

# **Woolgoolga to Ballina Pacific Highway upgrade**

**Operation Phase Threatened Mammals  
Monitoring Program: Connectivity Structure  
and Road Mortality Monitoring,  
sections 1 to 11**

Annual Report 2020-21

Version 2.0



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# Woolgoolga to Ballina Pacific Highway Upgrade

Operation Phase Threatened  
Mammals Monitoring Program:  
Connectivity Structure and Road  
Mortality Monitoring sections 1 to  
11

Annual Report 2020-21

Sandpiper Ecological

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Alstonville  
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# 1. Introduction

## 1.1 Background

The Woolgoolga to Ballina (W2B) Pacific Highway Upgrade received State approval under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) on 24 June 2014 and Federal approval under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) on 14 August 2014. The Threatened Mammal Management Plan (TMMP) (Roads and Maritime Services, version 3.3, September 2017) was developed to meet the requirements of the NSW Government Approval (MCoA) D8 and Commonwealth EPBC Act Condition of Approval (CoA) 12.

The TMMP identified potential impacts of the upgrade on threatened mammal species listed under the EPBC Act and the NSW *Biodiversity Conservation Act 2016* (BC Act) which were considered to be directly impacted or at greatest risk of impact from the project. The TMMP proposed mitigation measures to be implemented to minimise impacts on threatened mammals and presented a program for monitoring the effectiveness of these measures.

Mammal species covered by the TMMP include:

- Brush-tailed phascogale (*Phascogale tapoatafa*)
- Long-nosed potoroo (*Potorous tridactylus*)
- Rufous bettong (*Aepyprymnus rufescens*)
- Spotted-tailed quoll (*Dasyurus maculatus maculatus*)

The TMMP collectively refers to these species as ‘threatened mammals’. Habitat requirements and distribution of the threatened mammals varies across the project area. Brush-tailed phascogale and rufous bettong broadly prefer dry, open sclerophyll forests and woodlands with a sparse understory and rufous bettong also inhabit areas of wet sclerophyll forest (Strahan 1995, RMS 2017). Long-nosed potoroo inhabit dry and wet sclerophyll forest but require areas of dense understory with occasional open areas (NSW Office of Environment and Heritage (OEH) 2017). Spotted-tailed quoll occurs across a broad range of habitats including open forest and woodland, rainforest and coastal heath (OEH 2018).

The TMMP proposed several mitigation measures aimed at ensuring the continued viability of threatened mammal populations in the project area. Those related to the current report include:

- Fauna Connectivity Strategy and mitigation measures including arboreal crossing structures, widened medians, dedicated underpasses and combined drainage/fauna crossing structures;
- Permanent fauna exclusion fencing;
- Establishment of a comprehensive monitoring program to assess the effectiveness of mitigation measures.

The aims of such measures are to:

- Minimise threatened mammal mortality due to vehicle strike in the project area;
- Provide functional crossing opportunities;
- Maintain connectivity for daily movements and gene flow.



To assess the effectiveness of the proposed mitigation measures, the TMMP details a comprehensive monitoring program. The components of the monitoring program include:

1. Threatened mammal population monitoring.
2. Fauna crossing structure monitoring.
3. Road mortality monitoring.
4. Nest box monitoring.
5. Habitat revegetation monitoring.

The following report addresses components 2 (fauna crossing structures) and 3 (road mortality) of the monitoring program. Components 1, 4 and 5 (population, nest boxes and habitat revegetation) are not part of the scope of this report.

### 1.1.1 Fauna crossing structure monitoring

The intention of the crossing structure monitoring program is to select a range of structures located within 5 km of population monitoring sites, including all dedicated fauna crossing structures within the home range and dispersal range of population monitoring sites. The TMMP directs that monitoring should focus on underpass structures for which there is little information about usage, such as combined structures greater than 60m long. As such, the selection process should focus on structures 60m or greater that occur within proximity of native vegetation and target populations. Combined structures located in cleared, disturbed or modified areas should be avoided (RMS 2017).

The goals of the fauna connectivity structures monitoring are:

1. Monitoring shows fauna crossing structure effective at facilitating the movements of threatened mammals.
2. Monitoring shows fauna exclusion fencing effective at reducing road mortality.

To determine the effectiveness of fauna crossing structures, Table 8-6 (and referred to in Table 7-3) of the TMMP outlined three performance indicators (1, 2, 3) and their respective corrective actions (a, b, ... etc.). They are as follows:

1. Monitoring surveys undertaken identify no evidence of use of designated connectivity structures by targeted threatened mammal species (including no potoroo recorded using underpasses near population monitoring sites 3A, 4A, 5A, 6A) after three consecutive monitoring periods (i.e. three years).
  - a. Review monitoring methods, considering increasing frequency, intensity and duration, to ensure individuals are identified.
  - b. Check connectivity structures for damage. Any structure found to be damaged during a maintenance check is to be repaired. Initiate repair works within 5 days of identification.
  - c. Investigate habitat adjoining the crossing. Consider improving habitat condition and connectivity.
  - d. Consider need for additional fauna furniture/retro-fitting existing structures. Where deemed appropriate, work will be completed within six months of identification.
  - e. Check fauna exclusion fencing – any fence found to be damaged during a maintenance check is to be repaired. Initiate repair works within five days of identification.
2. Relative population decline at the impact monitoring sites in proximity to the connectivity structure, compared to population density at control sites.

*(Refer to population monitoring report).*

3. High levels of structure usage (>25% increase) by exotic predators reported after the first monitoring period and each subsequent monitoring period (as clarified in Table 7-3).
  - a. Meet with regional pest control stakeholders as soon as practical and contribute to pest control program where reasonable and feasible.
  - b. Implement pest control program around crossing structures to reduce pest animal predation where deemed required.

After a minimum of three consecutive monitoring periods (i.e. three years), Transport for NSW (TfNSW) will evaluate if there is a residual impact to connectivity. Unless connectivity measures can be demonstrated to be effective at successfully mitigating the barrier and fragmentation impact to threatened mammal species, the residual impact to connectivity shall be offset.

Predator monitoring results will be reviewed after each subsequent monitoring period to review their presence and density. Results will guide discussions with relevant stakeholders and management programs at a regional scale. Ideally, targeted feral animal control would seek to link with existing programs undertaken by adjoining land owners/managers.

### **1.1.2 Road mortality monitoring**

Monitoring of threatened mammal mortality along the highway will be undertaken during the connectivity structure and population monitoring periods described in Table 8-4 (RMS 2017). Incidental observations recorded by TfNSW staff will also be collected. Road mortality monitoring is not proposed for the long-nosed potoroo, as it is not likely to contribute an acceptable amount of information to inform the monitoring program. However, incidental records of potoroo road mortalities will be recorded and reported.

The goal of road mortality monitoring is:

1. Zero mortality of threatened target mammal species at mitigation sites.

To determine the effectiveness of mitigation measures in eliminating threatened mammal road mortality, Table 8-7 of the TMMP outlines one performance indicator and several corrective actions (a, b, ... etc.). They are as follows:

1. A single reported road kill of a targeted threatened mammal species.
  - a. Check fauna exclusion fencing in proximity to road kill for any damage. Any fencing found to be damaged is to be repaired. Initiate repair works within 5 days of identification.
  - b. If road kill is found in an area of with no fauna exclusion fencing, evaluate the need for additional fencing.
  - c. If the road kill is found in proximity to a crossing structure, check structure for damage. Any structure found to be damaged during a maintenance check is to be repaired. Initiate repair works within five days of identification.
  - d. Review habitat adjoining the structure. Consider improving habitat condition and connectivity.
  - e. Re-evaluate mitigation measures if road mortality of threatened mammal species is observed over three monitoring periods.
  - f. Consider additional mitigation measures.

## 1.2 Scope

Sandpiper Ecological was engaged by Jacobs in January 2017 to undertake the crossing structure monitoring and road mortality monitoring components of the W2B threatened mammal monitoring program. The current annual report refers to the third year (i.e. Year 3) of operation phase monitoring activities in sections 1 and 2, and the first year (i.e. Year 1) for sections 3-11. Monitoring activities for sections 1 and 2 (sites M1-M10) were undertaken between May 2020 and March 2021. This period equates with Q2/Q3/Q4 2020 and Q1 2021. Due to the section 2a (Wells Crossing to Glenugie) upgrade the remaining section 1 and 2 sites (M11-M14) were monitored between January 2021 and July 2021. Section 3-11 sites (M15-M79) were also monitored between January 2021 and July 2021. This period equates with Q1-Q2 2021. It should be regarded as complementing results of threatened mammal population monitoring which is reported on elsewhere.

## 2. Methods

### 2.1 Study area

The study area includes sections 1-11 of the W2B Pacific Highway upgrade, between Woolgoolga and Pimlico and habitat within 100 m of the project alignment (Figures 1-7). Population monitoring, which is not the subject of this report, includes habitat up to 2 km beyond the project alignment to incorporate population survey sites (RMS 2017). Habitat within the study area broadly consists of dry sclerophyll forest, wet sclerophyll forest, floodplain forest and cleared land predominantly used for intensive agriculture (sugar cane). The study area is located within the north coast bioregion and experiences a largely sub-tropical climate (NSW NPWS 2003).

Monitoring sites were selected from a list of all pipe culverts, box culverts and bridges within sections 1-13. Bridges were excluded from sections 1 and 2 and were kept at a minimum for sections 3-11 as previous monitoring has shown that they are used by a range of fauna. A subset of potential monitoring sites was initially developed and each site was inspected to determine its suitability for monitoring. Priority was given to dedicated box culverts that were within 5km of population monitoring sites, sites within the dispersal range of target species from population monitoring sites, sites that provided a reasonable spatial distribution across the sample area, sites that had contiguous vegetation near both ends, and sites that are monitored as part of the W2B koala underpass monitoring program. A small number of pipe culverts were selected to address the issue of collecting information on structures for which there is limited data on fauna usage. Structures within 5km of potoroo population monitoring sites 3A, 4A, 5A and 6A were also assessed.

Monitoring was conducted at a total of 79 sites. This included the same 14 sites in sections 1 and 2 that were monitored during year one and two (Figure 1), consisting of 11 box culverts and three pipes – collectively referred to as underpasses (Plate 1). A further 65 sites were monitored in sections 3-11, including 38 box culverts, 17 bridges and 10 pipes (Figure 2-7). Underpasses were spatially spread where possible and ranged in length from 16-132m. All box culverts (excluding two sites) and 11 of 17 bridges featured post-and-rail furniture through their length. No furniture was included in pipes (Plate 1). Floor substrate included concrete, concrete and raised gravel path, and timber mulch on concrete.



**Plate 1:** The majority of monitored box culverts contained timber post-and-rail furniture and some featured mulch spread over the concrete floor (left). Pipes did not feature fauna furniture or mulch (right).

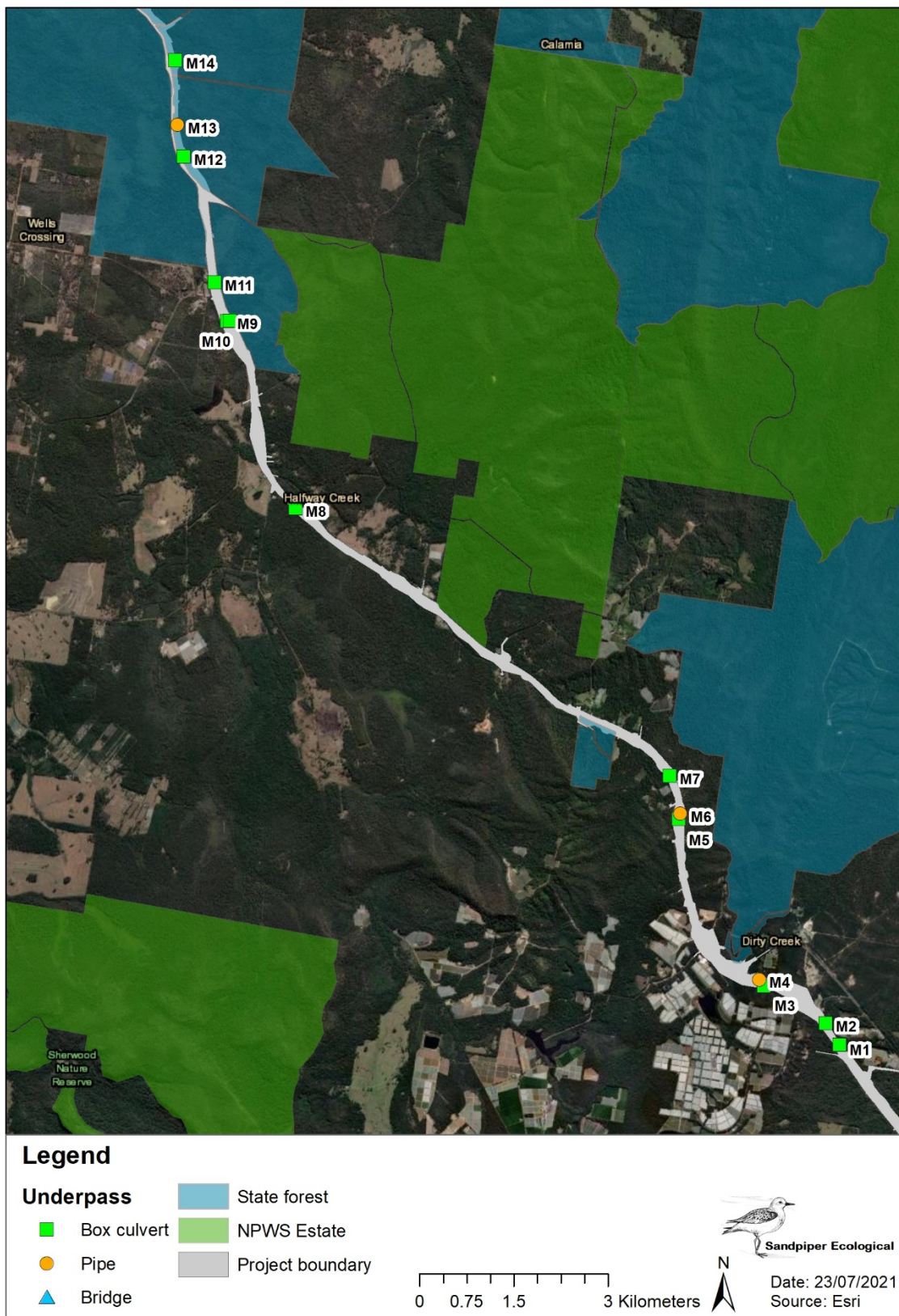


Figure 1: W2B threatened mammal underpass monitoring sites M1-M14.

