Woolgoolga to Ballina Pacific Highway Upgrade

Threatened mammal underpass monitoring program, sections 3-11, year 2 operation phase.

Annual Report 2021-22

Transport for New South Wales | May 2023 | Final report

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Annual Report 2021-22

SANDPIPER ECOLOGICAL SURVEYS

Final Report
May 2023

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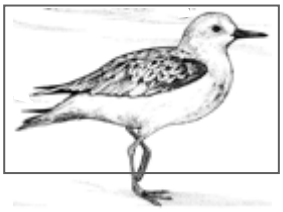

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Cover Photo: Brush-tailed phascogale photographed during glider population monitoring near Glenugie on 30 March 2023 (Source F. Makin).

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1 Introduction

1.1 Background

The Woolgoolga to Ballina (W2B) Pacific Highway Upgrade was opened to traffic in two main stages. Sections 1 and 2 were opened to traffic in 2018 and Sections 3-11 were opened progressively throughout 2020. Conditions of approval for the W2B upgrade required Transport for New South Wales (TfNSW) to monitor 64 underpasses for use by koalas (*Phascolarctos cinereus*) and 79 underpasses for use by other threatened mammals, including brush-tailed phascogale (*Phascogale tapoatafa*), spotted-tailed quoll (*Dasyurus maculatus*), rufous bettong (*Aepyprmnus rufescens*) and long-nosed potoroo (*Potorous tridactylus*). Details on the required underpass monitoring program are included in the Koala Management Plan (KMP; RMS 2016) and the Threatened Mammal Management Plan (TMMP; TfNSW 2015).

To assess the effectiveness of the proposed mitigation measures, the TMMP and KMP detailed a comprehensive monitoring program. Components of the plan addressed in this report include:

1. Fauna crossing structure monitoring.
2. Road mortality and exclusion fence monitoring.

Sandpiper Ecological Surveys (Sandpiper) was contracted by Transport for NSW (TfNSW) to implement the fauna crossing structure and road mortality monitoring components of the KMP and TMMP. Monitoring in sections 1 and 2 commenced in 2018 and was completed in 2021 (see Sandpiper Ecological 2021a & b). Monitoring in sections 3-11 commenced in January 2021 (Sandpiper Ecological 2021a). The following report covers monitoring in spring/summer 2021 – year 1 operational phase sections 3-11 for koala, and summer/autumn and autumn/winter 2022 – year 2 operational phase sections 3-11 for threatened mammal. For comparative purposes data are also presented for year one operational phase threatened mammal sampling in summer/autumn and autumn/winter 2021 for sections 3-11.

1.2 Aim, program objectives and performance indicators

The primary aims of the monitoring programs is to: determine the effectiveness of mitigation measures implemented in Sections 1-11 of the upgrade for the target species and inform adaptive management actions.

The objectives of the monitoring program include:

1. *Evaluate the success of mitigation measures against the performance measures and corrective actions.*
2. *Assess the effectiveness of the fauna crossing structures and fauna exclusion fencing to facilitate movement of koalas across the upgraded highway.*

Based on the above objectives, the success or otherwise of the monitoring program shall be determined by program performance against relevant performance indicators (KMP) and mitigation goals (TMMP) (Table 1).

Table 1: Performance indicators and corrective actions relevant to fauna crossing structure and road mortality monitoring.

Performance indicator/mitigation goal	Performance threshold	Corrective actions
Koala Management Plan		
1. Road mortality	• No injury to an individual koala as a result of vehicle strike across all upgraded sections. • Section 10: no koala road mortality within the fenced areas of the upgrade, on existing Pacific Highway or Wardell Road.	• Examine fencing for breach or obstruction within 3 days of report & repair. • Retrofit exclusion fencing, or part there-of, with additional measures to deter koalas. • Section 10: RMS would consider erecting koala-proof fencing on Bruxner Hwy (a known koala road-kill black spot), to reduce koala mortality across the region.
2. Fauna crossing structures	• Evidence of at least one completed crossing by koalas at targeted fauna crossing structures. • Evidence of individual koalas using structures and/or breeding on either side of the highway, via scat analysis. • No evidence of high visitation/usage rates by exotic predators.	• Review monitoring methods. Consider increasing frequency, intensity and duration, to ensure individuals are identified. • Check fauna furniture associated with underpass for damage and rectify. • Investigate habitat adjoining underpass. Consider improving habitat condition and connectivity.
3. Fauna exclusion fence	• No breaches in fauna exclusion fence.	• Check fauna exclusion fencing, and fauna crossing structures for damage/blockage and rectify.
4. Predator attack near fauna crossing structures	• No koala deaths or injuries due to predator attack in the vicinity of fauna crossing structures.	• Where monitoring indicates that predators are a threat to koala movement through crossing structures, RMS will engage with North Coast LLS, NSW NPWS (Grafton), RLP Board (North East) & adjacent landowners to identify and implement strategies to reduce this predation risk.
Threatened Mammal Management Plan		
Maintain fauna exclusion fencing and connectivity structures for the life of the project.	• Maintenance of fauna exclusion fencing at connectivity structures as part of routine highway maintenance to remove debris and replace damaged rope crossings. • Monitor roadkill as part of the routine road maintenance and repair broken exclusion fencing or install new fencing where required.	• A maintenance check is to be performed within 5 days of any reported roadkill incident. • Any fence or structure found to be damaged during a maintenance check is to be repaired. Initiate repair work within 5 days of identification.
Crossing structures for threatened mammals facilitates natural daily movements. Potoroo recorded using underpasses after three consecutive	• Threatened mammals are not recorded using connectivity structures for three consecutive monitoring periods. • No Potoroo recorded using underpass structures at Site 3A, 4A, 5A, 6A post three consecutive monitoring periods after installation	Evaluate potential reasons for species not using crossing structure within three months of trigger. Assess fencing in the area of the structure, vegetation and habitat condition. Assess if pest animals are having an impact on mammals use of structures Corrective actions may include: • Greater maintenance of the existing connectivity structure/s

