>Hirundo sp.</em></td>
</tr>
<tr>
<td>Swamp Rat</td>
<td><em>Rattus lutreolus</em></td>
</tr>
<tr>
<td>Swamp Wallaby</td>
<td><em>Wallabia bicolor</em></td>
</tr>
<tr>
<td>Tammar Wallaby</td>
<td><em>Macropus eugenii</em></td>
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<tr>
<td>Tasmanian Devil</td>
<td><em>Sarcophilus harrisii</em></td>
</tr>
<tr>
<td>Tawny Frogmouth</td>
<td><em>Podargus strigoides</em></td>
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<tr>
<td>Tree Pipit</td>
<td><em>Anthus trivialis</em></td>
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<tr>
<td>Unidentified long-eared Bat</td>
<td><em>Nyctophilus sp.</em></td>
</tr>
<tr>
<td>Victorian Smooth Froglet</td>
<td><em>Geocrinia victoriana</em></td>
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<tr>
<td>Weasel</td>
<td><em>Mustela sp.</em></td>
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<tr>
<td>Wedge-tailed Eagle</td>
<td><em>Aquila audax</em></td>
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<tr>
<td>Welcome Swallow</td>
<td><em>Hirundo neoxena</em></td>
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<tr>
<td>Whistling Tree Frog</td>
<td><em>Litoria verreauxii verreauxii</em></td>
</tr>
<tr>
<td>White Eared Honey Eater</td>
<td><em>Lichenostomus leucotis</em></td>
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<tr>
<td>White Naped Honey Eater</td>
<td><em>Melithreptus albogularis</em></td>
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<tr>
<td>White Throated Tree Creeper</td>
<td><em>Cormobates leucophaeus</em></td>
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<tr>
<td>White’s Skink</td>
<td><em>Egerinia whitii</em></td>
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<tr>
<td>White-browed Scrubwren</td>
<td><em>Sericornis frontalis</em></td>
</tr>
<tr>
<td>Common Name</td>
<td>Scientific Name</td>
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<tr>
<td>----------------------------</td>
<td>-------------------------------</td>
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<tr>
<td>White-faced Heron</td>
<td><em>Egretta novaehollandiae</em></td>
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<tr>
<td>White-plumed Honey Eater</td>
<td><em>Lichenostomus penicillatus</em></td>
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<tr>
<td>White-striped Freetail Bat</td>
<td><em>Tadarida australis</em></td>
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<tr>
<td>White-winged Chough</td>
<td><em>Corcorax melanorhamphos</em></td>
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<tr>
<td>Willow warbler</td>
<td><em>Phylloscopus trochilus</em></td>
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<tr>
<td>Wolf</td>
<td><em>Canis lupus</em></td>
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<td>Wolf spider</td>
<td><em>Lycosa sp.</em></td>
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<td>Wombat</td>
<td><em>Vombatus ursinus</em></td>
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<tr>
<td>Yellow-bellied glider</td>
<td><em>Petaurus australis</em></td>
</tr>
<tr>
<td>Yellow-faced Honey Eater</td>
<td><em>Lichenostomus chrysops</em></td>
</tr>
<tr>
<td>Yellow-tailed Black Cockatoo</td>
<td><em>Calyptorhynchus funereus</em></td>
</tr>
<tr>
<td>Yellow-tufted Honeyeater</td>
<td><em>Lichenostomus melanops</em></td>
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