Sugarloaf Pipeline habitat linkages—camera monitoring of vehicle track underpasses for bandicoots

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Front cover photo: Long-nosed Bandicoot in box culvert underpass (top), and in the forest adjacent to the Sugarloaf Pipeline (bottom).

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Summary

During the construction of the Sugarloaf Pipeline in 2010, a number of dual pipe 'underpasses' and a single box culvert were installed under the Pipeline Vehicle Maintenance Track that runs beside the pipeline in order to facilitate crossing of the track by bandicoots. In 2015, once vegetation adjacent to the track had re-grown for five years, we deployed wildlife survey cameras on each side of four such underpasses, and also approximately 50 m into the forest each side of the track. These forest cameras each had an associated 'bait station' intended to attract wildlife. Over a period of 12 months, the cameras collected images of animals close to and using the underpasses, and of animals in the nearby forest. The pair of cameras at one of the round pipe underpasses was stolen after the first retrieval of images, so only one month of data was available from these two cameras.

A variety of native and introduced fauna were photographed, including the Long-nosed Bandicoot *Perameles nasuta*, Black Wallaby *Wallabia bicolor,* Common Wombat *Vombatus ursinus* and Red Fox *Vulpes vulpes*. Although there has been some suggestion of Southern Brown Bandicoots *Isoodon obesulus obesulus* in the area, this species was not recorded during this study, and based on known distribution and habitat requirements is unlikely to occur in the area. Eleven native and introduced vertebrate species used the box culvert, and nine species used the round pipe underpasses. The number of independent 'use of underpass' events were greater at the box culvert, with 90 documented use events, compared to the two pipe underpasses (10 and 33), once a large number of use events (66) by a single Bush Rat *Rattus fuscipes* in a pipe underpass were removed from the tally. Four species were photographed entering and/or exiting all monitored underpasses: the Common Wombat, Black Wallaby, European Rabbit *Oryctolagus cuniculus* and Cat *Felis catus*. Each of these four species were more frequently photographed using the box culvert compared to the round pipe underpasses.

Activity of most fauna species observed was higher in the forest than at the underpasses. Almost all species were recorded in the forest at generally equal frequencies both on the east and west of the Pipeline Vehicle Maintenance Track, suggesting that the track does not form a significant barrier to movement of these species. A total of just 204 independent 'use of underpass' events were recorded during the 12 month study, a relatively low number when compared with other studies assessing use of road underpasses by bandicoots. In addition, there was a much higher rate of usage of the verge of the track in the vicinity of the culverts, compared to individuals going through the culverts. It is likely that most species, including the Long-nosed Bandicoot, would readily cross the narrow track without the aid of underpass structures, and the hence the underpasses are providing little benefit.

1 Introduction

Barriers to wildlife movement are recognised as threats to many wildlife populations, including threatened species (e.g. Heard et al. 2015). Consequently, crossing structures such as over- and underpasses are increasingly being installed with the intention of facilitating the movement of wildlife, maintaining the 'permeability' of the pre-barrier landscape, and mitigating the negative effects of barriers (Taylor 2010). However, a recurrent issue with crossing structures is that, while many studies report the use of structures by wildlife, too few studies report on the *effectiveness* of these structures. Use does not equate to effectiveness (van der Grift et al. 2013).

Several studies have shown that bandicoots (*Isoodon* and *Perameles* spp.) will use underpasses beneath barriers such as roads (Taylor and Goldingay 2003; Bond and Jones 2008; Hayes and Goldingay 2009; Harris et al. 2010; Taylor and Goldingay 2014; Chambers and Bencini 2015). While underpasses can facilitate safe passage of bandicoots under roads (Taylor and Goldingay 2003), underpasses may be avoided by bandicoots if the roads are (or become) too wide (Taylor and Goldingay 2014), and they may contribute to declines of bandicoots if introduced predators, such as the Red Fox *Vulpes vulpes*, use the underpasses for movement or are attracted to the area to prey on bandicoots (Harris et al. 2010).

A linear strip of native vegetation in the Toolangi State Forest, approximately 50 km north-east of Melbourne, was cleared during construction of the Sugarloaf Pipeline, which was completed in 2010. To provide access to the pipeline for ongoing maintenance, a 'Pipeline Vehicle Maintenance Track' was also constructed within this cleared strip. With the aim of mitigating the impact of this cleared strip, several culverts were constructed underneath the access track in drainage lines to facilitate the movement of wildlife, especially bandicoots from one side of the track to the other.

There are historic records of bandicoots in the area, with the Long-nosed Bandicoot *Perameles nasuta* the species most likely to occur in the area(Fig. 1; Victorian Biodiversity Atlas). Within western Victoria, the Long-nosed Bandicoot occurs to the west of and within the Otway Ranges, and in eastern Victoria from the northern fall of the Great Dividing Range to the eastern tip of the State (Fig. 1), typically in high rainfall areas (Menkhorst and Seebeck 1996a). In much of their range they occur at low densities and "are restricted to wetter and more fertile sites such as those along streams" (Menkhorst and Seebeck 1996a: 77). Menkhorst and Seebeck (1996a: 77) describe the habitat of the Long-nosed Bandicoot as "damp areas with patchy, dense ground or shrub cover within vegetation formations ranging from rainforest through wet forest and grassland. They are common in riparian vegetation such as fern or Blackberry thickets on river and creek flats in the ranges, and in forests or woodlands where the understorey is dense heath." The habitat along the Pipeline Vehicle Maintenance Track accords well with this description.