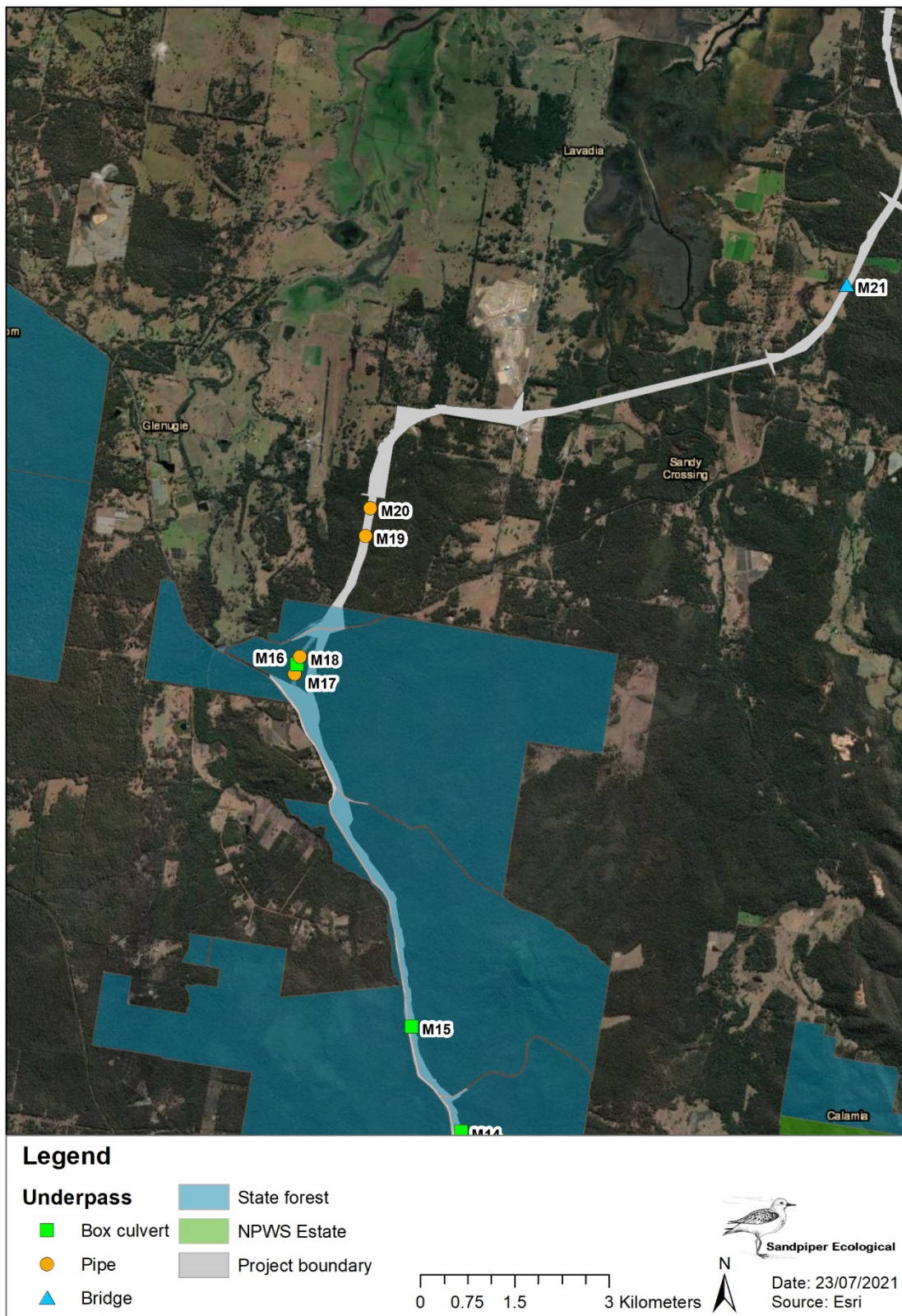


Figure 2: W2B threatened mammal underpass monitoring sites M15-M21.



Figure 3: W2B threatened mammal underpass monitoring sites M22-M25.

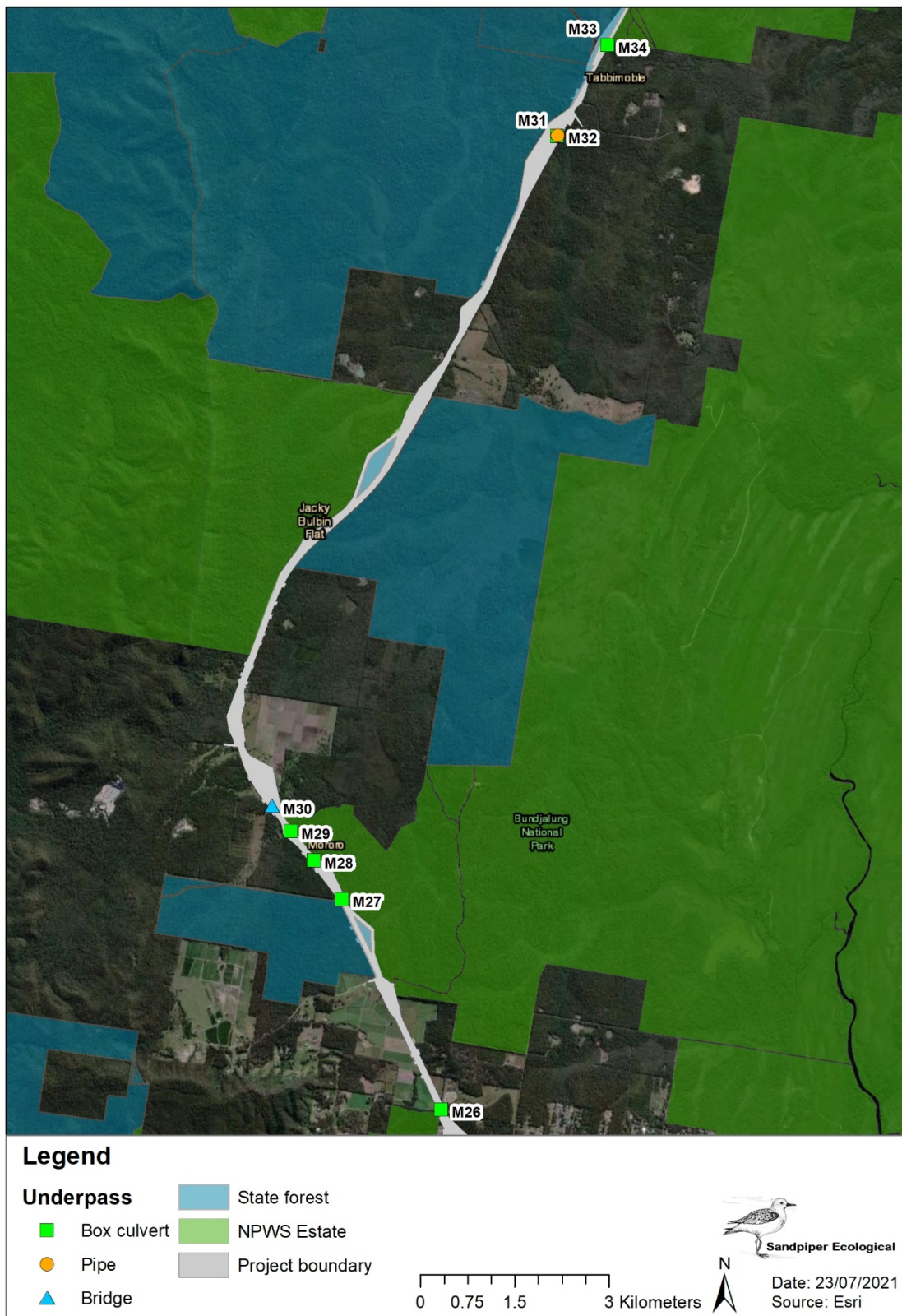


Figure 4: W2B threatened mammal underpass monitoring sites M26-M34.



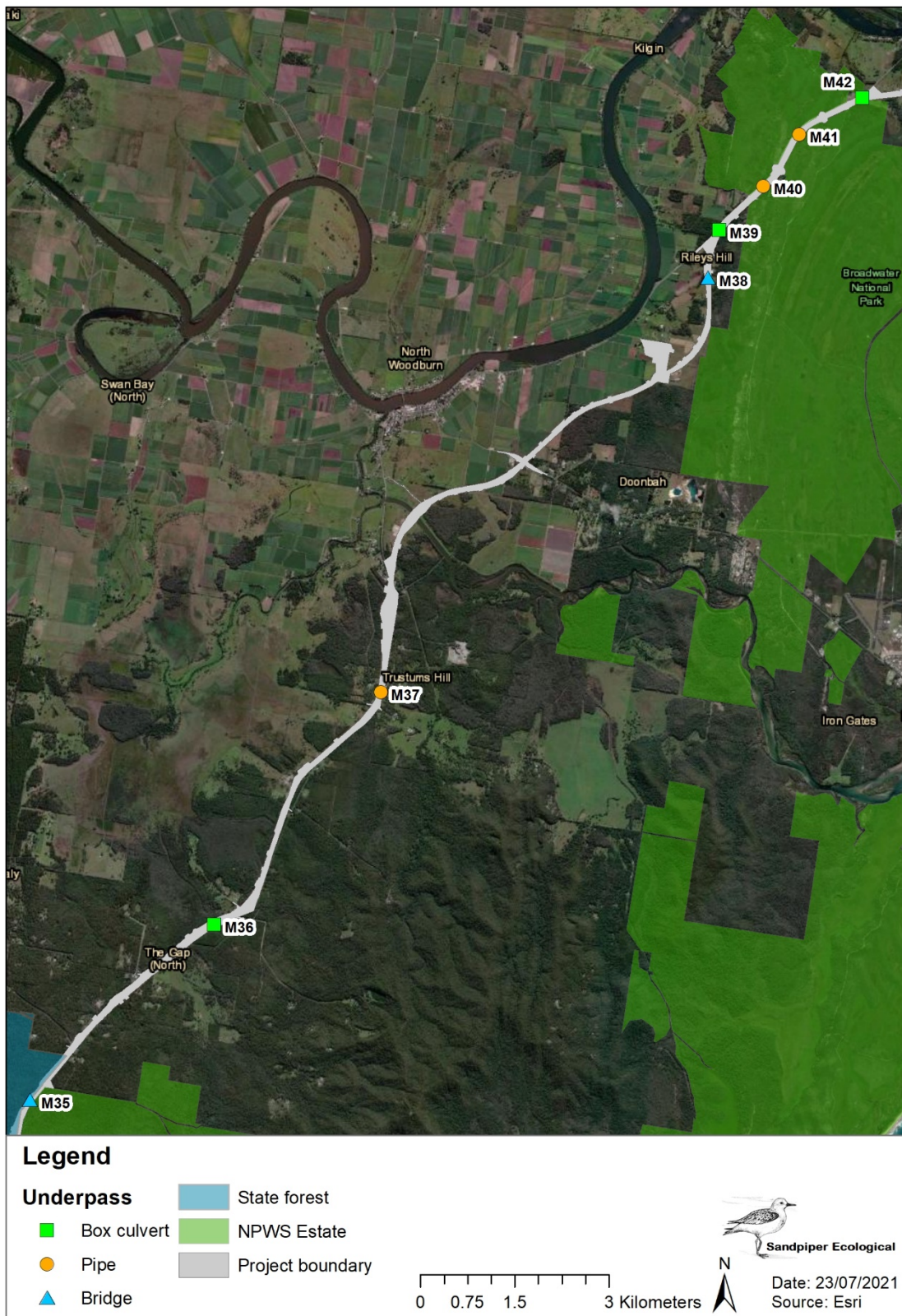


Figure 5: W2B threatened mammal underpass monitoring sites M35-M42.



Figure 6: W2B threatened mammal underpass monitoring sites M43-M64.



Figure 7: W2B threatened mammal underpass monitoring sites M65-M79.

## 2.2 Underpass monitoring

### 2.2.1 Camera traps

Underpasses were monitored with Swift 3C, Swift Enduro cameras or Scoutguards (*Outdoor Cameras Australia*) for two eight-week sessions during the 2020/2021 monitoring year. For culverts and bridges, two cameras were mounted on the central post of the post-and-rail furniture – one positioned to capture animals moving along the rail and the other positioned approximately 400mm above ground level to capture animals moving along the floor (Plate 2). Both cameras were oriented east. For culverts and bridges without post-and-rail furniture and pipes, a single camera was installed at the end of each structure and oriented inwards (Plate 2). All cameras were housed in security cases with padlocks.

Cameras in sites M1-M10 (S1&2) were installed on 4/5/2020 and retrieved between 8 - 9/7/2021 for the autumn/winter session. Cameras in sites M11-M14 (S1-2) were not sampled during this autumn/winter period due to the construction of section 2a, and instead were sampled with the S3-11 sites (sites M15-M79). These cameras were deployed between 5 - 6/5/2021 and retrieved between 8 - 15/7/2021. For the summer sampling period, cameras at all sites (M1-M79) were installed between 5 - 21/1/2021 and retrieved between 18 - 23/3/2021, except for site 38 which was retrieved on 16/4/2021 due to flooding. Cameras were set on high sensitivity and programmed to take 10 seconds of video on activation. They were scheduled to turn on at 1730hr and turn off at 0600hr. Cameras were inspected during the middle of each session to change batteries and SD cards. All but nine cameras were active for the full duration of monitoring during summer and seven during autumn/winter due to malfunction or battery fatigue (Table 1). An additional eight cameras were stolen during the autumn/winter period, and one site (two cameras) was inaccessible due to construction work.