Performance indicator/mitigation goal	Performance threshold	Corrective actions
monitoring periods after installation		• Update design of existing measures where feasible and reasonable • Consider additional offset measures to improve connectivity elsewhere • Increase pest animal control if they are found to occur at crossing structures. • TfNSW to consult with relevant agencies to determine appropriate actions as soon as possible.

2 Study area

The broader study area includes sections 1-11 of the W2B Pacific Highway upgrade alignment and adjoining habitat. The 155 km-long upgrade stretches from Woolgoolga in the south to Ballina in the north. It is entirely located within the NSW North Coast Bioregion, one of the most diverse in NSW (W2B Planning Alliance 2012). The project boundary is located within a landscape that has been either fragmented or cleared for agriculture and rural development although a substantial area of forest persists across the broader study area (W2B Planning Alliance 2012).

For the purposes of this report, monitoring activities were conducted in sections 1-11 (road mortality monitoring) and sections 3-11 (crossing structure monitoring) (Figures 1). The study area is focussed on the W2B alignment and vegetation within 100m of sample sites (i.e., underpasses).

Figure 1: Sections 1-11 (orange line) of the Woolgoolga to Ballina Pacific Highway Upgrade.

3 Methods

3.4 Crossing structure monitoring

3.4.1 Sample sites

A total of 74 sites were monitored, including 56 sites for koala and 71 sites for threatened mammals (Table 2, Figures 2-7). Three structure types were sampled, reinforced concrete box culverts (RCBC), reinforced concrete pipes (RCP) and bridges. RCBC ranged in aperture size from 1.2x1.2m to 3x3m and in length from 15m to 66m. RCBC and bridge underpasses featured timber post-and-rail (fauna) furniture through their length (Plate 1). Underpass floor substrate varied and included bare concrete, concrete and raised gravel path, mulch on concrete and a combination of gravel and soil. All RCP had a bare concrete base.

Table 2: Number and type of structures sampled during year one of the operational phase in sections 3-11 of the W2B upgrade.

Structure type	Koala sites	Threatened mammal sites	Total sites
RCBC	33	38	39
RCP	5	10	12
Bridge	18	22	23
Totals	56	71	74

3.4.2 Sample periods and survey effort

Spring/summer 2021 koala monitoring commenced on 22 September 2021 and continued until mid-February 2022, with monitoring at some sites suspended between 16 December 2021 and 13 January 2022 (Table 3). The suspension was in response to camera theft, with 16 cameras from eight sites stolen between 22 September and 16 December 2021. Threatened mammal monitoring in summer 2022 was punctuated by two major flood events, which resulted in inundation of 47 cameras at 27 sites and delayed camera retrieval. Several sample sites remained inundated in late 2022 (Plate 1).

Table 3: Installation and retrieval dates for camera monitoring of underpasses in sections 3-11 of the W2B upgrade. T'mam = threatened mammal.

Sample period	Install dates	Retrieve dates	Notes
Koala (spring/summer)	22/9-9/10/2021	16/12/21 – reinstall 13/1/22 to 16/2/2022	16 cameras stolen from 8 sites
T'mam #1 (summer/autumn)	11-13/1/2022	28/3-5/4/2022	Major floods on 1/3/2022 & 30/3/2022. 27 sites and 47 cameras inundated on 1/3/22.
T'mam #2 (autumn/winter)	3-6/5/2022	9-22/7/2022	Several sites remained inundated

Spring/summer 2021

Fifty-six sites were sampled during the koala monitoring period with 66 pairs of cameras installed, including 11 bridges with four cameras at each. The minimum koala sample effort of 84 days was achieved at 68% of sites, with a further 7% of sites having at least one camera active for the minimum sample period. Failure to achieve minimum sample effort at the remaining 25% of sites was due to theft (13%), card error (4%), flooding (2%) and battery failure (6%). A total of 10,685 camera sample days was achieved during the spring/summer 2021 sample period, which equates to 96% of the total effort required. Total effort required equates to the

minimum number of cameras multiplied by the minimum sample period specified in the relevant management plan.