The study area is slightly beyond the known range of another bandicoot species, the Southern Brown Bandicoot *Isoodon obesulus obesulus* (Fig. 1), which tends to occur in drier vegetation communities with well-drained soils (Menkhorst and Seebeck 1996b), and has a more coastal distribution. This species is thus unlikely to occur in the immediate study area.

The objective of this project was to evaluate the suitability of specific culverts for use as underpasses by bandicoots. Because of the methods used, we are also able to report on the occurrence of and underpass use by a range of other fauna.

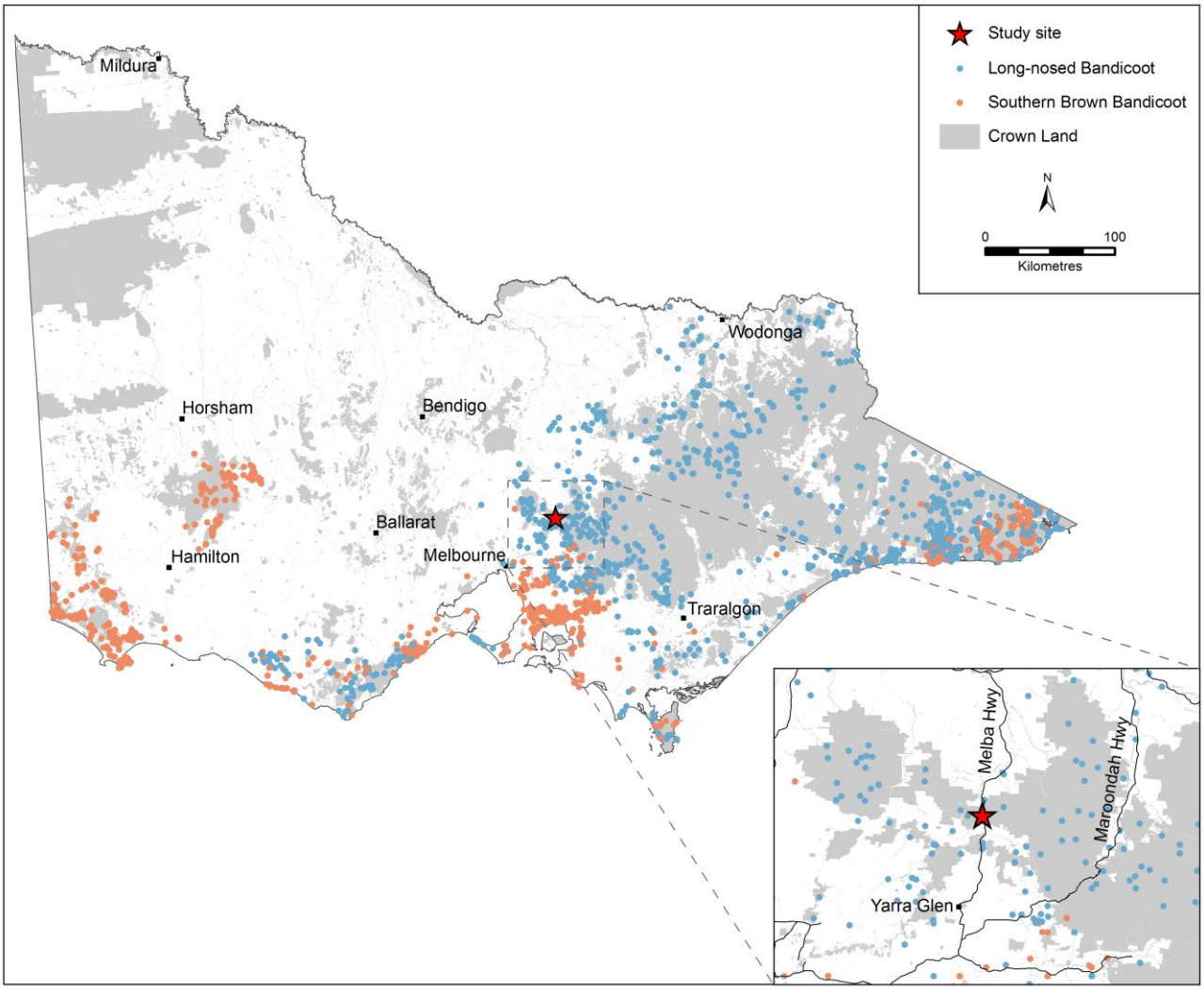

Figure 1. Records of the Long-nosed Bandicoot *Perameles nasuta* and the Southern Brown Bandicoot *Isoodon obesulus obesulus* in Victoria (source: DELWP Victorian Biodiversity Atlas). The red star denotes the location of the current study.

2 Methods

Four underpasses were monitored beneath the north–south orientated Pipeline Vehicle Maintenance Track (Fig. 2). Three of these underpasses consisted of paired 600 mm diameter concrete pipes (Fig. 3), and one consisted of a square-section concrete culvert ('box culvert', Fig. 4, Table 1). The track constitutes an unvegetated strip of bare ground approximately five metres wide; in the intervening five years since construction some low vegetation has naturally regenerated on the track verges. The underpasses were also approximately five metres in length (Fig. 3, 4). The vegetation community present in the vicinity of the track is Herb-Rich Foothill Forest in the southern portion of the study area and Damp Forest in the northern portion (DSE 2009).

We deployed heat-and-motion remote cameras (Reconyx HC600 Hyperfire HO Covert IR) at both the east and west entrances to each underpass (i.e. one camera at each side of each underpass). At a distance of approximately 50 m from each end of the underpass, we deployed a camera in the forest, such that for each monitored underpass four cameras were used—two at the underpass entrances, and two approximately 50 m into the forest on either side of the track. Coordinates for each underpass and for the eight forest cameras are presented in Table 1.