Underpass camera monitoring targeting koalas was also undertaken during the period 12/10/2020 – 23/12/2020 at nine of the 11 threatened mammal box culverts (i.e. M1, 3, 5, 7, 8, 9, 10, 11 & 12) and at box culverts K3 (220m north of M4) and K6 (2170m south of M8). Any threatened mammals that were detected during koala monitoring are reported on separately in the results section.



**Plate 2:** Cameras were installed on the centre post within each box culvert – one viewing along the rail and the other along the floor (left). White core-flute sheeting was placed between the side wall and the post to direct fauna past the camera.

**Table 1:** Underpass camera monitoring effort during 2020/2021 operational phase monitoring. CSAC = cams stolen after check; CSBC = cams stolen before check; \* = single carriageway only; H = height (m); W = width (m); L = length (m)

Site no.	Chainage	Section	Underpass type & size (HxWxL)	No. of videos (Culv:floor/rail; Pipe: east/west)		Days active (Culv: floor/rail; Pipe: east/west)	
				Aut/win	Sum	Aut/win	Sum
M1	6890	1	Culvert (3x3x44)	62/88	15/18	65/59	13/21
M2	7280	1	Culvert (3x3x73)	9/185	91/40	66/66	60/65
M3	8470	1	Culvert (3x3x49)	9/88	72/67	66/66	72/72
M4	8580	1	Pipe (1.2 $\phi$ x95)	14/7	17/18	66/66	72/72
M5	11710	1	Culvert (3x3x54)	58/16	63/151	66/66	72/72
M6	11710	1	Pipe (1.05 $\phi$ x82)	11/66	21/117	66/66	72/72
M7	12420	1	Culvert (3x3x49)	11/4	113/30	65/65	72/72
M8	19880	2	Culvert (3x3x52)	8/7	134/47	65/65	72/72
M9	23110 (west)	2	Culvert (3x2.4x19*)	8/49	67/291	65/65	72/72
M10	23110 (east)	2	Culvert (3x2.4x16*)	19/19	39/195	65/65	72/72
M11	23750	2	Culvert (3x2.4x21*)	0/19	25/175	35/2	72/72
M12	25850	2	Culvert (3x3x26*)	87/60	51/61	63/63	72/72
M13	26380	2	Pipe (0.75 $\phi$ x31*)	255/35	145/29	65/63	72/72
M14	27420	2	Culvert (3.6x3.6x60)	4/85	9/9	63/63	24/72
M15	29300	WC2G	RCBC (2.4x2.4x25)	23/100	11/34	63/63	77/77
M16	35100	3	RCP (1.2x47)	28/37	14/121	63/63	68/68
M17	35270	3	RCBC (2.7x3x37)	6/35	9/689	63/63	76/76
M18	35380	3	RCP (1.2x53)	34/153	4/11	63/63	68/68
M19	37600	3	RCP (0.825x0.825x52)	90/88	29/32	63/63	64/64
M20	38100	3	RCP (0.9x47)	10/41	18/44	63/63	64/64
M21	47200	3	Bridge (22L)	25/8	49/865	63/63	64/64
M22	66200	3	RCBC (3.6x3.6x42)	15/98	76/115	63/63	64/64
M23	75510	4	RCBC (2.4x3.6x47)	60/21	79/10	63/63	76/76
M24	76450	4	RCBC (2.4x3x51)	32/22	52/7	63/63	76/76
M25	83110	5	Bridge (25L)	18/33	88/13	63/63	64/64
M26	96050	5	RCBC (2.4x2.4x40)	14/70	8/22	65/65	76/76
M27	99750	6	RCBC (2.4x3x37&14)	78/237	0/19862	65/65	68/68
M28	100510	6	RCBC (1.8x2.4x66)	92/69	52/123	65/65	68/68
M29	101100	6	RCBC (2.4x3x40)	12/15	60/43	65/65	76/76
M30	101550	6	Bridge (10.5x132)	65/22	47/11	65/65	68/68
M31	113840	7	RCBC (2.4x2.4x40)	1/3	3/2	65/65	76/76
M32	113860	7	RCP (1.2x41)	12/13	4/9	65/65	64/64
M33	115500 (west)	7	RCBC (1.2x1.2x20*)	26/116	12/71	65/65	76/76
M34	115500 (east)	7	RCBC (1.2x1.2x19*)	17/213	71/65	65/65	76/76
M35	118450	7	Bridge (18L)	14/1	4/4	65/65	76/76
M36	122550	7	RCBC (47L)	9/4	9/115	65/65	63/63
M37	127210	8	RCP (2.1x46)	52/38	15/14	65/65	68/68
M38	136650	8	Bridge	271/1698	979/1225	63/71	87/64

Site no.	Chainage	Section	Underpass type & size (HxWxL)	No. of videos (Culv:floor/rail; Pipe: east/west)		Days active (Culv: floor/rail; Pipe: east/west)	
				Aut/win	Sum	Aut/win	Sum
			(23L)				
<b>M39</b>	137400	8	RCBC (2.4x2.4x66)	<b>61/115 CSAC</b>	100/140	37/37	76/76
<b>M40</b>	138400	9	RCP (1.5x62)	78/36	33/26	71/71	66/66
<b>M41</b>	139420	9	RCP (1.5x69)	106/29	29/22	71/71	66/66
<b>M42</b>	140600	9	RCBC (2.4x2.4x39)	NA	9/288	NA	78/78
<b>M43</b>	142200	9	RCBC (2.4x2.4x39)	<b>CSBC</b>	15/79	0/0	66/66
<b>M44</b>	142720	9	RCBC (1.2x1.2x25)	40/108	46/57	64/64	64/64
<b>M45</b>	143400	9	RCBC (2.4x42)	283/118	271/523	64/64	73/73
<b>M46</b>	143700	9	RCP (1.2x36)	188/118	18/86	64/64	64/64
<b>M47</b>	144280	9	RCBC (3x3x34)	222/3	173/18	64/64	72/72
<b>M48</b>	144760	9	RCBC (35L)	<b>198/49 CSAC</b>	84/144	36/36	72/72
<b>M49</b>	146000	10	Bridge (40L)	366/253	3725/817	63/63	50/51
<b>M50</b>	146250	10	RCBC (3x3x38)	39/57	13/15	64/64	71/71
<b>M51</b>	146380	10	RCBC (3x3x39)	5/18	11/70	64/64	71/71
<b>M52</b>	146610	10	Bridge (21L)	64/6	41/5	64/64	72/72
<b>M53</b>	146850	10	Bridge (22L)	20/23	26/18	63/63	73/73
<b>M54</b>	147090	10	RCBC (2.4x2.4x38)	70/7	10/26	63/63	73/73
<b>M55</b>	148600	10	RCBC (3x3x44)	54/15	16/3	64/64	77/77
<b>M56</b>	149250	10	Bridge (35L)	58/24	78/29	70/70	78/78
<b>M57</b>	150030	10	Bridge (22L)	33/41	293/4	70/70	72/72
<b>M58</b>	150550	10	RCBC (3x3x42)	7/27	3/12	63/63	71/71
<b>M59</b>	150600	10	Bridge (20L)	62/15	700/30	63/63	71/71
<b>M60</b>	151200	10	RCBC (2.4x2.4x38)	92/75	43/84	63/63	71/71
<b>M61</b>	151800	10	Bridge (38L)	85/12	123/707	63/63	72/45
<b>M62</b>	152050	10	RCBC (2.4x2.4x36)	17/297	2/58	63/63	71/71
<b>M63</b>	152780	10	RCBC (2.4x2.4x27)	10/269	7/23	63/63	72/72
<b>M64</b>	152880	10	Bridge Bench (5x1.5x15)	1793/293	336/111	59/63	71/71
<b>M65</b>	153050	10	RCBC (3x3x37)	43/46	15/27	63/63	73/73
<b>M66</b>	153600	10	RCBC (3x3x48)	39/59	17/4	70/70	72/72
<b>M67</b>	153900	10	Bridge (25L)	61/24	187/6	70/70	71/71
<b>M68</b>	154050	10	Bridge (25L)	49/28	114/21	70/70	72/72
<b>M69</b>	154750	10	RCBC (2.4x2.4x44)	92/46	49/269	63/48	70/70
<b>M70</b>	155290	10	RCBC (2.4x2.4x38)	120/129	34/123	63/63	70/70

Site no.	Chainage	Section	Underpass type & size (HxWxL)	No. of videos (Culv: floor/rail; Pipe: east/west)		Days active (Culv: floor/rail; Pipe: east/west)	
				Aut/win	Sum	Aut/win	Sum
M71	155910	10	RCBC (2.4x2.4x33)	12/6	15/16	70/70	71/71
M72	156280	10	Bridge (25L)	8/14	3/3	70/70	71/71
M73	156930	10	RCBC (2.4x2.4x36)	24/82	50/48	70/70	71/71
M74	157300	10	RCBC (2.4x2.4x38)	4/997	5/58	70/41	71/71
M75	157300	10	RCP (2.4x2.4x38)	39/62	92/22	70/70	63/63
M76	157600	10	RCBC (2.4x3x35)	<b>5/36 CSAC</b>	13/76	32/32	72/72
M77	157740	10	RCBC (3x3x45)	1/17	3/7	64/64	72/72
M78	157900	10	Bridge (22L)	266/12	50/29	64/64	72/72
M79	158880	11	RCBC (2.1x2.4x17)	42/47	17/9	64/64	70/70

## 2.2.2 Hair funnels

Hair funnel sampling was conducted at sites M1 to M14 during each monitoring session. Three funnels were installed at each culvert during each sample session - one funnel was attached to the fauna furniture near floor level and one funnel each was placed on the ground in adjoining habitat either side of the culvert. For pipes, hair funnels were only placed in adjoining habitat. Funnels were baited with peanut butter and oats and left in place for a minimum of 14 nights/session. Hair funnel sampling was not undertaken at sample sites in sections 3-11 as previous sampling in sections 1 and 2 found the technique to be of limited value.

Hair funnels were retrieved at the end of each sampling period and sent to a recognised hair identification analyst (Robyn Carter and Georgeanna Story). Hair funnels were deployed for 35 days during autumn/winter (3/6- 08/7/2020) and 15 days during summer (3/3 –18/3/2021).

## 2.2.3 Scat and track searches

Scat and track searches were conducted on two occasions during each monitoring session. Searches were completed while checking cameras and/or installing hair funnels. On each occasion the ground within 5m of each underpass entrance and the culvert floor/furniture were searched for scats and evidence of tracks. Predator scats were collected and sent to a recognised hair identification analyst.

## 2.3 Road mortality monitoring

Road mortality surveys were conducted quarterly during the 2020/21 monitoring period. The car-based surveys entailed a driver and passenger observer travelling both the northbound and southbound length of sections 1 and 2 (Q3 and Q4 2020) and sections 1-13 (Q1 and Q2 2021). The survey vehicle featured a 'Vehicle Frequently Stopping' sign on the back and flashing light and travelled at 80-90 km/h in the left-hand lane. Surveys involved the passenger scanning the road surface and road shoulder for animal carcasses. When a carcass was observed, the location was recorded using Motion X-GPS application and the species recorded into a handheld voice recorder. If a potential threatened species was identified, the vehicle would pull over at the nearest safe location and the passenger would walk back to inspect the carcass behind the guard rail. The location of each carcass was later recorded into an excel spreadsheet and referred to in subsequent surveys to avoid double-counting.

Unidentifiable macropods were scored according to the following size categories:

- Small = <5 kg (includes long-nosed potoroo and rufous bettong).
- Medium = 5 - 25 kg (includes red-necked wallaby and swamp wallaby).
- Large = >25 kg (includes eastern grey kangaroo).

Unidentifiable quadruped mammals (i.e. four-legged, which includes brush-tailed phascogale and spotted-tailed quoll) were scored according to the following size categories:

- Small = <0.5 kg (includes brush-tailed phascogale, rodents and small gliders)
- Medium = 0.5 - 5 kg = (includes spotted-tail quoll, cats, bandicoots, possums & large gliders).
- Large = >5 kg (includes dogs, foxes).

A hair sample was collected from any unidentifiable carcasses that were suspected of being a target threatened mammal. Samples were sent to a recognised hair analyst for identification. Surveys were completed on 09/07/2020 (Q3), 16/10/2020 (Q4), 23/02/2021 (Q1) and 07/05/2021 (Q2).

## 2.4 Data analysis

### 2.4.1 Underpass camera data

Underpass camera images were uploaded to a desktop computer and viewed using Windows Photo Viewer. Data recorded included: site, sample period, species and the number of complete or incomplete crossings including crossing direction (east or west). An ecologist reviewed all images, with reference to standard field guides (i.e. Menkhorst & Knight 2010; Menkhorst et al. 2017; Swan et al. 2004) and senior staff. A hierarchical approach was adopted for species identification, which included: species, genus or group. Microbats were recorded as presence only and birds, reptiles and amphibians were not included in the data.

To determine the likelihood of an underpass crossing, footage was scored according to the following criteria:

- *Complete crossing* - animal demonstrates directional movement along floor/furniture and does not return within 10 minutes.
- *Incomplete crossing* – animal demonstrates directional movement along floor/furniture but returns within 10 minutes, exhibits no directional movement or shows only exploratory movement.

According to these definitions, a 'complete crossing' is inferred from display of strong directional movement and no evidence of return movement. For pipes, where cameras are installed at either end of the structure, the absence of concurrent footage at the other end of the pipe is presumed to be an instance of detection evasion. These definitions are consistent with other underpass investigations (see Goldingay *et al.* 2019), including other Pacific Highway upgrade sites (see Sandpiper 2017, 2018a, 2019).

To control for variation in camera survey effort between sites, totals for complete crossings were converted to a per week value by dividing the number of crossings by the number of sample weeks. The number of sample weeks was derived by dividing the number of sample days by seven. Data were summarised according to underpass, native or introduced species, introduced predators (i.e. cat, dog, fox), and compared between monitoring years. The data summary has focussed primarily on sites M1-M14 in sections 1 and 2 as this report covers the final sample year at those sites.