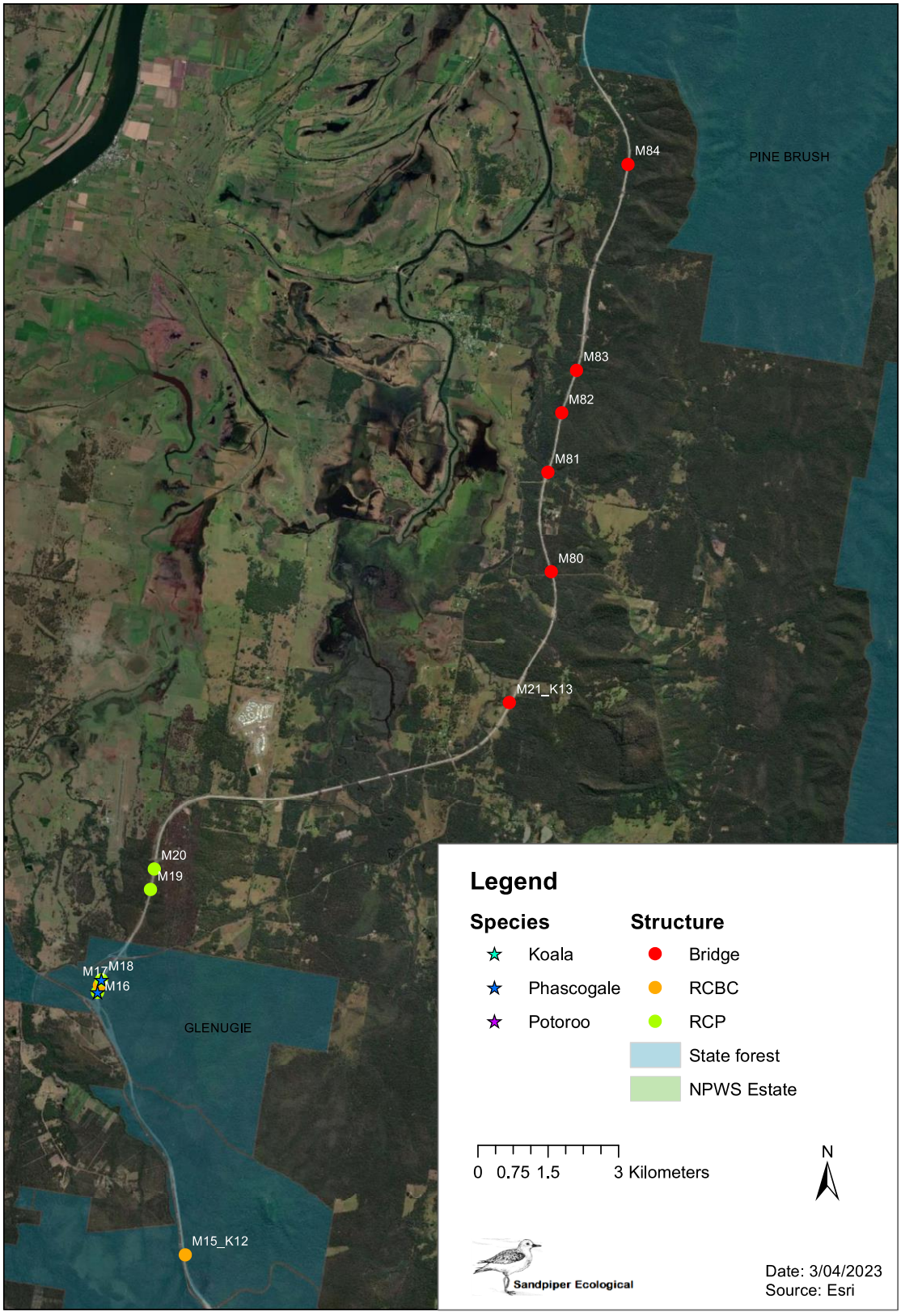

Figure 2: Location of underpass sample sites in the Glenugie area.