The cameras at either end of the underpasses were set to record use of the underpasses by vertebrate fauna. These cameras were not accompanied by an attractant 'bait station' so as not to artificially draw animals in to the underpasses. The cameras set approximately 50 m from the underpasses were intended to record fauna in the adjacent forest, to indicate the fauna species that were present in the general area. Each of these cameras was augmented by a bait station (consisting of a bait holder constructed of white PVC pipe and wire mesh, secured to the ground using a tent peg). The bait consisted of rolled oats mixed with peanut butter and honey, with a few drops of truffle oil added. Bait stations were located approximately three metres from the camera, and the vegetation between the camera and the bait station was removed to permit clear photographs of animals and to minimise triggering of the cameras by movement of vegetation. The cameras in the forest were either attached to the trunks of trees or mounted on stakes. The cameras at the entrances to the underpasses were mounted on stakes and draped in camouflage material in order to make them less conspicuous to people using the vehicle track. Camera settings were: high sensitivity; no delay (i.e. no 'sleep' time between detections); rapid fire (i.e. each detection resulted in five images being taken with less than one second between images); five consecutive pictures taken to provide different angles in order to aid in species identification.

We deployed the cameras on 28 April 2015 and subsequently changed batteries and memory cards on three occasions: 26 May 2015, 12 August 2015 and 2 February 2016. The cameras were retrieved on 20 April 2016. The initial survey period prior to the first change of batteries and memory cards was shorter (around 1 month, *c.f.* several months for subsequent periods) to check the cameras were operating as anticipated.

Each time we retrieved the memory cards, we downloaded the recorded images for analysis. For each series of photographs from each camera we constructed a list of the species that were photographed, taking particular note of any bandicoots and any use of the underpasses by fauna. Images of fauna were flagged as 'using underpass' when the animal entered or exited an underpass, or was photographed entirely inside an underpass. We used an arbitrary period of 10 minutes between images of particular species at either end of underpasses to label use of the underpass as independent in order to estimate the number of 'use events' at each underpass (reasoning that images of the same species in an underpass, or entering one end and exiting the other end, captured < 10 minutes apart could be the same individual making a single trip through the underpass).