## 3. Results

### 3.1 Underpass monitoring

#### 3.1.1 Fauna detections all sites

Underpass camera monitoring yielded 6247 mammal detections (i.e. sum of complete and incomplete crossings) during the two seasons of monitoring at an overall rate of  $4.32 \pm 5.61$  detections/underpass/week. Detections were slightly higher during autumn/winter ( $4.68 \pm 5.51$  detections/underpass/week) than summer ( $3.78 \pm 7.02$  detections/underpass/week). The majority of detections (90%) were complete crossings. Twenty species and four fauna groups were recorded during underpass camera monitoring (Appendix A, Table A1). Species ranged in size from house mouse (*Mus musculus*) to eastern grey kangaroo (*Macropus giganteus*). The introduced black rat was the most frequently detected species with an overall rate of 82.81cc/week, followed by swamp wallaby with 58.37cc/week and eastern grey kangaroo with 29.65cc/week. More complete crossings were made by native taxa (56%) (i.e. excluding rodent spp and small mammal spp. which may include native and/or introduced species) than introduced species (44%).

M38 featured the highest rate of native species detections with 41.21 detections/week, which were attributed to eastern grey kangaroo and swamp wallaby. This was followed by M48 with 21.29 detections/week and M47 with 13.45 detections/week. Both sites had high use by swamp wallaby and M48 also by brushtail possum. M70 featured the highest use by introduced species (8.8 detections/week), predominantly by black rat. The highest native fauna diversity was at M1, M3 and M47 (7 species/groups) and the least diverse was M62, M64, M66 and M74 (0 species/groups) (Appendix A, Table A1).

#### 3.1.2 Section 1 and 2 detections

Detections/week of native species in sections 1 and 2 (sites M1-M14) were higher in year three than year two at sites M1-M3, M5, M6 and M8, similar at sites M9 and M10 and lower at sites M7 and M11-M14. At sites M11-M14 native species detections declined substantially from year 2 to year 3, with the converse recorded for introduced species (Figure 8). In year 3, native species in sections 1 and 2 averaged  $2.09 \pm 2.08$  detections/underpass/week compared with  $1.50 \pm 1.33$  detections/underpass/week for introduced species (Figure 9). Overall detections/underpass/week between year two and year three increased by 14% for native species and 108% for introduced species (Figure 9).

#### 3.1.3 Target species

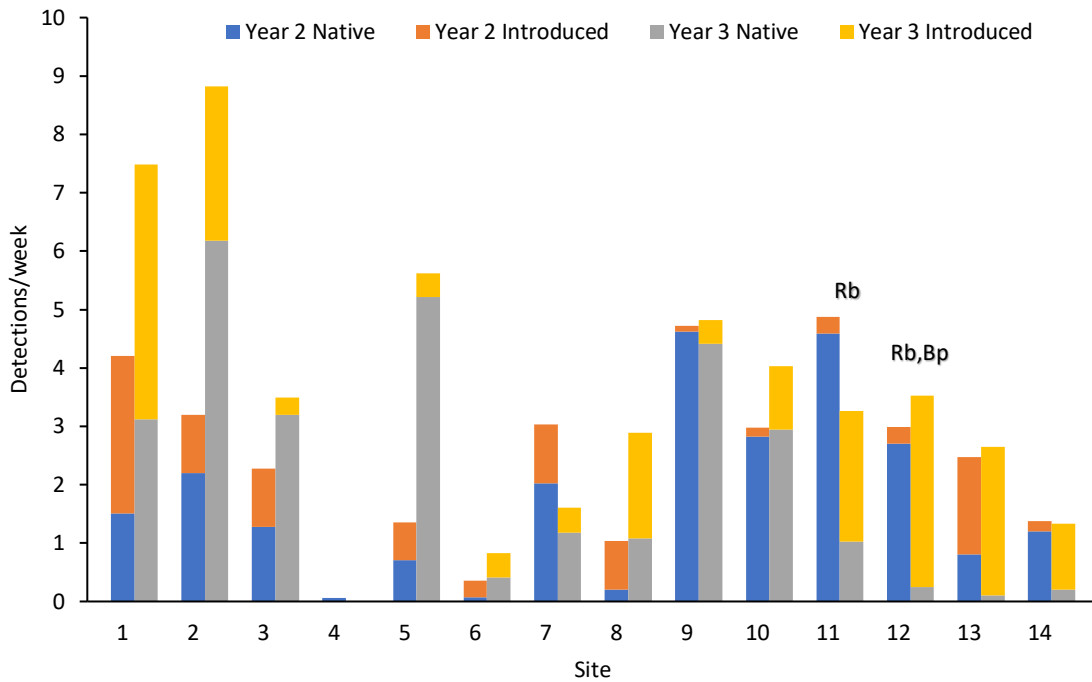
Two target threatened mammal species, brush-tailed phascogale and rufous bettong, were detected during summer at two sites, and brush-tailed phascogale was detected during autumn/winter at three sites (Figures 10 & 11). In sections 1 and 2:

- Brush-tailed phascogale was recorded on the furniture at M12 on 2/3/2021 making a complete west crossing (Plate 3, Figure 10), and a complete east crossing on the ground on 3/3/2021.
- Rufous bettong was recorded at M11 on 13/1/2021 (Plate 5, Figure 10), and at M12 on 14/2/2021 heading east.

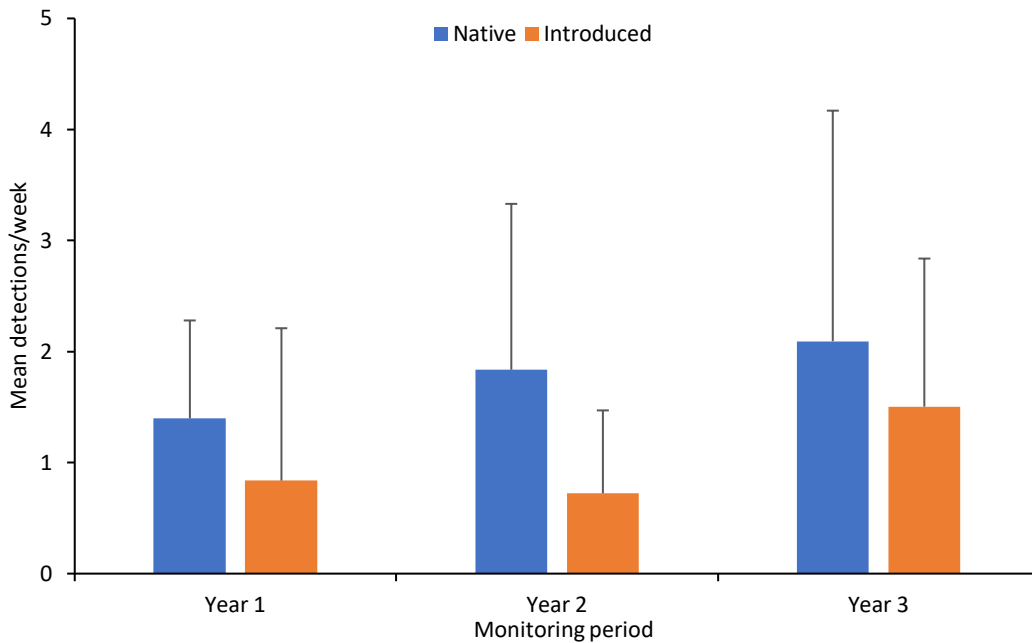
In sections 3-11:

- Brush-tailed phascogale was recorded on the furniture at M15 on 19/5/2021 making a complete crossing westward (Plate 4, Figure 10) and a complete crossing eastward through 1200mm-diameter pipes at M16 on 2/6/2021 (Figure 11) and at M32.

During koala underpass monitoring a rufous bettong was recorded making four complete eastward crossings at K11 between 27/9/2020 and 6/11/2020 (Figure 10).



**Figure 8:** Overall camera detections/week for native and introduced species at each monitoring site for year 2 and year 3 monitoring periods. Detections are the sum of complete and incomplete crossings. Rb= Rufous bettong detection. Bp= Brush-tailed phascogale detection.



**Figure 9:** Mean number of camera detections/week/underpass (+SD) for native and introduced species during year one (n=13), year two (n=14) and year three (n = 14) monitoring periods.



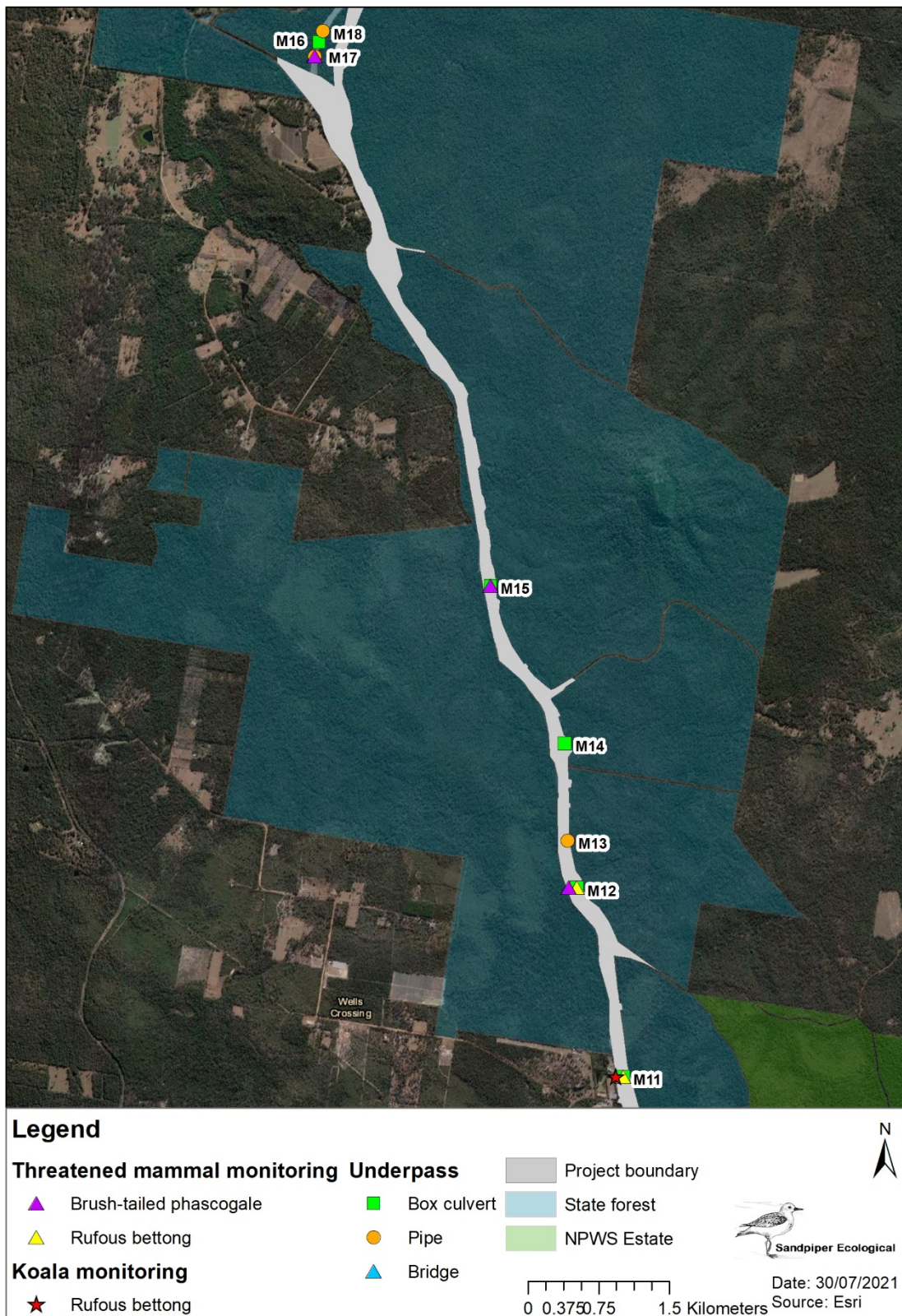
**Plate 3:** A brush-tailed phascogale was captured on video moving west on the furniture at M12 during the summer monitoring period 2021.



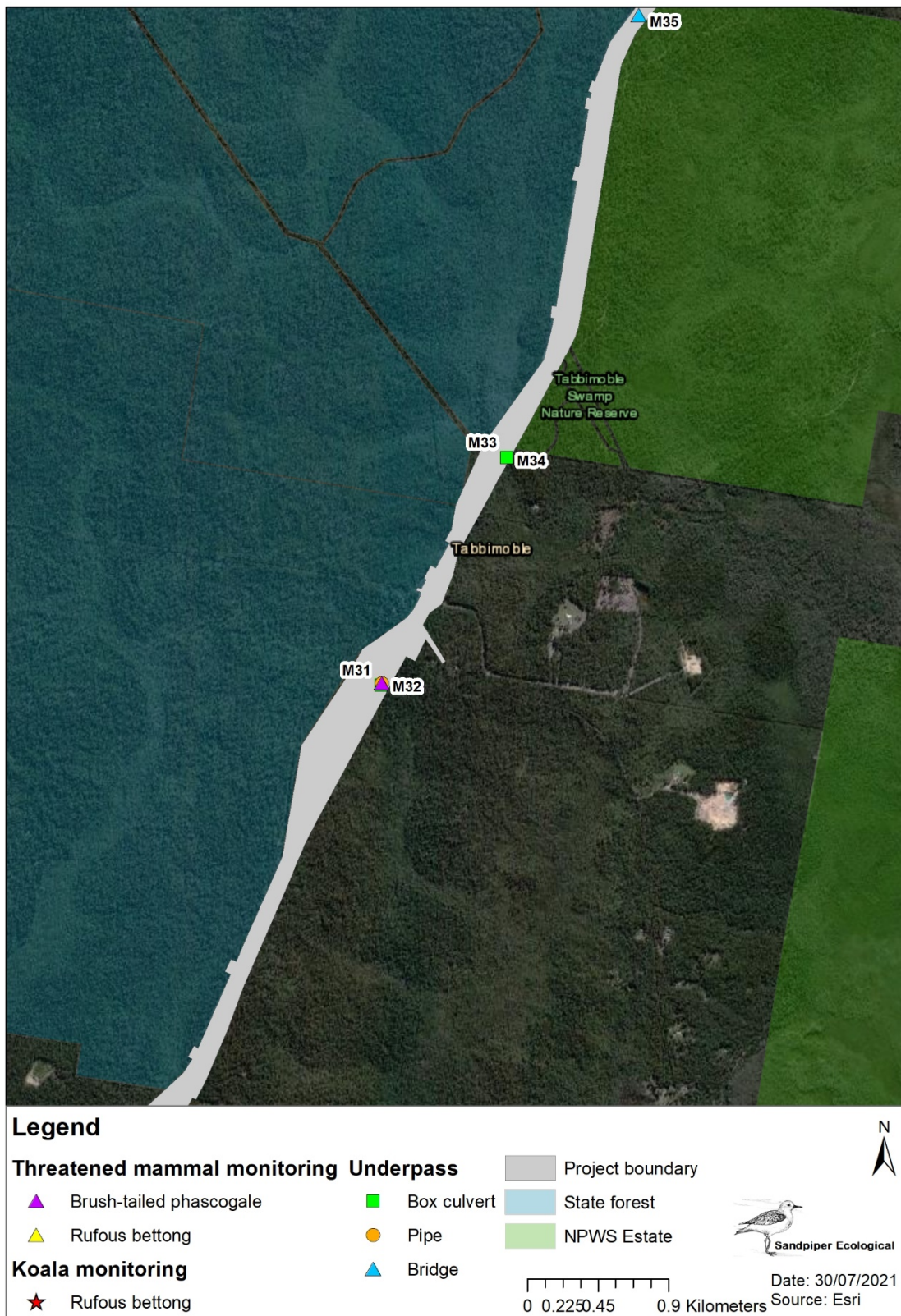
**Plate 4:** A brush-tailed phascogale was captured on video moving west on the furniture at M15 during the autumn/winter monitoring period 2021.