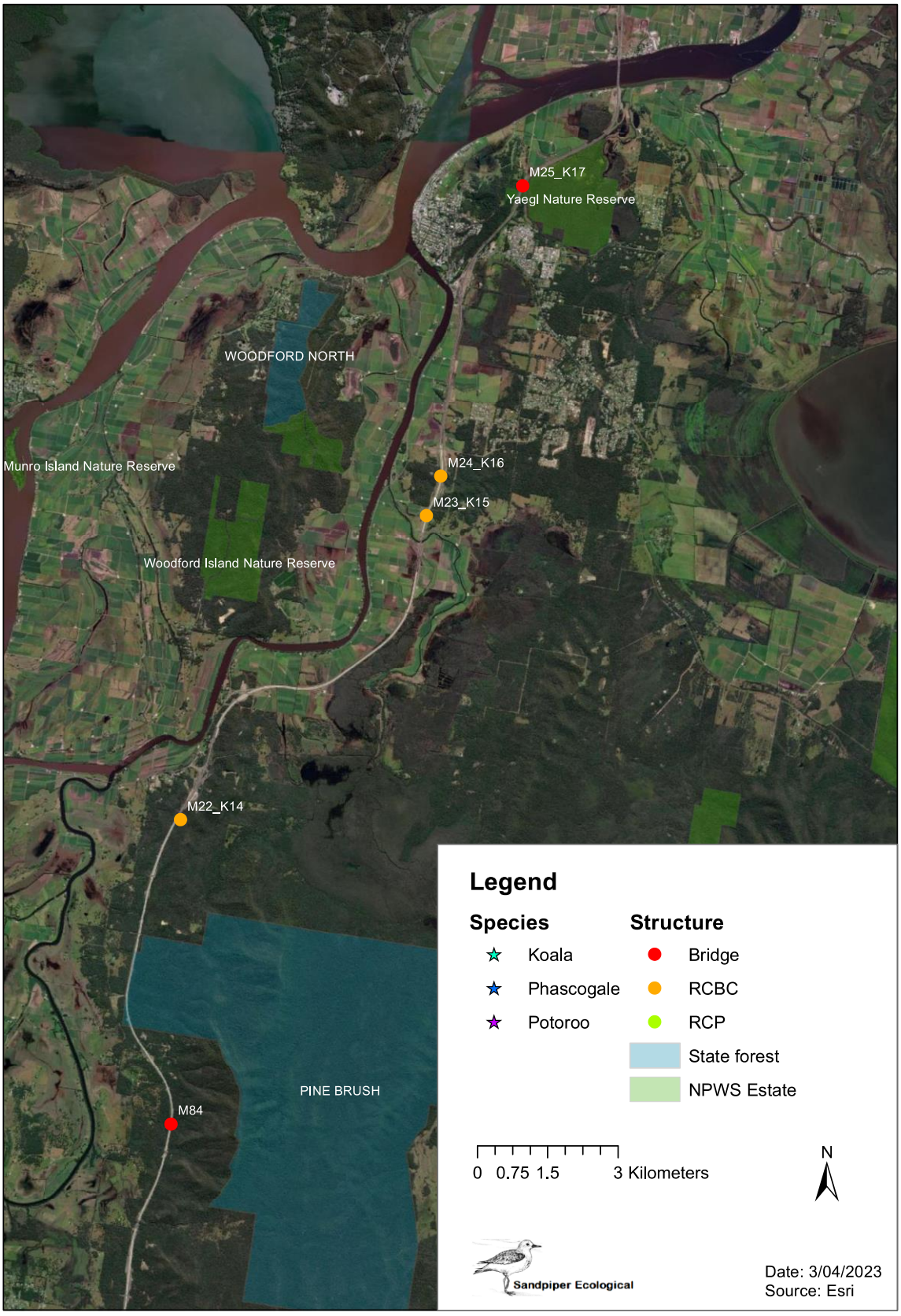

Figure 3: Location of underpass sample sites in the Maclean area.

Figure 4: Location of underpass sample sites in the Mororo area.

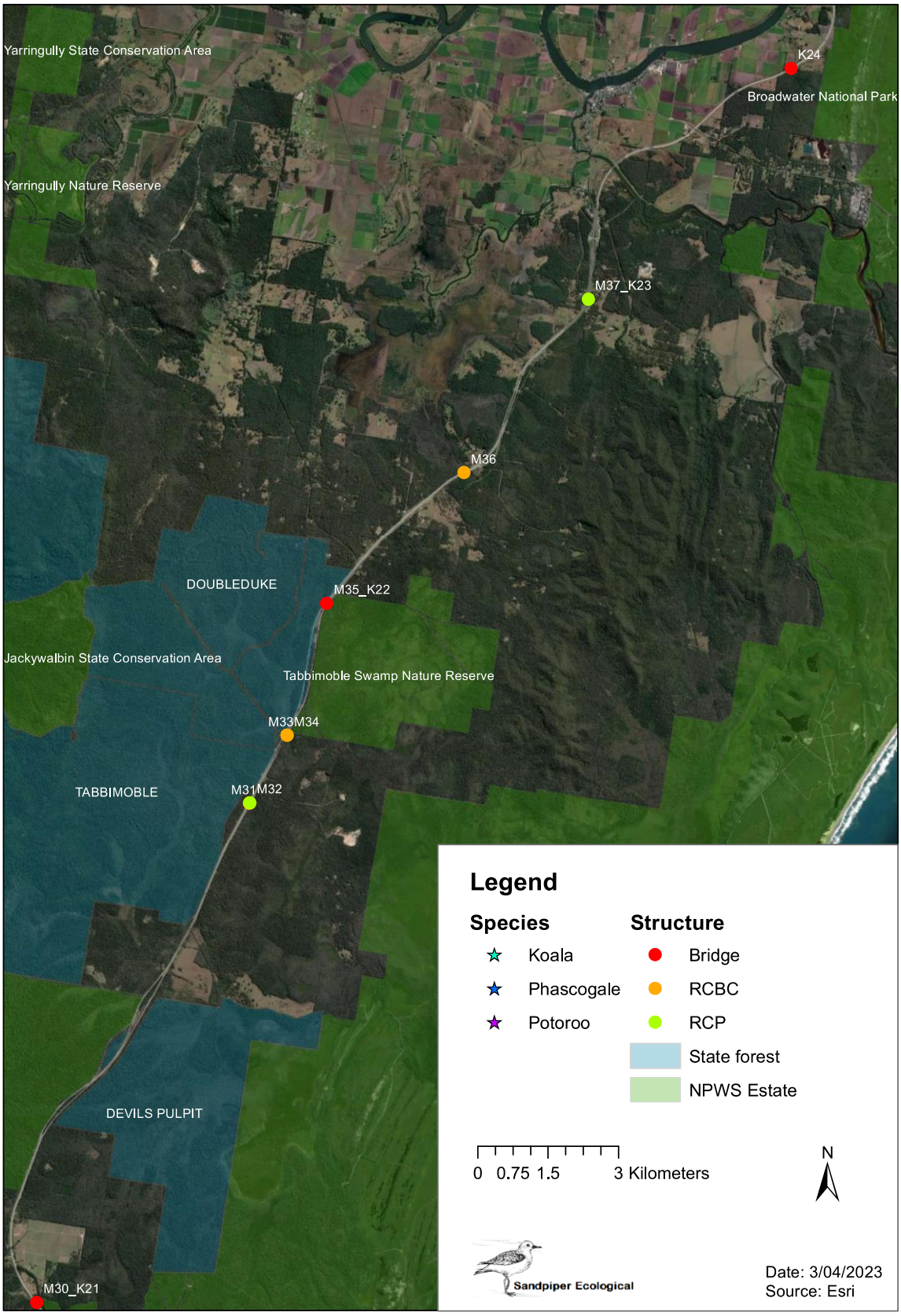

Figure 5: Location of underpass sample sites in the Tabbimoble area.