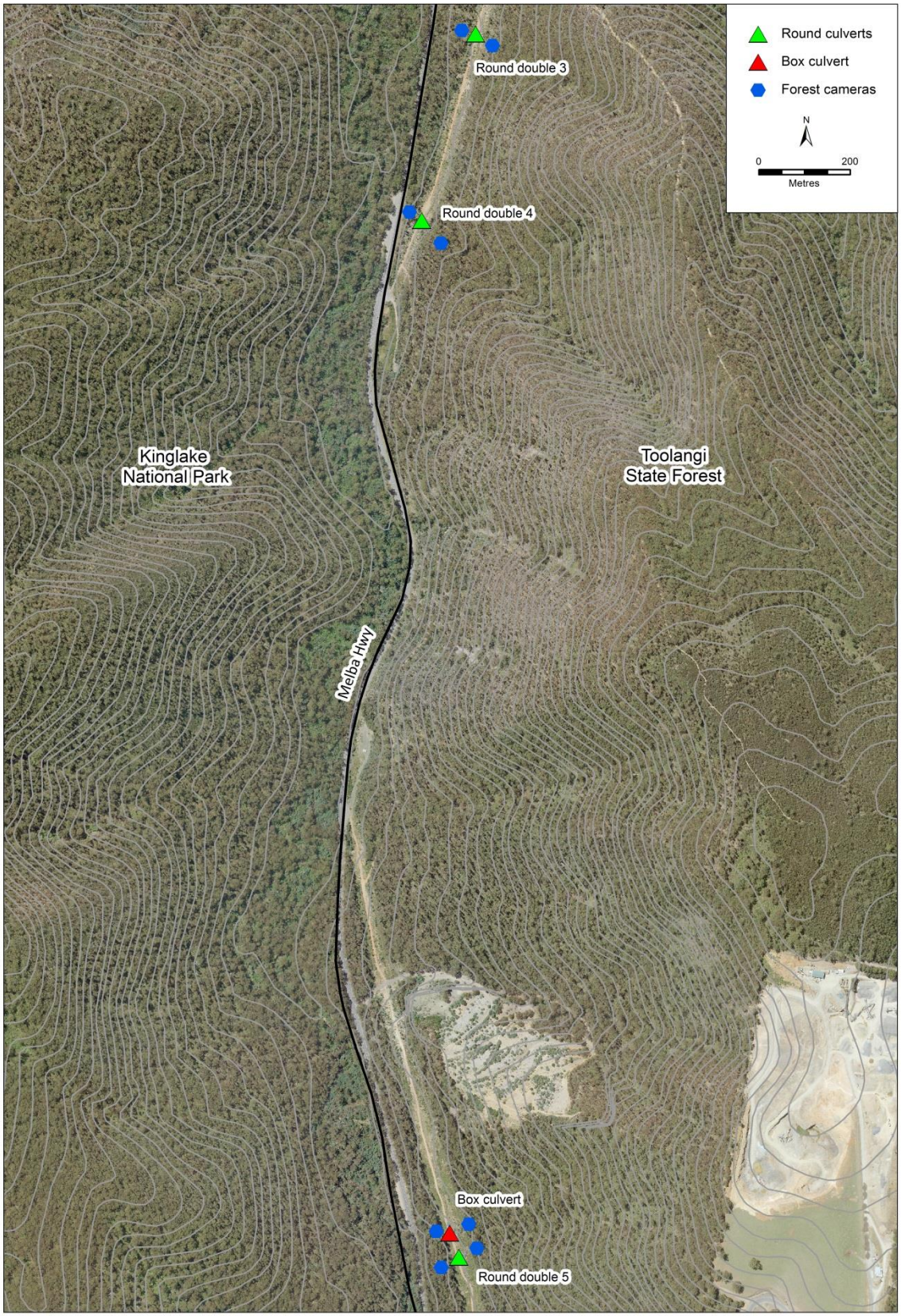

Figure 2. Location of underpasses (triangles) and forest cameras (blue hexagons) along the Pipeline Vehicle Maintenance Track (dirt track just east of the Melba Highway) in Toolangi State Forest.

Figure 3. Dual round 'underpass' under the Pipeline Vehicle Maintenance Track, Toolangi State Forest.

Figure 4. Box culvert under the Pipeline Vehicle Maintenance Track, Toolangi State Forest.

Table 1. Details of fauna survey cameras located along the Pipeline Vehicle Maintenance Track in Toolangi State Forest.

Datum for coordinates is GDA94, zone 55H. Culvert cameras were located at the culvert openings either side of the track; for each culvert there is a single set of coordinates because the distance separating the cameras on either side of a culvert is close to the resolution of the GPS unit used to record the coordinates.

Underpass name	Camera	Easting	Northing
Round Double 3	Culvert (x2)	360387	5851580
Round Double 3	Forest east	360424	5851555
Round Double 3	Forest west	360357	5851588
Round Double 4	Culvert (x2)	360269	5851171
Round Double 4	Forest east	360311	5851122
Round Double 4	Forest west	360242	5851190
Round Double 5	Culvert (x2)	360350	5848900
Round Double 5	Forest east	360390	5848920
Round Double 5	Forest west	360312	5848878
Box Culvert	Culvert (x2)	360330	5848953
Box Culvert	Forest east	360372	5848973
Box Culvert	Forest west	360301	5848957

3 Results

Collectively, 171,506 images were taken by the cameras. Two cameras positioned near underpass 'Round Double 4' were stolen some time after the first camera check on 26 May 2015 and before the second check on 12 August 2015, which meant that only one month of survey data was collected from this camera pair, and no fauna were detected using the underpasses on these cameras during that month. A total of 31 vertebrate species were detected, including nine species of native mammals, five species of introduced mammals, 14 species of birds, two species of reptiles and one frog (Table 2). The only frog detected by the cameras was a Pobblebonk *Limnodynastes dumerilii* being dragged by an Agile Antechinus *Antechinus agilis*. The Appendix contains sample images of some of the species recorded.

The number of images collected per species varied widely, and some species were only detected by cameras in the forest and not by cameras at the underpasses, such as a Dunnart *Sminthopsis* sp., Mountain Brushtail Possums *Trichosurus cunninghami* and several bird species (Table 3). Commonly photographed species included the Black Wallaby *Wallabia bicolor* (Figure 5), Common Wombat *Vombatus ursinus* (Figure 6), Red Fox and European Rabbit *Oryctolagus cuniculus*. Table 3 shows the total number of images for each species taken by the cameras in the forest and those facing the underpasses. As the cameras were set to take five images each time they were triggered, the number of trigger events will be less than one fifth of the number of images outlined in Table 3. More images were collected by the baited cameras set in the forest (av. 7569 per camera) compared to the unbaited cameras set on the edge of the cleared area at the round underpasses (av 4335 per camera). In contrast, even though the cameras at the box culvert were not baited, more images were taken at the cameras set either end of the box culvert (av. 6058 per camera) compared to in the forest (av. 3087 per camera). It is not clear what might be influencing this result. While there were a large number of images collected from the cameras at the entrances to the culverts, only a small proportion of these were of animals actually entering the culverts (see below).

Patterns of detection rates in the forest versus at the entrances to the underpasses were variable and species-dependent. Black Wallabies were among the more frequently photographed species by the underpass cameras, but were even more frequently photographed in the forest (Table 3). The same was true for Bush Rats *Rattus fuscipes*, with the exception of the box culvert where they were photographed more often than by the forest cameras 50 m to the east and west. Images of rabbits were relatively common at the underpass cameras compared to the forest cameras, and foxes were generally detected more often by forest cameras than by cameras at underpasses (Table 3).

No Southern Brown Bandicoots were detected on any cameras during the study. Long-nosed Bandicoots were detected at six out of eight forest cameras, and at the entrances to two of the underpasses (Table 3, Figures 7 and 8). While detected by a camera at the western end of the 'Round Double 5' underpass on two consecutive nights in March 2016 (resulting in 17 images; Table 3), the species was not observed to enter this underpass, nor exit at the other end. Long-nosed Bandicoots were detected in the vicinity of the entrances to the box culvert (533 images) but were only observed to actually enter the box culvert on two occasions (Table 4): at 9:58 pm on 22 June 2015, and at 2:46 am on 20 March 2016.

In general, while there were a large number of images from cameras set facing the culverts (Table 3), the majority of these images were of animals passing by the entrances, rather than entering the underpasses. There were just 204 independent observations of use of the three underpasses that were monitored for the full 12 month duration of the study (Table 4). This equates to an average of one animal using an underpass once every five days. Thirteen species were observed to use underpasses, and were photographed entering, exiting or entirely within the culverts, comprising six species of native mammals, four species of introduced mammals, two bird species and one reptile species(Table 4). Animals would often enter an underpass and then exit at the same end, rather than using the underpass to travel from one side of the Pipeline Vehicle Maintenance Track to the other.