**Plate 5:** A rufous bettong was captured moving east at M11 during the summer monitoring period 2021.



**Figure 10:** Location of brush-tailed phascogale and rufous bettong underpass records from threatened mammal monitoring 2020/2021 and koala monitoring in spring 2020.

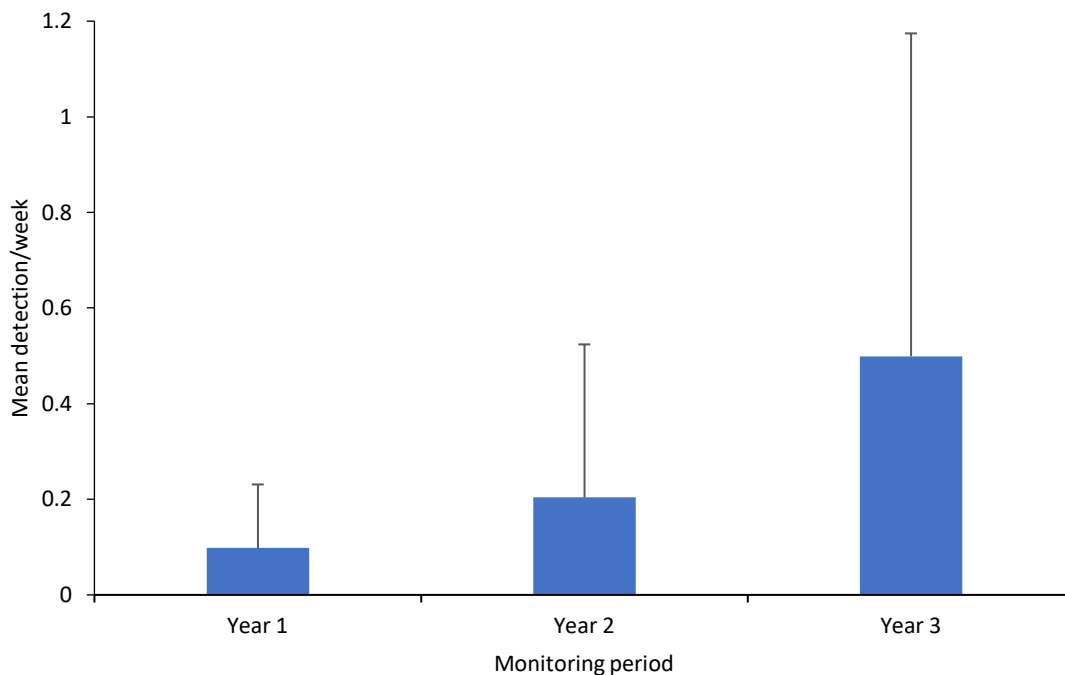


**Figure 11:** Location of brush-tailed phascogale and rufous bettong underpass records from threatened mammal monitoring 2020/2021 and koala monitoring in spring 2020.

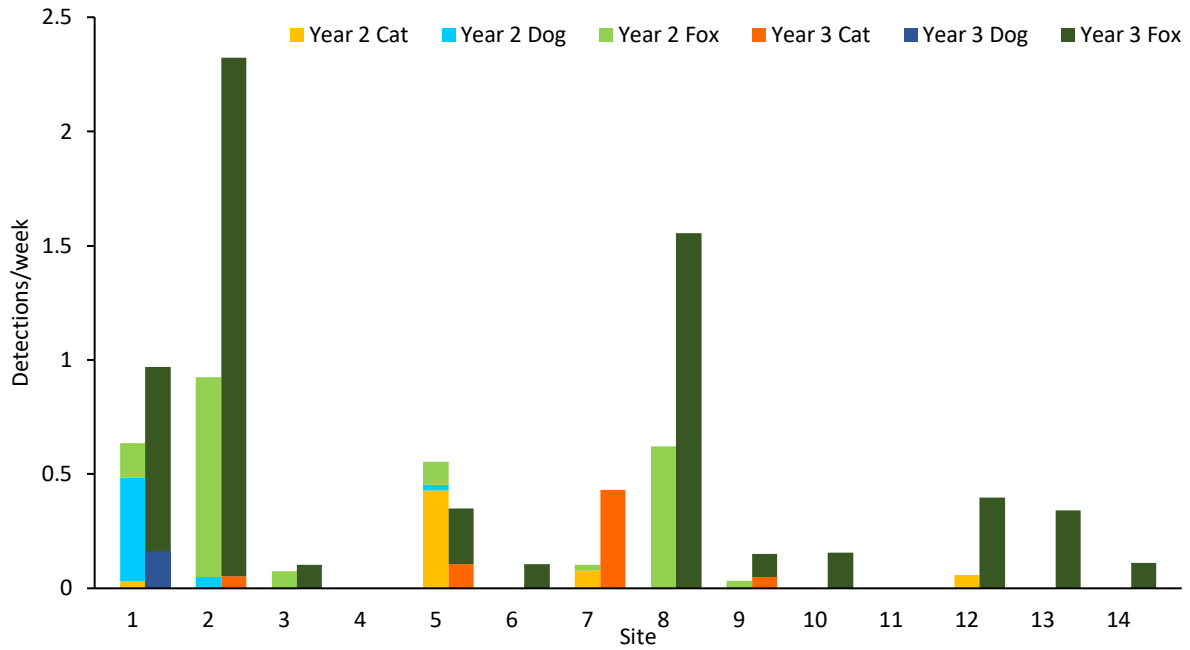
### 3.1.4 Introduced predator activity

Introduced predators (i.e. fox, cat and dog) were detected at 63 of the 79 sites, and accounted for 12.5% of all fauna detections (Appendix A, Table A1). Fox (*Vulpes vulpes*) was recorded at 56 sites and accounted for 73% of introduced predator detections at a mean detection rate of  $0.39 \pm 0.65$  detections/week/underpass (Appendix A, Table A1). Cat (*Felis catus*) was recorded at 20 sites and had a mean detection rate of  $0.09 \pm 0.26$  detections/week/underpass, and dog (*Canis lupus familiaris*) was detected at three sites (M1, M22 and M25) with a mean detection rate of  $0.06 \pm 0.37$  detections/week/underpass (Appendix A, Table A1). The frequency of visits by introduced predators was highest at sites M22 (5.1/week), M75 (3.7/week) and M2 (2.3/week) (Appendix A, Table A1).

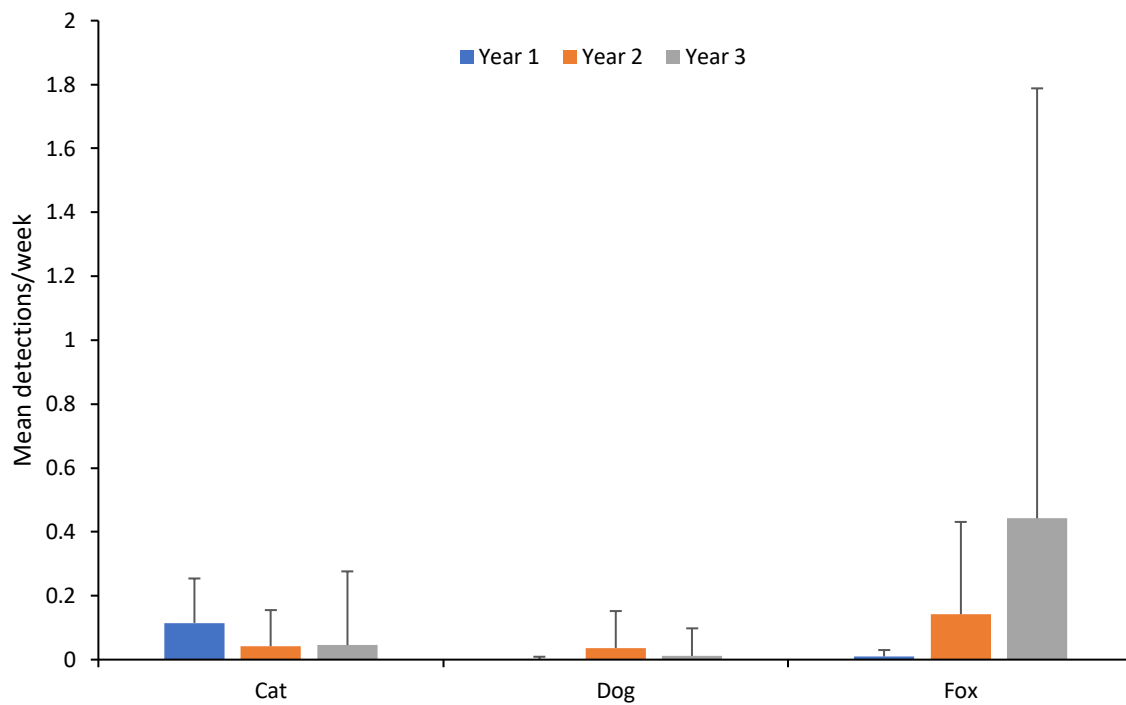
For sections 1 and 2 (underpasses M1-M14), the mean number of introduced predator detections/week/underpass increased from  $0.2 \pm 0.32$  to  $0.50 \pm 0.68$  between year two and year three – an increase of 145% (Figure 12). In year three, introduced predators were recorded at 12 of the 14 sample sites, compared to eight of 14 sites in year two (Figure 13). Foxes displayed the most obvious increase in distribution and detections. Foxes were recorded at 11 of 14 sites in year three compared to seven of 14 in year 2. This increase in distribution coincided with a substantial increase in detections. Alike year two, M2 and M8 accounted for the majority of fox detections. Dogs displayed the opposite trend with occurrence declining from three sites in year two to one in year three, and detections declining by more than 50% at the most frequently used site (M1). No dogs were recorded at sites M2 and M5 where they were detected in year 2. Over the three sample years dog numbers remained reasonably low and consistent (Figure 14). Cats were recorded at the same number of sites (i.e. 4) in years 2 and 3, although distribution changed (Figure 13). Overall, cat detections were similar between years 2 and three, and less than year 1 (Figure 14).



**Figure 12:** Overall mean (+SD) number of camera detections/week/underpass for introduced predators (cat, dog, fox) during year 1 (n=13), year 2 (n=14) and year 3 (n=14) monitoring periods.



**Figure 13:** Introduced predator (cat, dog, fox) detections/week during year two and year three monitoring in Sections 1 and 2. Detections = sum of complete and incomplete crossings.



**Figure 14:** Mean (+SD) number of camera detections/week/underpass for introduced predator species (cat, dog, fox) during year 1 (n=13), year 2 (n=14) and year 3 (n = 14) monitoring periods.

### 3.1.2 Hair funnels

Four species were recorded during hair funnel sampling (Table 2). Yellow-footed antechinus (*Antechinus flavipes*) was recorded at eight sites in autumn/winter, and two sites in summer. Bush rat (*Rattus fuscipes*) was recorded at two sites in summer, house mouse (*Mus musculus*) was recorded at one site in autumn/winter and summer, and a species of brushtail possum (*Trichosurus* spp) was recorded at one site in summer. Yellow-

footed antechinus was recorded in adjacent habitat and the underpass at seven sites. No threatened mammals were detected by hair funnels set in adjoining forest or culverts.

**Table 2:** Hair funnel detections in S1 & 2 during autumn/winter and summer 2020/21. All detections are definite except those labelled (pr) probable. p = pipe.

Site No.	Funnel position	Autumn/winter	Summer
M1	Forest	Antechinus flavipes, Mus musculus	nil
	Culvert	Antechinus flavipes	nil
M2	Forest	Antechinus flavipes (pr)	nil
	Culvert	Antechinus flavipes	nil
M3	Forest	Antechinus flavipes	Rattus fuscipes
	Culvert	Antechinus flavipes (pr)	nil
M4p	Forest	Antechinus flavipes	Rattus fuscipes
M5	Forest	Antechinus flavipes	Antechinus spp.
	Culvert	Antechinus flavipes	Trichosurus spp.
M6p	Forest	Antechinus flavipes	nil
M7	Forest	Antechinus flavipes	Antechinus spp.
	Culvert	nil	nil
M8	Forest	nil	Antechinus flavipes
	Culvert	nil	Antechinus flavipes
M9	Forest	Antechinus flavipes	Antechinus flavipes
	Culvert	Antechinus flavipes	Antechinus flavipes
M10	Forest	Antechinus flavipes, Rattus spp.	Antechinus spp.
	Culvert	Antechinus flavipes (pr)	Antechinus spp.
M11	Forest	N/A	nil
	Culvert	N/A	nil
M12	Forest	N/A	Mus musculus
	Culvert	N/A	nil
M13p	Forest	N/A	nil
M14	Forest	N/A	nil
	Culvert	N/A	nil

### 3.1.3 Scat and track searches

Scats and tracks of a range of taxa were detected during four inspections of underpasses performed during the 2020/21 monitoring year (Table B1, Appendix B). Rodent scats were most common, with detections in 38 underpasses, followed by microbat spp. in 15 underpasses, and wallaby spp. in 14 underpasses. Rodent and antechinus scats were primarily detected on culvert rails rather than the culvert floor. Scat detections on the culvert floor included short-beaked echidna (Plate 6), bandicoot, brushtail possum, eastern grey kangaroo, wallaby, microbat, rodent, fox, dog, cat and cow. Canid (inc. fox and dog) scats were detected at nine underpasses. Three scat samples were sent for analysis, two fox scats and one swamp wallaby (*Wallabia bicolor*). The fox scats contained hair of bush rat and swamp wallaby.