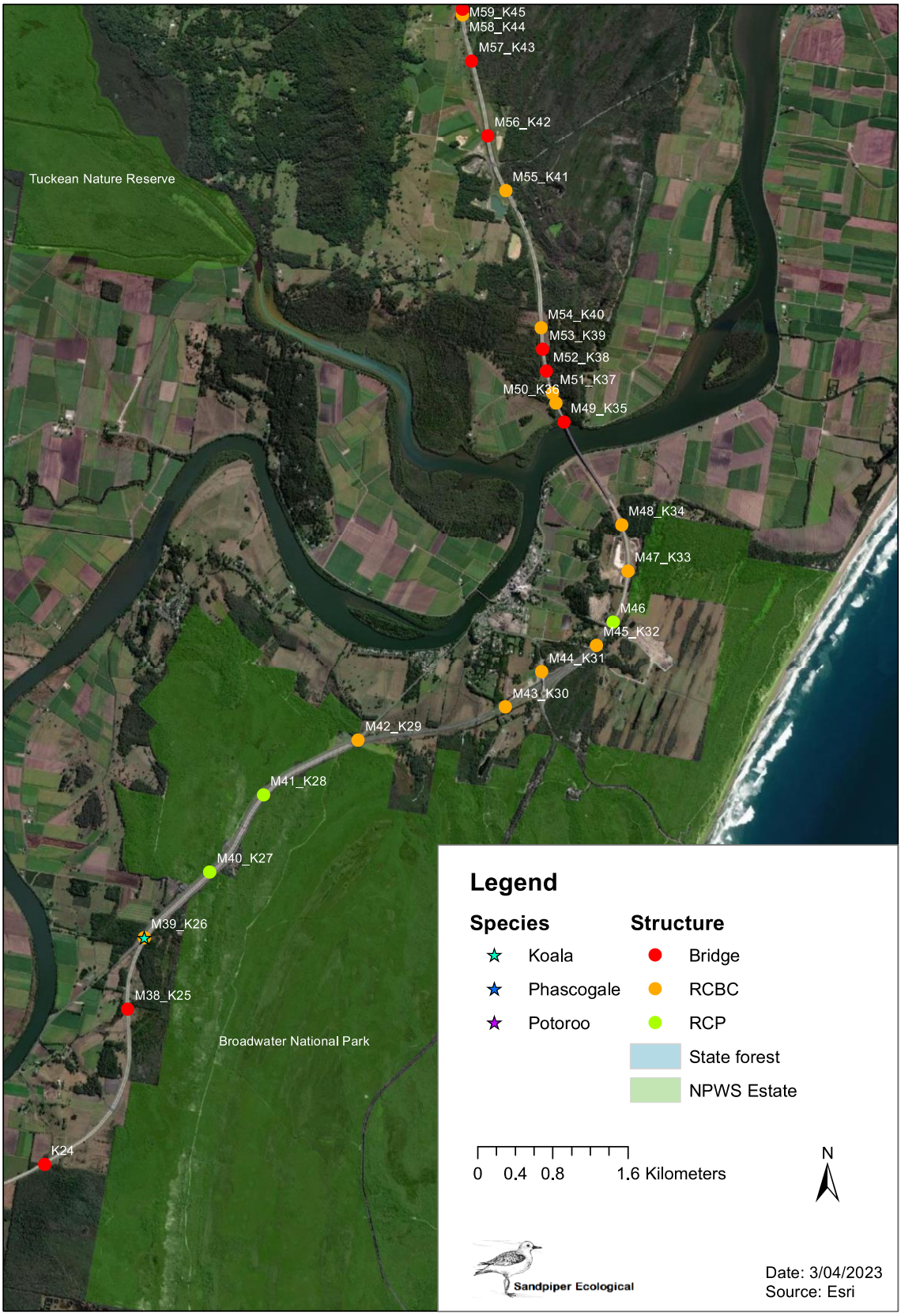

Figure 6: Location of underpass sample sites in the Broadwater area.