The Round Double 5 culvert recorded the largest number of independent use events, however this was largely due to a presumed single Bush Rat entering and exiting the eastern end of this culvert on many occasions between May and October 2015. Removing this Bush Rat's 66 use events from the total for this culvert reveals that the box culvert was used much more frequently than the round pipe culverts. The box culvert was used nine times more than the Round Double 3 culvert, and more than twice as often as the Round Double 5 culvert (when the Bush Rat use is omitted; Table 4). Because there was only a single box culvert underpass, we cannot test for statistical significance in the differences in outright numbers of animals, or of species, using the box culvert versus the round underpasses. However, a wider range of species used the box culvert, compared to the round pipe culverts. Exceptions included the House Mouse and Agile Antechinus that were recorded in a round underpass, but not in the box culvert. Long-nosed Bandicoot, Grey Shrike-thrush, Common Bronzewing and Black Rock Skink were recorded in the box culvert, but not in the round underpasses (Table 4).

The introduced predators, Red Foxes and Cats (Figures 9 and 10) also used the culverts, but at a low rate with 10 observed use events for each species (Table 4). Both species, however, spent more time at the entrances to the culverts than going through them, especially the box culvert (Table 3). One image showed evidence of a fox taking a small mammal at the box culvert (Figure 11).

Table 2. Fauna recorded on survey cameras located along and beside the Pipeline Vehicle Maintenance Track, Toolangi State Forest, during this study.

Common name	Scientific name
Mammals	
Short-beaked Echidna	*Tachyglossus aculeatus*
Agile Antechinus	*Antechinus agilis*
Dusky Antechinus	*Antechinus swainsonii*
Long-nosed Bandicoot	*Perameles nasuta*
Dunnart sp.	*Sminthopsis* sp.
Mountain Brushtail Possum	*Trichosurus cunninghami*
Common Wombat	*Vombatus ursinus*
Black Wallaby	*Wallabia bicolor*
Bush Rat	*Rattus fuscipes*
House Mouse*	*Mus musculus*
Red Fox*	*Vulpes vulpes*
Cat*	*Felis catus*
European Rabbit*	*Oryctolagus cuniculus*
Sambar Deer*	*Rusa unicolor*
Birds	
Yellow-faced Honeyeater	*Caligavis chrysops*
New Holland Honeyeater	*Phylidonyris novaehollandiae*
Spotted Quail-thrush	*Cinclosoma punctatum*
Grey Shrike-thrush	*Colluricincla harmonica*
Bassian Thrush	*Zoothera lunulata*
Eastern Yellow Robin	*Eopsaltria australis*
Superb Fairy-wren	*Malurus cyaneus*
White-browed Scrubwren	*Sericornis frontalis*
Red-browed Finch	*Neochmia temporalis*
Superb Lyrebird	*Menura novaehollandiae*
Laughing Kookaburra	*Dacelo novaeguineae*
Common Bronzewing	*Phaps chalcoptera*
Crimson Rosella	*Platycercus elegans*
Grey Currawong	*Strepera versicolor*
Reptiles	
Black Rock Skink	*Egernia saxatilis intermedia*
Blotched Blue-tongued Lizard	*Tiliqua nigrolutea*
Frogs	
Pobblebonk	*Limnodynastes dumerilii*

Table 3. Numbers of images collected of each fauna species detected by the cameras set facing the underpasses and in the forest along the Pipeline Vehicle Maintenance Track.

Numbers indicate the total number of images collected, with up to five images per camera trigger event. 'Culvert' columns are tallied images on cameras at either end of each culvert, and do not reflect independent use events (see Table 4). Note that only forest cameras were baited. ^Cameras at this culvert stolen after one month, whereas the two adjacent forest cameras operated for 12 months. *Introduced species.

Species Common Name	RndDbl3 Forest west	RndDbl3 culvert	RndDbl3 Forest east	RndDbl4 Forest west	RndDb4 culvert^	RndDbl4 Forest east	RndDbl5 Forest west	RndDbl5 culvert	RndDbl5 Forest east	Box Forest west	Box culvert	Box Forest east	Total
Mammals													
Short-beaked Echidna	37	15	77	190		83	175	71	95	28	376	40	**1,187**
Agile Antechinus	32	3	189	306	5	130	22	51	20	15	60		**833**
Dusky Antechinus				211		30			25		17		**283**
Long-nosed Bandicoot	1			3			118	17	430	485	533	63	**1,650**
Dunnart sp.			11										**11**
Mountain Brushtail Possum			3									15	**18**
Common Wombat	1,293	564	439	223		1,893	652	1,910	1,019	262	2,321	829	**11,405**
Black Wallaby	6,015	575	3,451	3,478	206	6,529	4,665	2,048	4,155	371	4,759	1,612	**37,864**
Bush Rat	70		179	468		642	1,322	592	336	1,087	1,205	228	**6,129**
House Mouse*		3		150				81		5	74		**313**
Red Fox*	820	96	413	149		361	57	20	221	623	611	109	**3,480**
Cat*		29	64	2,680	32		20	30	35	7	194	65	**3,156**
European Rabbit*	503	1,045	1,256	19		744		953	59		1,512	55	**6,146**
Sambar Deer*	50		24	60		122	160		761	5		100	**1,282**
Unidentified mammal	23	21	40	18	3	61	23	58	75	1	149	79	**551**
Unidentified small mammal	17	3	31	49	4	9	5	36	78	20	32	5	**289**
Birds													
Yellow-faced Honeyeater				2									**2**
New Holland Honeyeater								45					**45**
Spotted Quail-Thrush		5											**5**