Roosting microbats were detected in 11 underpasses, with scats observed in an additional seven underpasses (Table B1, Appendix B). Three species listed as vulnerable under the NSW *Biodiversity Conservation Act 2016* were confirmed using underpasses, these included little bent-winged bat (*Miniopterus australis*), large bent-winged bat (*Miniopterus orianae oceanensis*), and southern myotis (*Myotis macropus*). *M. australis* were



detected roosting in five underpasses, including three box culverts (M17, M23 and M24) and two pipes (M4 and M37), during autumn/winter only. *M. oriana oceanensis* were detected in autumn/winter in the joints of one box culvert (M23) and *M. macropus* in august/winter in the joints of two box culverts (M36 and M55; Plate 7). Additional species included eastern horseshoe bat (*Rhinolophus megaphyllus*) roosting in summer on the rail at M5 (Plate 8), and a wattled bat (*Chalinolobus spp*) roosting in a bat box at M8 in summer. M50 and M51 had roosting microbats of unknown species in the joints in autumn/winter.

A total of 11 species/fauna groups were recorded during track searches of the underpass entrance and floor areas (Table B1, Appendix B). Tracks of introduced predators were detected at 14 underpasses. Dog tracks were detected at M7. M8, M65 and M70 had both fox and dog tracks, and the remaining ten underpasses had fox tracks (Table B1, Appendix B).



Plate 6: Short-beaked echidna scat recorded during autumn/winter at M47.



Plate 7: *Myotis macropus* roosting in culvert joints at site M36 in autumn/winter 2021.



**Plate 8:** Eastern horseshoe bat (*Rhinolophus megaphyllus*) roosting in summer on the rail at M5.

### 3.2 Road mortality

Due to a technical issue associated with an on-line mapping program, data from the Q2 2021 road mortality survey are not available, however, no threatened mammals were identified during that, or any of the preceding surveys. Excluding the Q2 survey, 58 vertebrates were recorded, including 29 mammals (50%) (Table 4). Mammal road-kills were recorded at a rate of  $0.07 \pm 0.03$  kills/km over the three survey quarters (Table 4).

The most common taxa group recorded was medium mammals ( $n = 16$ ), which consisted of seven unidentified species, five bandicoot spp., two cats, one northern brown bandicoot, and one European hare. Six macropods (inc. two eastern grey kangaroo, three medium/large macropod and one swamp wallaby) were recorded, as well as five flying-fox (inc. three little-red flying-fox and two flying-fox spp.). The remaining road-kills were comprised of birds (35%), reptiles (14%) and an amphibian (0.02%). Mammal kills/km were highest in Q3 and were similar between Q4 and Q1 (Table 4). Full details of road mortality surveys are provided in Appendix C, Table C1.

**Table 3:** Species of vertebrate fauna recorded during road-kill surveys throughout the operational phase of the W2B upgrade. \* denotes threatened species; \*\* = 500m walking transects at each underpass; ^ = driving transect of sections 1 and 2; # = driving transect of sections 1-11.

Species	Q3 (Jun) 2018	Q4 (Dec) 2018	Q1 (Feb) 2019	Q2 (Apr) 2019	Q3 (Aug) 2019	Q4 (Oct) 2019	Q1 (Feb) 2020	Q2 (Apr) 2020	Q3 (July) 2020	Q4 (Oct) 2020	Q1 (Feb) 2021	Total
<b>Mammals</b>												
Short-beaked echidna	1											1
Spotted-tailed quoll*	1											1
Northern brown bandicoot			1	2	1				1			5
Bandicoot spp.	1								1	1	3	6
Common brushtail possum	1			1								2
<i>Trichosurus</i> spp.	1						1					2
Eastern grey kangaroo	1				1					1	1	4
Red-necked wallaby				1				1				2
Swamp wallaby	1	1			1	1					1	5
Wallaby spp.	1	2					1					4
Medium macropod	2				3	2		1			1	9
Med/large macropod											2	2
Large macropod		1	1				2					4
Macropod spp.				1								1
Grey-headed flying-fox*					1							1
Little red flying-fox											3	3
<i>Pteropus</i> spp.											2	2
Microbat spp.	4											4
Rodent spp.	1											1
Medium mammal				1					1		6	8
Large mammal								1				1
Unidentified mammal	2		1									3
<b>Total mammals</b>	<b>17</b>	<b>4</b>	<b>3</b>	<b>6</b>	<b>7</b>	<b>3</b>	<b>4</b>	<b>3</b>	<b>3</b>	<b>2</b>	<b>19</b>	<b>71</b>
<b>Birds</b>												
Australian wood duck	1											1
Pacific black duck								1				1
Crested pigeon								1				1
Tawny frogmouth				1	1							2
Australian magpie	2							1			4	7
Purple swamphen							1					1
Eastern barn owl	1											1
Laughing kookaburra	1									1		2
Fairy wren spp.				1								1
Yellow thornbill	1											1
Noisy friarbird								1				1
Pied currawong											1	1
Eastern yellow robin				1								1
Small bird											3	3
Medium bird				2				1			10	13
Unidentified bird			1		1							2
<b>Total birds</b>	<b>6</b>		<b>1</b>	<b>5</b>	<b>2</b>		<b>1</b>	<b>5</b>		<b>1</b>	<b>18</b>	<b>39</b>
<b>Reptiles</b>												
Lace monitor	1		1								1	3
Eastern bearded dragon			1									1
Medium lizard											1	1
Carpet python			1			1					3	5
Eastern small-eyed snake				1							1	2
Yellow-faced whipsnake			1									1
Bandy-bandy				1								1
Large reptile							1					1
Unidentified snake	1			1							2	4
<i>Chelidae</i> spp.								1				1
<b>Total reptiles</b>	<b>2</b>		<b>4</b>	<b>3</b>		<b>1</b>	<b>1</b>				<b>8</b>	<b>19</b>
<b>Introduced species</b>												
House mouse	2											2
European fox							1		1			2
Dog								1	1			2
Cat					1					1	1	3
European hare					1				1			2

W2B Threatened mammal underpass and road mortality monitoring

Species	Q3 (Jun) 2018	Q4 (Dec) 2018	Q1 (Feb) 2019	Q2 (Apr) 2019	Q3 (Aug) 2019	Q4 (Oct) 2019	Q1 (Feb) 2020	Q2 (Apr) 2020	Q3 (July) 2020	Q4 (Oct) 2020	Q1 (Feb) 2021	Total
Chicken											1	1
Cane toad											1	1
Total introduced species	2				2		1	1				6
Total fauna	27	4	8	14	11	4	7	10	6	4	48	143
Total mammals	19	4	3	6	9	3	4	4	6	3	20	81
Total kms surveyed	11**	11**	11**	12**	57.4^	57.4^	57.4^	57.4^	57.4^	57.4^	328#	
Mammal kills/km	1.73	0.36	0.27	0.50	0.16	0.05	0.07	0.07	0.1	0.05	0.06	

## 4. Discussion

### 4.1 Underpasses

#### 4.1.1 Use by target species

Camera monitoring of 79 sites during 2020/2021 demonstrated considerable use of both the underpass floor and furniture by 24 species/fauna groups. Species diversity was similar to that recorded at the Nambucca Heads to Urunga (NH2U) Pacific Highway upgrade (n = 25) (Sandpiper 2020a) and Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway upgrades (n = 21) (Sandpiper 2020b). In sections 1 and 2 native species accounted for 58% of all fauna detections. This was lower than year two (68.3%), similar to WC2NH (Sandpiper 2020b), and higher than recorded at NH2U (Sandpiper 2020a). This variation is attributed to the prevalence of black rat (*Rattus rattus*) in 2021. The substantial increase in black rat detections recorded in sections 1 and 2 between years 2 and 3 may be due to increased breeding success following high rainfall in 2020 and early 2021 as has been shown for other rodent species in eastern Australia (Lock & Wilson 2017). Increased abundance of black rat and rainfall may also be correlated to the increase in red fox detections (Scroggie et al. 2018).

Two targeted threatened mammal species, brush-tailed phascogale and rufous bettong, were detected using connectivity structures during the 2020/21 monitoring period. Brush-tailed phascogale were detected at four sites, M12 (box culvert), M15 (box culvert), M16 (pipe culvert) and M32 (pipe culvert), with records in summer, and autumn/winter. Individuals were recorded using both the fauna furniture and culvert floor. These records are consistent with results obtained during year one and two monitoring when phascogales were recorded at M13 (750mm pipe culvert), and M12 (Sandpiper 2019a, 2020c). Phascogales have previously been recorded moving through the Glenugie Creek Bebo Arch (Sandpiper 2017a, 2017b). Findings to date show that brush-tailed phascogales will utilise a variety of structure sizes and types and use both furniture and the floor to cross beneath the highway.

Rufous bettong was recorded moving eastward through M11 and M12 during the summer 2021 monitoring period and at M11 during the spring 2020 koala underpass monitoring (Sandpiper 2021). Threatened mammal monitoring in 2019/20 and koala underpass monitoring in 2019 also detected rufous bettong in the nearby M9 and M10 box culverts (Sandpiper 2020c,d). Spotted-tail quoll and long-nosed potoroo were not detected during the 2020/21 sample period. Koala underpass monitoring in 2019 did however detect long-nosed potoroo in a box culvert on Wardell Road situated to the east of M62 and M63 (Sandpiper 2020c). Koala underpass monitoring in 2018 also detected a long-nosed potoroo using a box culvert to the north of site M4 and a spotted-tail quoll carcass was observed during road mortality surveys near site M10 (Sandpiper 2019b).

Microbats were recorded at 57 sites with six species/groups recorded. Three of the six species/groups are listed as vulnerable under the NSW *Biodiversity Conservation Act 2016*. These include little bent-wing bat (*Miniopterus australis*), large bent-wing bat (*Miniopterus orianae oceanensis*) and large-footed myotis (*Myotis macropus*). Other sections of the Pacific Highway upgrade such as NH2U and WC2NH have also shown use of underpasses by microbats (Sandpiper 2020a,b), reinforcing the importance of underpass structures as roosting habitat. Underpasses have also been found to reduce barrier effects of roads by facilitating movement of microbat species, especially those that are clutter and edge adapted (Bhardwaj et al. 2017).

### **Performance indicator**

*“Monitoring surveys undertaken identify no evidence of the use of designated connectivity structures by targeted threatened mammal species after three consecutive monitoring periods.”*

- a) Over three years of monitoring in sections 1 and 2 brush-tailed phascogale has been consistently recorded using sites M12 and M13.
- b) In year one monitoring in sections 3-11 brush-tailed phascogale were recorded using M15, M16 and M32.
- c) Phascogales have been recorded using a variety of structures ranging in size from 750mm diameter pipes to 9m wide bebo arch, and using both fauna furniture and the floor.
- d) Over three years of monitoring in sections 1 and 2 rufous bettong were detected using sites M9, M10, M11 and M12, all of which are box culverts.
- e) Rufous bettong were not detected at structures in sections 3-11 during year one monitoring.
- f) A high diversity of non-threatened native species were recorded using underpasses.

#### **4.1.2 Introduced predators in sections 1 and 2**

In sections 1 and 2, introduced predator detection rates increased by 145% between year two and year three monitoring. Foxes accounted for 88.6% of all introduced predator detections, an increase of 60.6% from year two (Sandpiper 2020d). Cat and dog accounted for approximately 9% and 2% respectively of underpass detections, with detection rates for cat slightly increasing and dog decreasing between years 2 and 3. Introduced predators were detected at 12 of the 14 sites. The substantial increase in fox detection is likely related to improved breeding success and abundance associated with a combination of high rainfall in 2020 and 2021 and higher abundance of prey, particularly rodents. The trend recorded for fox has been a year on year increase in detections.

Both rufous bettong and brush-tailed phascogale are within the weight range targeted by foxes, and cats would target phascogales. Overlap in structure use with foxes and cats places bettongs and phascogales at risk of predation, whilst predation may not occur within structures the structures enable foxes to access threatened species habitat. In sections 1 and 2, the fox is the only predator whose activity consistently overlaps that of phascogale and bettong. For example, in 2021 foxes were recorded using all sites where target species were recorded (i.e. M9, M10, M12 and M13). Visitation by foxes at these sites was generally low, in the order of 0.1-0.2 crossing/week. Exceptions were M12 and M13 in summer where fox detections were 0.7/week at each site.

Interactions with feral predators may adversely affect underpass use by native fauna through predation or avoidance of the area (Little 2003). Feral predators regularly utilise underpasses and there are numerous examples of predators moving through underpasses with prey, however, there is no evidence to show that predators intentionally target prey within or at the entrance to underpasses (Little *et al.* 2002). Monitoring in sections 1 and 2 has shown a definite overlap in structure use by threatened species and foxes and it is possible that fox predation on threatened mammals could contribute to nil results at structures situated in suitable habitat.

Monitoring data do not provide information on fox abundance and it is likely that visitation to many sites could be attributed to one or two individuals and some individuals may utilise more than one structure. The likelihood that the number of individuals using structures is small means that positive outcomes are likely from a targeted control program. The substantial increase in fox activity from year two to year three means that targeted feral predator control should be considered.

Feral predator abundance is known to fluctuate in relation to environmental conditions and prey abundance (Scroggie *et al.* 2018), and declines in fox activity may occur due to climate induced changes in prey availability, parasite loads and interactions with mesopredators (Lentic *et al.* 2010). The current forecast of a continuation of the La Nina weather pattern into late 2021 and early 2022 favourable conditions for foxes could persist for several years. This means that control in the short-term is likely to have positive benefits for prey species.