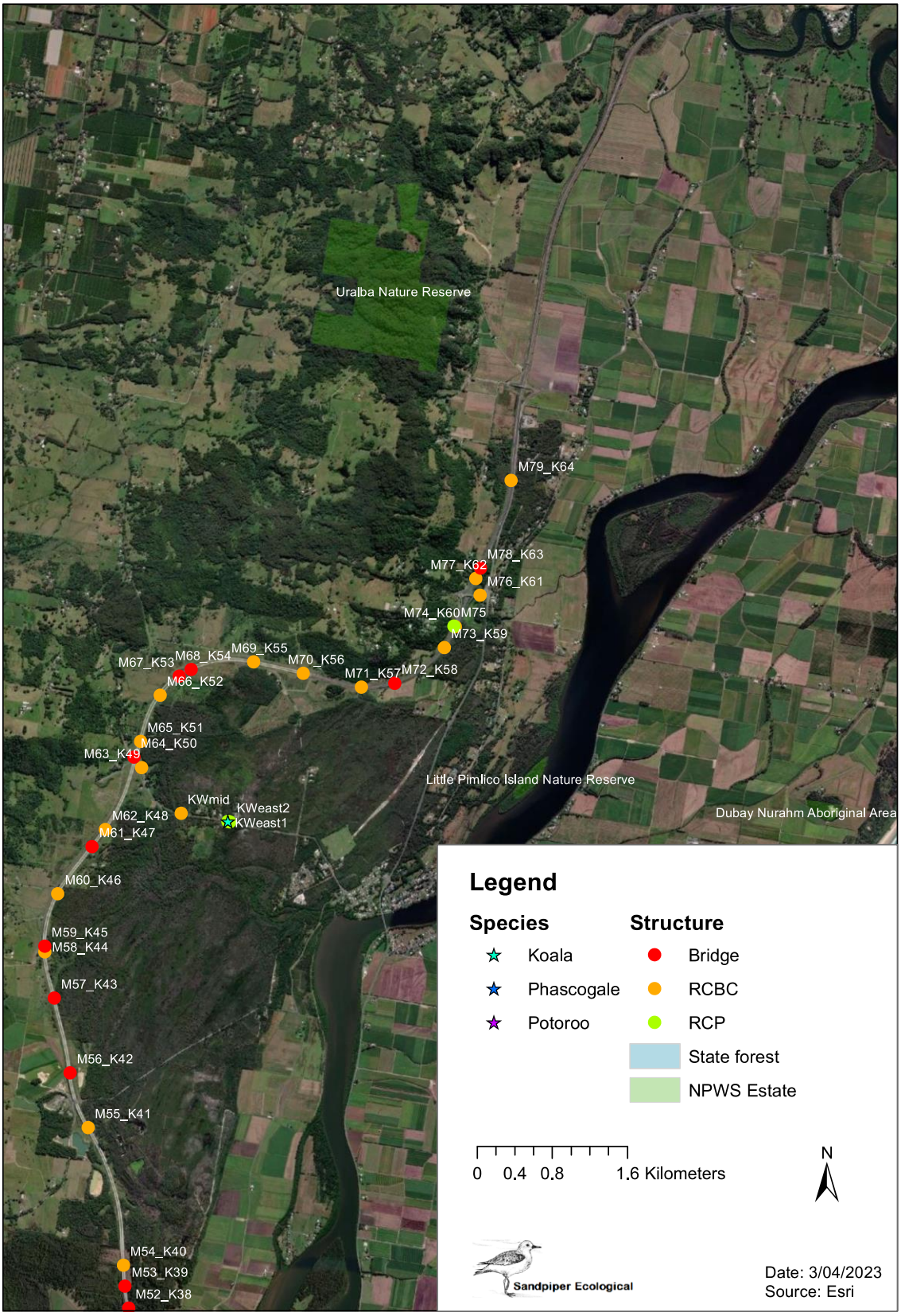

Figure 7: Location of underpass sample sites in the Wardell area.

Plate 1: Bridge underpass (M68/K54) remained inundated throughout 2022. This photograph was taken in August 2022 six months after the initial flood event.

Summer/Autumn 2022

A total of 71 structures were inspected during the summer/autumn 2022 monitoring period with cameras installed at 69 structures (Table 4). The two structures not sampled were M76 and M77 at Coolgardie Road as both were inundated at the beginning of the sample period. Survey effort was increased in summer/autumn 2022 by sampling an additional five bridges in Section 3. A total of 79 camera pairs were sampled. The minimum threatened mammal sampling effort of 56 days by two cameras was achieved at 70% of sites, with an additional 10% of sites achieving this threshold for one camera. The minimum sample effort was not achieved at the remaining 20% of sites. This was primarily due to inundation of many ground cameras in late February/early March. A total of 10,186 camera sample days was achieved during the summer/autumn 2022 sample period, which is 15% higher than the total effort required.

Autumn/Winter 2022

The same structures were sampled in autumn/winter 2022 as during the summer/autumn period (Table 4). During autumn/winter 91% of sites received the minimum camera sampling effort with a further 3% of sites having one camera active for the minimum period. The remaining 6% of sites did not achieve the minimum camera monitoring requirement. A total of 12,186 camera sample days was achieved during the autumn/winter 2022 sample period, which higher than the total effort required.

The 69 structures monitored in sum/aut and aut/wint 2022 was five more than required by the TMMP.

Table 4: Underpass camera monitoring effort during 2021/2022 operational phase monitoring in sections 3-11 of the W2B upgrade. CE – Card Error; CSAC = cams stolen after check; CSBC = cams stolen before check; * = single carriageway only; H = height (m); W = width (m); L = length (m), **actual size is 900mm x 1200mm due to inclusion of 300mm slab in base.