Species Common Name	RndDbl3 Forest west	RndDbl3 culvert	RndDbl3 Forest east	RndDbl4 Forest west	RndDb4 culvert^	RndDbl4 Forest east	RndDbl5 Forest west	RndDbl5 culvert	RndDbl5 Forest east	Box Forest west	Box culvert	Box Forest east	Total
Grey Shrike-thrush	5		6	25		4	5	85	60		129		**319**
Bassian Thrush									10				**10**
Eastern Yellow Robin				5									**5**
Superb Fairy-wren	5	23	37	175	5	10	19	74	10	8	37	5	**408**
White-browed Scrubwren	13		5	20		5		139	20	20	15		**237**
Red-browed Finch											5		**5**
Superb Lyrebird									388		8	5	**401**
Laughing Kookaburra	9												**9**
Common Bronzewing									11	21	21		**53**
Crimson Rosella		5			13			5	12		5		**40**
Grey Currawong		15	25	35		5					20		**100**
Unidentified bird	17	4	5	19		20		38	46	5	28		**182**
Reptiles													
Black Rock Skink								5			4		**9**
Blotched Blue-tongue lizard								5					**5**
Total	**8,910**	**2,406**	**6,255**	**8,285**	**268**	**10,648**	**7,243**	**6,263**	**7,866**	**2,963**	**12,115**	**3,210**	**76,432**

Table 4. Fauna species that entered underpasses along the Pipeline Vehicle Maintenance Track. Numbers indicate the number of independent use events at an underpass by each species. *Introduced species. Round Double 4 culvert not shown as no use events were observed during the one month of available data.

Common Name	RndDbl3 culvert	RndDbl5 culvert	Box culvert	Total
Short-beaked Echidna		1	7	**8**
Agile Antechinus		2		**2**
Long-nosed Bandicoot			2	**2**
Common Wombat	4	11	26	**41**
Black Wallaby	1	4	18	**23**
Bush Rat		66	4	**70**
House Mouse*		5		**5**
Red Fox*	1		9	**10**
Cat*	2	3	5	**10**
European Rabbit*	2	12	15	**29**
Grey Shrike-thrush			2	**2**
Common Bronzewing			1	**1**
Black Rock Skink			1	**1**
Total	**10**	**104**	**90**	**204**

Figure 5. Black wallaby using one of the round pipe culverts.

Figure 6. Common Wombat travelling through the box culvert underpass.

Figure 7. Long-nosed Bandicoot in the box culvert underpass.

Figure 8. Long-nosed Bandicoot in the forest 50 m west of the box culvert underpass.

Figure 9. Red Fox exiting the box culvert underpass.

Figure 10. Cat entering the box culvert underpass.

Figure 11. A Red Fox taking a small mammal at the box culvert underpass.

4 Discussion

Thirteen vertebrate fauna species were recorded using the underpasses beneath the Pipeline Vehicle Maintenance Track during this study, including Long-nosed Bandicoots. No Southern Brown Bandicoots were recorded at any cameras during this study. Although the reasonably large number of images of bandicoots on the cameras at the entrances to the culverts and in the surrounding forest, indicated there was ample opportunity for animals to use the culverts to cross the track, there were only two occasions in the 12 month study that Long-nosed Bandicoots were recorded travelling through the culverts. Thus it does not appear that the underpasses are regularly used to facilitate movement of bandicoots from one side of the Pipeline Vehicle Maintenance Track to the other.

Overall, there were few observations of fauna species entering culverts over the 12 month study period with only 204 observations of culvert use (Table 4). Actual 'through culvert' traverses by animals were even less frequent than the 'use of culvert' occasions detailed in Table 4, with not all animals travelling all the way through an underpass. While the figures on the use of culverts (Table 4) are not directly comparable to the number of images shown in Table 3, as multiple photographs were taken from each trigger event, the scale of the differences is still apparent. For example, the Black Wallaby entered the underpasses only infrequently (23 independent use events, Table 4) compared with the number of images collected of this species at the underpass entrances (7,588 images collected across all underpass cameras, Table 3). Often animals appeared to be photographed while foraging within the vicinity of the entrance rather than interacting with the structure at all. In addition, many of the independent 'use of culvert' events reported in Table 4 were of animals seemingly investigating the culvert itself rather than using it to travel between forest habitat on either side of the track. Many species entered and exited the same end of a culvert without travelling all the way through; Black Wallabies occasionally used the box culvert as a shelter site on hot days, and a Bush Rat may have been using the eastern end of the Round Double 5 culvert as a shelter or feeding site.