### **Performance indicator**

*“High levels of structure usage (>25% increase) by exotic predators reported after the first monitoring period and each subsequent monitoring period.”*

- a) Introduced predator detection rates (detections/week/underpass) increased by 145% between year two ( $0.2 \pm 0.32$ ) and year three monitoring ( $0.50 \pm 0.68$ ).
- b) Greater than 25% increase of exotic predator use detected at M1, M2, M3, M7, M8, M9 and M12.
- c) Structures M6, M10, M13 and M14 detected use by feral predators in year three but not in year two.
- d) Greater than 25% increase in fox detections at M1, M2, M3, M5, M8 and M9 from year 2 to year 3.
- e) Structures M6, M10, M12, M13 and M14 detected use by foxes in year three but not in year two.
- f) Structures known to be used by at risk target threatened mammal species include: M9, M10, M11, M12, M13, which are all situated from just south of Parker Road to Franklins Road. In addition, M14 is situated near a rufous bettong population monitoring site, and long-nosed potoroo were recorded at a koala monitoring site just north of K4.

## **4.2 Road mortality**

The range of species recorded during road mortality surveys was similar to that recorded at other north coast Pacific Highway upgrade sites (see Taylor & Goldingay 2004; Sandpiper 2018a, 2019a). Encouragingly, no target threatened mammals were recorded. Vehicle strike rates in sections 1 and 2 in year three were similar to year two monitoring (Sandpiper 2020d). The continued detection of medium and large mammals in vehicle strike surveys reinforces the risk that vehicle strike poses to targeted threatened mammals and the importance of detecting breaches in the exclusion fence.

### **Performance indicator**

*“A single reported road-kill of a targeted threatened mammal species.”*

- a) No targeted threatened mammal species reported during year three operational phase monitoring.

## **4.3 Site selection**

There is considerable overlap in sample sites between the W2B threatened mammal underpass monitoring program and the W2B koala underpass monitoring program. Importantly, the koala sampling program includes numerous bridges, which has contributed to the number of bridges sampled during this study. Achieving an appropriate spatial distribution of sample sites, whilst operating within the limitations imposed by the site selection criteria was challenging. Spatial gaps in sampling are evident south of Tyndale, and south of New Italy. Prior to the 2022 underpass sample period underpasses in these areas will be re-inspected to determine if there are suitable additional sites to sample. This assessment would commence with a desktop review of the underpass types and locations.

### 4.3 Recommendations

RMS (2017) identify corrective actions if structure usage by feral predators exceeds the stated threshold of 25% increase between years. These actions include:

1. Meet with regional pest control stakeholders as soon as practical and contribute to pest control program where reasonable and feasible.
2. Implement pest control program around crossing structures to reduce pest animal predation where deemed required.

Recommendations to address corrective actions are detailed in Table 4.

**Table 4:** Recommendations following year three operational phase threatened mammal monitoring and Transport for NSW response.

Number	Recommendation	Transport for NSW Response
1.	Initiate a meeting with appropriate stakeholders to discuss pest animal control within sections 1 and 2.	
2.	If possible coordinate feral predator control at high priority structures with other local control programs.	
3.	Implement control measures for fox at sites M9 to M14. The rationale being: these sites are in known bettong and phascogale habitat, or within 3 km of habitat, have been used by target threatened mammal species, and had a > 25% increase in fox detection between year two and three.	
4.	Sites M1 to K4 (koala monitoring site) should be considered as a secondary priority for fox control.	
5.	Review structure types and habitat connectivity south of Tyndale and New Italy to determine if additional sites can be sampled in year 2 monitoring of sections 3-11.	



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## Appendix A – Underpass camera detections

**Table A1:** Species/groups of fauna recorded per week by camera traps at 79 underpasses during 2020/2021 monitoring. Aut/win = autumn/winter, Sum = summer, C = complete crossing, IC = incomplete crossing, SBE = short-beaked echidna, Ant = antechinus, BtPhas = brush-tailed phascogale, NBB = northern brown bandicoot, LNB = long-nosed bandicoot, BC = bandicoot, SEBtP = short-eared brushtail possum, CBtP = common brushtail possum, BtP = brushtail possum, RB = rufous bettong, EGK = eastern grey kangaroo, RnW = red-necked wallaby, SW = swamp wallaby.

Site	Species Period	SBE		Ant spp.		BtPhas		NBB		LNB		BC spp		SEBtP		CBtP		BtP spp		RB		EGK		RnW		SW	
		C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC
1	Aut/win			1.4	0.1						0.1		0.1										0.3				0.5
	Sum			1.3	0.3								0.5				0.3										
2	Aut/win			6.6	1.1																						
	Sum			1.7	0.4									0.7				1.6				0.1					
3	Aut/win			3.0	0.2																	0.1					
	Sum	0.1		1.9	0.4			0.1				0.2				0.1		0.3									
4	Aut/win																										
	Sum																										
5	Aut/win			0.3	0.3											0.2								0.2		1.8	
	Sum			6.0	0.1																					0.2	
6	Aut/win			0.4																							
	Sum			0.0	0.3																						
7	Aut/win																									0.2	
	Sum			0.8						0.0	0.1	1.3															
8	Aut/win		0.1																							1.2	0.1
	Sum			0.5	0.1							0.1															
9	Aut/win			1.7									0.1														
	Sum			5.8	1.0							0.2															
10	Aut/win			0.9	0.3							0.3															
	Sum			3.2	0.6					0.1	0.1	0.1															
11	Aut/win			1.3	0.7															0.1							
	Sum																										
12	Aut/win																										
	Sum			0.1		0.2						0.1										0.1					
13	Aut/win			0.1																							
	Sum											0.1															
14	Aut/win				0.1																						
	Sum			0.3																							
15	Aut/win			1.2	0.4	0.1				0.1		0.8															
	Sum			0.3	0.1							0.1															
16	Aut/win			0.1		0.1																					
	Sum													0.4	0.1	0.1											
17	Aut/win			0.3												0.4											
	Sum													7.0	1.4												
18	Aut/win											0.1															
	Sum																										0.1

Site	Species Period	SBE		Ant spp.		BtPhas		NBB		LNB		BC spp		SEBtP		CBtP		BtP spp		RB		EGK		RnW		SW		
		C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	
19	Aut/win	0.3	0.1	1.8	0.4																							
	Sum	0.4											0.1															
20	Aut/win	0.1		0.8	0.3																							
	Sum			1.9	0.4																							
21	Aut/win																						0.3					
	Sum																						0.4					
22	Aut/win																											
	Sum			0.7	1.0							0.1											0.4	0.2				
23	Aut/win																						0.1	0.3				
	Sum																						0.3			0.9		
24	Aut/win																						0.2					
	Sum			0.1																			0.9	0.1	0.2			
25	Aut/win																						0.3				0.1	
	Sum																						0.1					
26	Aut/win	0.1																										
	Sum																											
27	Aut/win							0.1		0.3		1.6																
	Sum			0.1																								
28	Sum											0.5																
29	Aut/win			0.1						0.1																		
	Sum			0.9	0.1							0.6												0.6				
30	Aut/win	0.1						0.2				0.1											0.2			0.4	0.1	
	Sum																						0.4	0.1		1.4		
31	Sum																											
32	Aut/win					0.1																						
	Sum			0.1																								
33	Aut/win	0.1								0.1				0.1	0.1			0.1									0.3	
	Sum																											
34	Aut/win			0.1						0.2				0.1														
	Sum											0.1																
35	Aut/win																											
	Sum																									0.1		
36	Aut/win																											
	Sum																											
37	Aut/win									0.2	0.1	0.2																
	Sum											0.1																
38	Aut/win																						12.6			11.1		
	Sum																						39.4	0.8		17.9	0.6	
39	Aut/win													5.1	0.2											2.3		
	Sum													0.4	9.1											4.1	0.0	
40	Aut/win									1.0	0.2	0.4											0.2	0.4		0.1	0.1	
	Sum									0.1	0.1	0.1											0.1			0.2	0.2	
41	Aut/win									2.3	0.2															0.6	0.1	
	Sum																									0.3	0.3	
42	Sum																											

Site	Species Period	SBE		Ant spp.		BtPhas		NBB		LNB		BC spp		SEBtP		CBtP		BtP spp		RB		EGK		RnW		SW	
		C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC
43	Sum									0.1		0.1															
44	Aut/win	0.3																									
	Sum									0.2																0.2	
45	Aut/win																										
	Sum																										
46	Aut/win	0.2										0.1										0.1				0.7	
	Sum											0.1														0.3	0.1
47	Aut/win	0.2										0.7											0.4			14.7	0.1
	Sum	0.1										0.2											0.5			7.8	0.1
48	Aut/win									1.9		1.6		8.2	0.2	0.4							0.2			17.1	0.4
	Sum											0.1		0.6		4.3		4.1					1.1			2.5	
49	Aut/win											0.1														0.4	0.2
	Sum																									0.1	
50	Aut/win											0.1															
	Sum										0.1	0.1															
51	Aut/win			0.5																						0.1	
	Sum																										
52	Aut/win			0.2																						1.5	0.1
	Sum																									0.7	
53	Aut/win																									0.4	0.1
	Sum																									0.5	
54	Aut/win																						0.1			5.2	
	Sum																									0.1	
55	Aut/win																									4.2	
	Sum																									1.0	
56	Aut/win																									1.3	
	Sum																								0.1	0.1	
57	Aut/win	0.2										0.1											0.1	0.1			
	Sum																									0.4	0.2
58	Aut/win																									0.2	
	Sum																									0.1	
59	Aut/win																									1.3	
	Sum																									0.2	
60	Aut/win							0.1				0.1														4.4	0.1
	Sum																									1.3	
61	Aut/win																									0.9	
	Sum																									0.4	
62	Aut/win																										
	Sum																										
63	Aut/win																										
	Sum																										
64	Aut/win																										
65	Aut/win																										
	Sum																									0.1	

Site	Species Period	SBE		Ant spp.		BtPhas		NBB		LNB		BC spp		SEBtP		CBtP		BtP spp		RB		EGK		RnW		SW	
		C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC
66	Aut/win																										
	Sum																										
67	Aut/win																										3.3
	Sum																										0.4
68	Aut/win																										
	Sum																										
69	Aut/win																										0.3
	Sum																										
70	Aut/win											0.6														0.2	0.1
	Sum											0.1															
71	Aut/win			0.2																							
	Sum																										
72	Aut/win	0.1																									
	Sum																										0.2
73	Aut/win	0.1																									0.3
	Sum																										
74	Aut/win																										
	Sum																										
75	Aut/win	0.2										0.1	0.4	0.1				1.1	0.1								
	Sum	0.1											0.1					1.1									
76	Aut/win												2.6	0.7													
	Sum												3.9	0.3													
77	Aut/win																										
	Sum																										
78	Aut/win												0.4					0.1									
	Sum												0.8														
79	Aut/win		0.1											3.3	0.5			0.1									
	Sum																	0.3									

**Table A1:** Species/groups of fauna recorded per week by camera traps at 79 underpasses during 2020/2021 monitoring. Aut/win = autumn/winter, Sum = summer, C = complete crossing, IC = incomplete crossing, Wal = wallaby, MB = microbat, WR = water rat, SR = swamp rat, BuR = bush rat, HM = house mouse, BR = black rat, Rod = rodent, SmM = small mammal, EH = European hare.

Site	Species Period	Wal spp.		MB spp.	WR		SR		BuR		HM		BR		Rod spp		SmM		Fox		Dog		Cat		EH		Cow	
		C	IC	Present	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC
1	Aut/win			P									3.6	0.9	0.1						0.3							
	Sum	1.1		P									2.3						1.6									
2	Aut/win			P							0.1		0.2	0.1	0.6	0.5	0.1		0.1				0.1					
	Sum								0.1			0.2		0.3					4.4									
3	Aut/win			P											0.1			0.1	0.1									
	Sum			P								0.3	0.1	0.1					0.1									

Site	Species	Wal spp.		MB spp.	WR		SR		BuR		HM		BR		Rod spp		SmM		Fox		Dog		Cat		EH		Cow	
	Period	C	IC	Present	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC
4	Aut/win			P																								
	Sum			P																								
5	Aut/win	1.1		P																			0.2					
	Sum	0.1		P			0.1												0.4	0.1					0.1			
6	Aut/win			P								0.5	0.1			0.1				0.2								
	Sum			P				0.1							0.1													
7	Aut/win			P																			0.6	0.2				
	Sum			P											0.1													
8	Aut/win	0.1		P									0.2															
	Sum			P									0.2	0.1	0.1				3.0	0.1								
9	Aut/win			P											0.2					0.1						0.1		
	Sum			P									0.3		0.1					0.1				0.1		0.1		
10	Aut/win			P											0.1					0.1	0.1					0.1	0.1	
	Sum			P	0.3						0.5		1.0	0.2	0.1			0.1	0.1									
11	Aut/win			P							0.1		3.6	0.8	0.1													
	Sum			P																								
12	Aut/win			P									2.1	0.2	1.1					0.1						0.2		
	Sum			P									2.2	1.0	0.4					0.7								
13	Aut/win			P							0.7	0.2	1.9	1.4	0.2													
	Sum			P									0.1	0.1	0.3					0.4	0.3							
14	Aut/win			P											0.2					0.2								
	Sum			P									1.8														0.3	
15	Aut/win			P									2.7	0.8	0.7					0.4								
	Sum			P									1.1							0.3								
16	Aut/win			P						0.1						0.6	0.1	0.1					0.3					
	Sum			P					0.1	0.1	0.2		0.1	0.2	0.1										0.1	0.1		
17	Aut/win			P																								
	Sum			P									0.1															
18	Aut/win			P																	0.1	0.1			0.4			
	Sum			P								0.1																
19	Aut/win			P			0.1					1.2	0.2			1.2	0.2	0.4					0.1	0.1				
	Sum			P				0.1				1.3	0.4			0.1												
20	Aut/win			P			0.1			0.1		0.2				0.1				0.1				0.2			0.1	
	Sum			P						0.2						0.3				0.3						0.1		
21	Aut/win			P																1.0								0.6
	Sum			P																0.1								1.9
22	Aut/win	0.8		P								0.3	0.1							3.4	0.1	2.0		0.1				
	Sum	0.4		P	0.1							3.4	0.3	0.3							0.1		4.2	0.1	0.3			
23	Aut/win	2.7		P								0.0	0.1							0.1					0.8			
	Sum	2.4		P											0.1									0.3	0.1			
24	Aut/win	1.9		P																0.1				1.0	0.4			
	Sum	1.3		P																		0.1		0.7				
25	Aut/win			P																		2.2						
	Sum			P																								