Site no. (tmam/ koala)	Chainage	Section	Underpass type & size (HxWxL)	Koala (spr/sum 2021)		Threatened mammals			
				No. of videos (floor/rail; or east/west)	Days active (floor/rail; or east/west)	No. of videos (floor/rail; or east/west)		Days active (floor/rail; or east/west)	
						Aut/win	Sum/aut	Aut/win	Sum/aut
KW east1	152500	10	RCPx1* (1x15)	1433/163	76/103	NS	NS	NS	NS
KW east2	152500	10	RCPx2* (0.9x15)**	856/76	103/103	NS	NS	NS	NS
KW mid	152547	10	RCBC* (1.2x2.4x15)	89/0 (CE)	114/114	NS	NS	NS	NS
M15/K12	29300	2	RCBC (2.4x2.4x25)	41/644	84/84	19/50	5/40	107/107	74/74
M16	35100	3	RCP (1.2x47)	NS	NS	54/24	35/13	79/79	74/74
M17	35270	3	RCBC (2.7x3x37)	NS	NS	36/12	19/29	79/79	74/74
M18	35380	3	RCP (1.2x53)	NS	NS	860/0 (CE)	10/81	107/107	74/74
M19	37600	3	RCP (0.825x0.825x52)	NS	NS	278/47	113/34	107/107	74/74
M20	38100	3	RCP (0.9x47)	NS	NS	288/193	40/85	107/107	74/74
M21/K13	47200	3	Bridge (22L)	380/2	84/84	0/647	115/0	79/79	74/39
N1	50300	3	Bridge (32L)	NS	NS	57/21	14/35	79/79	35/35
N2	52500	3	Bridge (82L)	NS	NS	234/76	48/0	79/79	35/0
N3	53800	3	Bridge (26L)	NS	NS	7/76	13/14	79/79	35/35
N4	54700	3	Bridge (72L)	NS	NS	93/137	0/135	79/79	0/35
N5	59300	3	Bridge (26L)	NS	NS	84/38	52/13	79/79	35/35
M22/K14	66200	3	RCBC (3.6x3.6x42)	92/287	84/84	495/69	76/51	107/107	74/36
M23/K15	75510	4	RCBC (2.4x3.6x47)	119/9	84/84	39/54	88/9	107/107	75/75
M24/K16	76450	4	RCBC (2.4x3x51)	80/12	84/84	53/30	27/45	107/107	75/75
M25/K17	83110	5	Bridge (25L)	1251/47	82/84	41/90	6/28	80/80	61/75
M26/K18	96050	5	RCBC (2.4x2.4x40)	14/21	84/84	233/13	20/175	79/79	75/75
M27/K19	99750	6	RCBC (2.4x3x37& 14)	171/388	85/85	40/0 (CE)	110/62	35/35	75/75
M28	100510	6	RCBC (1.8x2.4x66)	NS	NS	65/114	171/63	107/107	75/75
M29/K20	101100	6	RCBC (2.4x3x40)	19/39	84/84	0(CE)/1	8/33	107/107	75/75
M30/K21	101550	6	Bridge (10.5x132)	Nth 50/219	82/95	52/no install	221/30	107/0	75/75
				Sth 168/64	95/65	10/no install	71/7	107/0	37/37
M31	113840	7	RCBC (2.4x2.4x40)	NS	NS	45/41	15/24	107/107	34/75
M32	113860	7	RCP (1.2x41)	NS	NS	140/203	10/119	107/107	34/34
M33	115500 (west)	7	RCBC* (1.2x1.2x20)	NS	NS	99/120	103/265	108/108	75/75
M34	115500 (east)	7	RCBC * (1.2x1.2x19)	NS	NS	61/189	19/220	108/108	75/75
M35/K22	118450	7	Bridge	63/0	84/84	403/0	41/0	108/108	75/75