Aside from the Bush Rat that habitually used one end of a round pipe culvert, the box culvert was used more frequently, and by more species, than the round underpasses (Table 4). Larger native mammal species such as the Common Wombat and Black Wallaby appeared to more readily enter the box culvert than the round culvert. Foxes and Cats were recorded at the box culvert more often than the round culverts, although records of these species entering into the underpasses were low (Table 4) relative to activity in front of the entrance or in the surrounding forest (Table 3). The box culvert was also the only underpass to be entered by Long-nosed Bandicoots, albeit only on two occasions. Greater use of the box culvert relative to the round underpasses may be due to the larger size of this culvert, or possibly because of the flat-bottomed shape of the structure. Underpass length was found to be negatively correlated with the frequency of underpass crossing by Southern Brown Bandicoots in Western Australia (Chambers and Bencini 2015), although the minimum underpass length in that study was 23 m and hundreds of underpass crossing events by bandicoots were observed. The length of all underpasses in the current study was approximately 5 m. Cross-sectional area of an underpass was not found by Chambers and Bencini (2015) to affect the frequency of use by Southern Brown Bandicoots. The quite narrow (*ca*. 5 m wide), infrequently used Pipeline Vehicle Maintenance Track in the current study is unlikely to be presenting enough of a barrier to movement for species such as bandicoots that they are seeking out the underpasses to facilitate crossing.

If the Pipeline Vehicle Maintenance Track was a significant barrier to movement, it would be expected that species activity would be lower to the west of the track in the narrow strip of forest between the track and the Melba Highway, which is likely to form more of a barrier, than in the continuous forest to the east of the track. However, the number of images captured of fauna species by cameras set in the forest on either side of the track generally show comparable levels of activity (Table 3), also suggesting that it does not form a major barrier for wildlife movement.

While there is no data on which species and how often animals may have crossed the track on the surface, because it is a narrow (*ca*. 5 m wide), single-vehicle forest track, it is probable that bandicoots and other species cross the track without using the underpasses. A recent telemetry study (Macak and Menkhorst 2016) showed that the small, native Smoky Mouse *Pseudomys fumeus* would cross a 30 m fire break in eucalypt forest in Victoria, demonstrating the ability of small mammals to cross much larger clearings. The propensity of these species to cross the track is likely to increase as the revegetation of the linear area cleared for the installation of the pipeline continues to mature, because this will provide increasingly dense cover close to the edge of the track, an important refuge for small and medium-sized mammals from predators (Chambers and Dickman 2002).

The main predators of bandicoots are the Red Fox and Cats (Coates and Wright 2003, Brown and Main 2010). It is plausible that underpasses such as these may become focal areas for predation by these introduced predators (Harris et al. 2010). While Little et al. (2002) concluded that there was scant evidence to differentiate between wildlife passages being actual 'prey-traps' versus sites of infrequent opportunistic predation, Harris et al. (2010) recorded dramatic declines in the use of underpasses by bandicoots once foxes began using the same underpasses. Thus, either via direct predation or because the presence of foxes repelled bandicoots, it is probable that in the area studied by Harris et al.(2010), introduced predators negated any benefits to the bandicoots of the underpasses. Some evidence (disappearance of Passive Integrated Transponder-tagged bandicoots, failure to recapture individuals, presence of foxes) suggested that the decline in bandicoot use of the underpasses studied by Harris et al. (2010) was directly due to predation by foxes. 'Critical-weight-range mammals' (mammals in the weight range 35 g to 5.5 kg), are most susceptible to decline and extinction in Australia (Burbidge and McKenzie 1989). Harris et al. (2010) note that Australian critical-weight-range mammals have not co-evolved with introduced predators, so any scent left by the predators may not be enough to deter native species from using underpasses. Predators such as foxes and cats may also learn that underpasses are productive foraging areas. It is difficult to determine if the underpasses under the Pipeline Vehicle Maintenance track may be used by foxes and cats as a 'prey-trap' for bandicoots. However, it appears that neither bandicoots nor foxes and cats frequently use of the culverts beneath the track, however all three species spent time at the entrances to the underpasses, especially the box culvert. While there was an observation of a fox taking a small mammal at the entrance to the box culvert, the relative rate of predation at the culverts and in the surrounding forest is unknown.

Conclusions

The results of this study demonstrate the occurrence of Long-nosed Bandicoots on both sides of the Pipeline Vehicle Maintenance Track, but that this species rarely enters the underpasses. It is probable that Long-nosed Bandicoots will cross the track away from or in the absence of the underpasses, particularly now that the vegetation is recovering in the areas disturbed during the installation of the Pipeline in 2010.

Other species observed during the study are also likely to cross the track without the aid of the underpasses, e.g. Black Wallaby, Common Wombat and Short-beaked Echidna. The benefit of road underpasses is maximised where the barrier created by the road is either wide and perceived to be impassable by fauna, or where road traffic presents a mortality risk to animals that attempt to cross. In this case the Pipeline Vehicle Maintenance Track is unlikely to present a significant barrier to movement of bandicoots and other fauna, as it is narrow and infrequently used by vehicles. Although the rate of small mammals attempting to cross the track at the surface was not assessed, our results indicate that the underpass culverts are very infrequently used. Evidence of activity at cameras in the forest indicate that fauna species occur on both sides of the track, and are presumably crossing the track without the aid of the culvert underpasses.

This then raises the question of the value of retaining the underpasses, if they are rarely used and there is an unknown risk of increased predation. The underpasses may be necessary to allow water to pass freely along the drainage lines and under the Pipeline Vehicle Maintenance Track. If this is the case, one option may be to allow an aperture just large enough to permit adequate flow of water. The underpasses could be largely filled with a jumble of rocks that extends beyond the underpass and into surrounding vegetation,

allowing water flow and the passage of small vertebrates, while providing cover that minimises the risk from predators. Examples of such rock piles already occur at the entrances to some underpasses on the Pipeline Vehicle Maintenance Track (Fig. 12.). Alternatively, the underpasses could be left in place, but allow the vegetation to continue to regrowth near the edges of the track to provide additional cover.

Figure 12. Rock jumble at the entrance to an underpass (dual pipes) beneath the Pipeline Vehicle Maintenance Track, Toolangi State Forest.