Site	Species	Wal spp.		MB spp.	WR		SR		BuR		HM		BR		Rod spp		SmM		Fox		Dog		Cat		EH		Cow	
		Period	C		IC	Present	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC
26	Aut/win			P							0.2		2.3	0.3					0.2									
	Sum												0.6	0.3														
27	Aut/win			P									2.5	0.1	0.1	0.1			0.1	0.1								
	Sum			P																				1.0	0.2			
28	Sum	0.1		P											0.1									0.2				
29	Aut/win	0.2		P									0.6	0.1	0.3				0.1									
	Sum	1.2		P									0.3	0.2										0.2				
30	Aut/win			P									2.4						0.2									
	Sum	0.4																										
31	Sum			P																								
32	Aut/win			P			0.1							0.2														
	Sum			P									0.1															
33	Aut/win			P									4.2	1.1	0.3	0.2												
	Sum			P								0.4	0.2	0.4	0.2	0.1												
34	Aut/win			P								1.0	0.1	1.9	1.1	0.2	0.1											
	Sum			P								0.7	0.1	1.8		0.1												
35	Aut/win																		0.2				0.2					
	Sum			P											0.1													
36	Aut/win			P									0.1															
	Sum			P									4.1	0.8														
37	Aut/win			P							0.5	0.2			0.1								1.8					
	Sum														0.2	0.1												
38	Aut/win			P											0.2				0.1									
	Sum																											
39	Aut/win	0.4											11.0	0.9														
	Sum												0.7															
40	Aut/win			P									0.8	0.1	0.6	0.2			0.4									
	Sum			P									0.6	0.1														
41	Aut/win			P									0.2	0.1					0.2				0.1	0.1				
	Sum			P											0.0	1.4												
42	Sum			P									1.0	0.8														
43	Sum			P									0.8	2.4														
44	Aut/win										0.4	0.1	3.8	0.7	0.1								1.1	0.3				
	Sum												2.3	0.4									1.9		0.1			
45	Aut/win			P									7.7	0.4	0.1													
	Sum			P									3.9	1.2														
46	Aut/win	0.1		P			0.3						10.5	1.2	2.2				0.4									
	Sum			P	0.2		0.2				0.1	0.2	1.1	0.8	0.4	0.1										0.1		
47	Aut/win	0.2											0.9															
	Sum	0.8		P									0.3						0.1								0.2	
48	Aut/win																		0.2								0.2	
	Sum			P									0.1														0.2	
49	Aut/win																			0.9								
	Sum																			0.1								



Site	Species	Wal spp.		MB spp.	WR		SR		BuR		HM		BR		Rod spp		SmM		Fox		Dog		Cat		EH		Cow	
	Period	C	IC	Present	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC
50	Aut/win												3.1	0.7	0.2													
	Sum			P									0.3						0.1									
51	Aut/win												0.4	0.1														
	Sum			P									2.9	1.0	0.1	0.4												
52	Aut/win												0.0	0.1							0.1							
	Sum			P									0.1								0.1							
53	Aut/win												0.7		0.3						0.4							
	Sum												0.8	0.1							0.1							
54	Aut/win			P							0.1		0.3							0.9	0.1							
	Sum			P									1.7	0.2						0.4								
55	Aut/win			P									0.7							0.2								
	Sum			P																								
56	Aut/win			P														0.1										
	Sum			P									0.6	0.1						0.4								
57	Aut/win	0.1											1.0	0.1	0.8	0.3				0.3								
	Sum																											
58	Aut/win			P																								
	Sum												0.1															
59	Aut/win																			1.2	0.2							
	Sum												0.1	0.1														
60	Aut/win										0.4		0.2	0.3						0.2					0.1			
	Sum										0.2									1.1				0.2				
61	Aut/win						0.1								0.1													
	Sum						0.1														0.1							
62	Aut/win												3.7	0.6						0.7	0.2							
	Sum														0.1					0.1				0.1				
63	Aut/win	0.3											15.2	0.6						0.2								
	Sum												0.3	0.3						0.1								
64	Aut/win														0.2													
65	Aut/win												1.2	1.4	0.1					1.7	0.6							
	Sum												0.8	0.5						0.9								
66	Aut/win												2.1	0.3	1.0					2.1	0.3							
	Sum																			0.8	0.2							
67	Aut/win												1.6							0.7								
	Sum												0.1							0.3								
68	Aut/win			P									0.6	0.2	0.3	0.1				2.5	0.2							
	Sum											0.1								0.1								
69	Aut/win	0.4											3.5	0.2	0.4					3.1	0.4							
	Sum		0.1										1.1	0.3	0.1	0.4				0.7	0.1							
70	Aut/win			P									9.0	1.7	0.1					2.3								
	Sum	0.2										0.1	0.1	2.7	1.0					0.6	0.1							
71	Aut/win														0.1					0.4								
	Sum												0.1	0.2						0.6	0.1							

Site	Species	Wal spp.		MB spp. Present	WR		SR		BuR		HM		BR		Rod spp		SmM		Fox		Dog		Cat		EH		Cow	
		C	IC		C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC	C	IC
72	Aut/win										0.1		0.9						0.2									
	Sum																											
73	Aut/win												2.5	0.1					0.5									
	Sum			P									1.6	0.1					1.1									
74	Aut/win												2.2	0.2	0.9													
	Sum												1.5	0.4	0.1				0.5									
75	Aut/win					0.2	0.1						1.7	0.7	0.3													
	Sum												0.2	0.2					7.1	0.2								
76	Aut/win												1.8	0.4					0.7									
	Sum												0.4	0.2					0.5									
77	Aut/win			P		0.1							0.7															
	Sum												0.3															
78	Aut/win										0.1				0.2				1.4									
	Sum																		0.1					0.1	0.1			
79	Aut/win										0.5		0.7		0.2				0.3									
	Sum										0.1		0.8						0.4							0.1		

## Appendix B – Scat & track survey data

**Table B1:** Species, site and location within each site of scat and track detections from four inspections (2/camera monitoring season). Rail = wooden rail of culvert furniture.

Species	Scat			Track	Present in underpass
	Rail	Floor	Rail & floor		
Antechinus	1-3,5,7,9-12,15,24,54		8,23		
Rodent	1,2,3,5,15,26,28,33,34,42,45,47,48,51,61-63,65,66,69,70,79	16,18,19,36,39,40,46,56,71,73	50,55,57,67,74,76	2,8,28,39,50,54,63,69,78	
Water rat				36	
Wallaby		15,27,28,34,39,40,41,48,52,53,56,57,59,67		3,5,9,10,24,34,39,46,47,54,58,60,61,63	
Eastern grey kangaroo		21,53		8,47	
Bandicoot		23,28,31,34,41,55,63		9-11,50,54	
Brush-tail possum	17,23,67	16,39,46,50		69	
Short-beaked echidna		47,51,52			
Fox		51,59		2,8,10,50,54,58,60,63,65,69-71,73	
Cat		23			
Dog		51		7,8,65,70	
Canid		15,35,52,60,67,79			
Horse				22	
Cow		21		21	
Pig				17	
Microbat spp.	52	4,5,8,17,19,23,24,27,36,37,42,50,51,55,58,62,72,79			50,51
Little bent-wing bat					4 (x 100s of ind.), 17 (x 2 ind.), 23 (4 x ind. in joints), 24 (13 x ind. in joint), 37 (1 x ind.)
Large bent-wing bat					23 (15 x ind.)
Eastern horseshoe bat					5 (1 x ind. on rail)
Chocolate wattled bat					8 (1 x ind. in bat box)
Myotis macropus					36 (4 x possible ind.), 55

## Appendix C – Road mortality survey data

**Table C2:** Road mortality survey data for three quarters.

Date	Survey period	Observers	Time start	Time end	Carriageway	Species	Easting	Northing	Cleared off Rd	Notes
9/07/2020	Q3	LA & NM	1345	1500	NB	Medium mammal	517704	6678360	No	50S corindi ck bridge
	Q3	LA & NM			SB	Fox	506466	6691379	Part of	500m s luthers rd
	Q3	LA & NM			SB	European hare	512250	6686252	Part of	McPhillips rd
	Q3	LA & NM			SB	NB bandicoot	514469	6682265	No	1200M s range road e
	Q3	LA & NM			SB	Dog	515200	6681967	No	1650M n mclaughlin rd
	Q3	LA & NM			SB	Bandicoot spp	517892	6678027	No	470M n kangaroo trail rd
16/10/20	Q4	NM & BT	1420	1530	SB	Laughing kookaburra	509392	6688190	Yes	Near servo
	Q4	NM & BT			SB	Cat	510391	6687391	Yes	Near servo
	Q4	NM & BT			NB	Bandicoot spp	517645	6678501	No	Corindi ck bridge
	Q4	NM & BT			NB	Eastern grey kangaroo	506546	6690606	No	Halfway ck bridge
23/2/21	Q1	NM & LA	740		NB	Medium bird	517634	6678527	No	Corindi river bridge
	Q1	NM & LA			NB	Small bird	515913	6680983	No	Near south median
	Q1	NM & LA			NB	Chicken	513461	6683153	No	180M n range road overpass
	Q1	NM & LA			NB	Lacey	506012	6692767	No	20S of culvert 9/10 median
	Q1	NM & LA			NB	Currawong	504252	6699564	No	Just n of Glenugie Ck glide bridge
	Q1	NM & LA			NB	Snake spp	512344	6716255	Yes	700M S one brush glide poles
	Q1	NM & LA			NB	Flying Fox spp	512847	6717985	No	200 S bostock road
	Q1	NM & LA			NB	Eastern small-eyed snake	513652	6721019	No	
	Q1	NM & LA			NB	Medium bird	513643	6721058	No	
	Q1	NM & LA			NB	Little red flying-fox	519373	6735134	No	900N shark creek
	Q1	NM & LA			NB	Med/large macropod	519583	6736577	No	360N mcintyres lane
	Q1	NM & LA			NB	Medium bird	519835	6738161	No	1Km S maclean exit
	Q1	NM & LA			NB	Small bird	520623	6740809	No	E of highland ridge rd

Date	Survey period	Observers	Time start	Time end	Carriageway	Species	Easting	Northing	Cleared off Rd	Notes
	Q1	NM & LA			NB	Medium bird	523377	6744010	No	Start of harwood bridge
	Q1	NM & LA			NB	Australian Magpie	524077	6750008	No	660S Carroll's lane, Chatsworth
	Q1	NM & LA			NB	Medium mammal	524419	6751226	No	Start of north arm bridge
	Q1	NM & LA			NB	Small bird	524360	6751519	No	Towards end of north arm bridge
	Q1	NM & LA			NB	Carpet python	520990	6760997	No	Parallel to pine rd ext
	Q1	NM & LA			NB	Carpet python	522479	6762951	No	W Mervs rd, Hway Ck
	Q1	NM & LA			NB	Australian Magpie	527326	6773040	No	Same as below
	Q1	NM & LA			NB	Medium bird	527326	6773045	No	Bridge 280S minyumai rd
	Q1	NM & LA			NB	Snake spp	531197	6777183	No	500S Norton's rd
	Q1	NM & LA			NB	Medium bird	533004	6780796	No	Tuckombil rd overpass
	Q1	NM & LA			NB	Eastern grey kangaroo	533265	6782146	No	300Ms tuckombil canal
	Q1	NM & LA			NB	Medium lizard spp.	543310	6791378	No	200m south of Richmond Bridge
	Q1	NM & LA			NB	Medium mammal	542142	6797807	No	Just before old 47b site
	Q1	NM & LA			NB	Medium bird	545120	6799547	No	
	Q1	NM & LA			NB	Cane toad	545147	6799550	No	
	Q1	NM & LA			SB	Swamp wallaby	546303	6800741	No	250n coolgardie rd
	Q1	NM & LA			SB	Medium mammal	541944	6795531	No	100N bingal Ck
	Q1	NM & LA			SB	Bandicoot spp	542041	6795065	No	30ms of Old B'tville rd
	Q1	NM & LA			SB	Medium bird	543178	6791648	No	End of richmond river bridge
	Q1	NM & LA			SB	Bandicoot spp	542070	6789275	No	Near old 29c
	Q1	NM & LA			SB	Medium mammal	538070	6785251	No	ch: 135800
	Q1	NM & LA			SB	Medium macropod	535063	6783071	No	
	Q1	NM & LA			SB	Cat	531397	6777593	No	Nortons rope bridge
	Q1	NM & LA			SB	Medium bird	530907	6776327	No	450N redgates rd
	Q1	NM & LA			SB	Little red flying-fox	527357	6773043	No	Near Minyumai bridge
	Q1	NM & LA			SB	Ff spp	526009	6769351	No	
	Q1	NM & LA			SB	Medium bird	521022	6758256	No	80m n tabbimobile Ck

Date	Survey period	Observers	Time start	Time end	Carriageway	Species	Easting	Northing	Cleared off Rd	Notes
	Q1	NM & LA			SB	Med/large mammal	523376	6748957	No	
	Q1	NM & LA			SB	Bandicoot spp	523283	6748528	No	Chatsworth rd turn off
	Q1	NM & LA			SB	Australian Magpie	518609	6732382	No	Near ch;72700
	Q1	NM & LA			SB	Australian Magpie	517961	6731840	No	Opp. Byrons In
	Q1	NM & LA			SB	Little red flying-fox	513223	6726190	No	Ch 63800
	Q1	NM & LA			SB	Carpet python	513569	6720736	Ch 58920	Shoulder
	Q1	NM & LA			SB	Med Mammal	516615	6680152	No	S1/2 median south end
	Q1	NM & LA			SB	Med/large macropod	517256	6679276	No	Corindi river bridge