References

Bond, A.R. and Jones, D.N. (2008). Temporal trends in use of fauna-friendly underpasses and overpasses. *Wildlife Research* **35(2)**, 103–112.

Brown, G.W. and Main, M.L. (2010) National Recovery Plan for the Southern Brown Bandicoot *Isoodon obesulus obesulus*. Draft for Comment June 2010. Department of Sustainability and Environment, Victoria.

Burbidge, A.A. and McKenzie, N.L. (1989). Patterns in the modern decline of Western Australia's vertebrate fauna: causes and conservation implications. *Biological Conservation* **50(1)**, 143–198.

Chambers, B. and Bencini, R. (2015). Factors affecting the use of fauna underpasses by bandicoots and bobtail lizards. *Animal Conservation* **18(5)**, 424–432.

Chambers, L.K. and Dickman, C. (2002) Habitat selection of the long-nosed bandicoot, *Perameles nasuta* (Mammalia, Peramelidae), in a patchy urban environment. Austral Ecology **23(3)**, 334–342.

Coates, T.D. and Wright, C.J. (2003). Predation of southern brown bandicoots *Isoodon obesulus* by the European red fox *Vulpes vulpes* in south-east Victoria. Australian Mammalogy **25,** 107-110.

Corlatti, L., Hacklander, K. and Frey-Roos, F. (2009). Ability of wildlife overpasses to provide connectivity and prevent genetic isolation. *Conservation Biology* **23(3)**, 548–556.

Department of Environment, Land, Water and Planning (DELWP). *Victorian Biodiversity Atlas*. DELWP. http://www.depi.vic.gov.au/environment-and-wildlife/biodiversity/victorian-biodiversity-atlas (accessed August 2016).

Department of Sustainability and Environment (DSE). EVC/Bioregion Benchmark for Vegetation Quality Assessment. Highlands – Northern Fall bioregion. http://www.dse.vic.gov.au/__data/assets/pdf_file/0008/241919/HNF_EVCs_combined.pdf (accessed October 2016).

Harris, I.M., Mills, H.R. and Bencini, R. (2010). Multiple individual southern brown bandicoots (*Isoodon obesulus fusciventer*) and foxes (*Vulpes vulpes*) use underpasses installed at a new highway in Perth, Western Australia. *Wildlife Research* **37(2)**, 127–133.

Hayes, I. and Goldingay, R.L. (2009). Use of fauna road-crossing structures in north-eastern New South Wales. *Australian Mammalogy* **31**, 89–95.

Heard, G.W., Thomas, C.D., Hodgson, J.A., Scroggie, M.P., Ramsey, D.S.L. and Clemann, N. (2015). Refugia and connectivity sustain amphibian metapopulations afflicted by disease. *Ecology Letters* **18(8)**, 853–863.

Little, S.J., Harcourt, R.G. and Clevenger, A.P. (2002). Do wildlife passages act as prey-traps? *Biological Conservation* **107**, 135–145.

Macak, P.V. and Menkhorst, P.W. (2016). Forest fire break not a barrier to movement for a threatened rodent, the smoky mouse, Pseudomys fumeus (Rodentia: Muridae). *Australian Mammalogy*. http://dx.doi.org/10.1071/AM15050

Menkhorst, P.W. and Seebeck, J.H. (1996a). Long-nosed Bandicoot *Perameles nasuta*. In: Menkhorst, P.W. (Ed.) *Mammals of Victoria: Distribution, Ecology and Conservation.* Oxford University Press, Melbourne, Victoria.

Menkhorst, P.W. and Seebeck, J.H. (1996b). Southern Brown Bandicoot *Isoodon obesulus*. In: Menkhorst, P.W. (Ed.) *Mammals of Victoria: Distribution, Ecology and Conservation.* Oxford University Press, Melbourne, Victoria.

Taylor, B.D. (2010). Use and effectiveness of engineered road crossing-structures for wildlife in eastern Australia. PhD thesis, Griffith University, Queensland.

Taylor, B.D. and Goldingay, R.L. (2003). Cutting the carnage: wildlife usage of road culverts in north-eastern New South Wales. *Wildlife Research* **30(5)**, 529–537.

Taylor, B.D. and Goldingay, R.L. (2014). Use of highway underpasses by bandicoots over a 7-year period that encompassed road widening. *Australian Mammalogy* **36(2)**, 178–183.

van der Grift, E.A., van der Ree, R., Fahrig, L., Findlay, S., Houlahan, J., Jaeger, J.A., Klar, N., Madrinan, L.F. and Olson, L. (2013). Evaluating the effectiveness of road mitigation measures. *Biodiversity and Conservation* **22(2)**, 425–448.

Appendix

Sample images of vertebrate fauna recorded on survey cameras at underpasses or in adjacent forest along the Pipeline Vehicle Maintenance Track, Toolangi State Forest

Blotched Blue-tongued Lizard *Tiliqua nigrolutea* in front of a round culvert.

Common Bronzewing *Phaps chalcoptera* in the surrounding forest.

Common Wombat *Vombatus ursinus* exiting the box culvert.

Short-beaked Echidna *Tachyglossus aculeatus* in a round culvert.

Short-beaked Echidna *Tachyglossus aculeatus* in the surrounding forest.

European Rabbit *Oryctolagus cuniculus* at the entrance to a round culvert.

Sambar Deer *Rusa unicolor* in the surrounding forest.

Black Wallaby *Wallabia bicolor* in the surrounding forest.

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