Site no. (tmam/ koala)	Chainage	Section	Underpass type & size (HxWxL)	Koala (spr/sum 2021)		Threatened mammals			
				No. of videos (floor/rail; or east/west)	Days active (floor/rail; or east/west)	No. of videos (floor/rail; or east/west)		Days active (floor/rail; or east/west)	
						Aut/win	Sum/aut	Aut/win	Sum/aut
			(18L)						
M36	122550	7	RCBC (47L)	NS	NS	16/3	7/5	107/107	75/75
M37/K23	127210	8	RCP (2.1x46)	255/31	84/84	181/292	38/24	78/78	75/75
K24	134600	8	Bridge (42L)	415/369	37/34 (flood)	NS	NS	NS	NS
M38/K25	136650	8	Bridge (23L)	972/1245	85/85	No install	736/194	0/0	35/35
M39/K26	137400	8	RCBC (2.4x2.4x66)	173/214	73/73	175/187	0/132	78/78	38/83
M40/K27	138400	9	RCP (1.5x62)	77/113	84/84	100/75	70/372	78/78	83/83
M41/K28	139420	9	RCP (1.5x69)	19/24	84/84	16/24	21/51	78/78	83/83
M42/K29	140600	9	RCBC (2.4x2.4x39)	85/85	84/84	41/169	26/44648	78/78	83/83
M43/K30	142200	9	RCBC (2.4x2.4x39)	102/236	71/71	43/50	21/235	78/78	46/38
M44/K31	142720	9	RCBC (1.2x1.2x25)	11/16	83/83	93/75	107/121	78/78	83/83
M45/K32	143400	9	RCBC (2.4x42)	328/75	95/95	578/319	193/165	108/108	83/83
M46	143700	9	RCP (1.2x36)	NS	NS	45/no install	47/44	108/0	83/83
M47/K33	144280	9	RCBC (3x3x34)	396/46	99/99	487/11	215/23	78/78	83/83
M48/K34	144760	9	RCBC (35L)	221/0 (CE)	99/0	143/94	59/75	78/78	83/83
M49/K35	146000	10	Bridge (40L)	1755/1428	98/84	24142/560	1872/4874	74/74	83/83
M50/K36	146250	10	RCBC (3x3x38)	81/160	84/84	34/32	49/90	71/71	83/83
M51/K37	146380	10	RCBC (3x3x39)	32/39	84/84	32/102	21/55	74/71	83/83
M52/K38	146610	10	Bridge (21L)	Nth 103/9	84/84	N 169/0	127/17	74/71	83/83
				Sth NS	NS	S 129/293	0/15	74/71	48/48
M53/K39	146850	10	Bridge (22L)	Nth 8/24	85/85	32/3	45/29	74/74	83/83
				Sth 52/0 (CE)	81/81	46/16	19/33	123/71	35/83
M54/K40	147090	10	RCBC (2.4x2.4x38)	**CSAC** 19/5	37/37	62/13	0/0	74/74	0/48
M55/K41	148600	10	RCBC (3x3x44)	**CSBC** 65/1	21/21	138/53	153/93	74/74	81/81
M56/K42	149250	10	Bridge (35L)	Nth 145/68	99/99	112/2	56/28	79/79	82/82
				Sth 50/36	99/99	0/3	35/26	34/34	82/82
M57/K43	150030	10	Bridge (22L)	Nth 45/102	82/82	1184/124	0/70	74/79	35/82
				Sth 330/67	99/99	875/15	181/18	79/79	82/82
M58/K44	150550	10	RCBC (3x3x42)	83/41	76/76	11/39686	7/299	67/67	36/84
M59/K45	150600	10	Bridge (20L)	Nth 189/54	83/83	233/6	71/15	66/66	36/84
				Sth 81/927	76/76	37/87	224/220	67/67	84/84
M60/K46	151200	10	RCBC (2.4x2.4x38)	101/72	75/75	44/233	171/386	67/67	84/84
M61/K47	151800	10	Bridge (38L)	**Nth CSBC**	0/0	44/0 (CE)	0 (CE) /422	64/0	0/0

Site no. (tmam/ koala)	Chainage	Section	Underpass type & size (HxWxL)	Koala (spr/sum 2021)		Threatened mammals			
				No. of videos (floor/rail; or east/west)	Days active (floor/rail; or east/west)	No. of videos (floor/rail; or east/west)		Days active (floor/rail; or east/west)	
						Aut/win	Sum/aut	Aut/win	Sum/aut
				Sth 177/36	75/75	22602/29	17/271	67/67	36/36
M62/K48	152050	10	RCBC (2.4x2.4x36)	**CSAC** 0/1	18/18	19/62	5/12	67/66	84/84
M63/K49	152780	10	RCBC (2.4x2.4x27)	37/36	84/84	247/20	4/7	66/66	84/36
M64/K50	152880	10	Bridge Bench (5x1.5x15)	11/381	75/102	160/54	3968/150	79/79	84/84
M65/K51	153050	10	RCBC (3x3x37)	88/201	103/103	Flood	39/130	0/0	36/36
M66/K52	153600	10	RCBC (3x3x48)	64/381	99/99	5/2	11/5	43/43	35/35
M67/K53	153900	10	Bridge (25L)	Nth 460/28	82/82	15/22	599/27	79/79	35/35
				Sth 349/157	99/99	246/6	74/9	79/79	82/82
M68/K54	154050	10	Bridge (25L)	Nth 199/659	82/82	32/58	7/10	79/79	37/37
				Sth 81/431	99/99	46/14	35/6	77/77	41/41
M69/K55	154750	10	RCBC (2.4x2.4x44)	**CSBC** 49/0 (CE)	21/21	32/19	65/0	67/67	82/0
M70/K56	155290	10	RCBC (2.4x2.4x38)	51/36	76/76	54/2	79/134	67/67	82/48
M71/K57	155910	11	RCBC (2.4x2.4x33)	21/10	99/99	0/904	24/22	66/66	82/82
M72/K58	156280	11	Bridge (25L)	Nth 24/381	82/82	53/3	0/0	77/77	35/0
				Sth 28/48	99/99	93/10	0/10	79/79	82/82
M73/K59	156930	11	RCBC (2.4x2.4x36)	206/403	103/103	1/54	39/165	79/79	82/82
M74/K60	157300	11	RCBC (2.4x2.4x38)	252/132	103/103	19/2	113/85	66/66	82/82
M75	157300	11	RCP (2.4x2.4x38)	NS	NS	63/35	17/302	66/66	82/82
M76/K61	157600	11	RCBC (2.4x3x35)	**CSAC** 35/30	37/37	Flood	Flood	Flood	Flood
M77/K62	157740	11	RCBC (3x3x45)	**CSAC** 3/27	100/105	Flood	Flood	Flood	Flood
M78/K63	157900	11	Bridge (22L)	Nth 43/80	83/83	291/69	13/42	79/80	34/81
				Sth 129/112	105/105	66/1297	93/103	77/77	81/81
M79/K64	158880	11	RCBC (2.1x2.4x17)	10/18	105/104	107/11	30/9	80/80	81/81

3.4.3 Camera traps

At the commencement of monitoring in September 2021 a combination of Swift 3C and Swift Enduro cameras were used with a small number of Reconyx HC500 and Moultrie S-50i at sites with a high-risk of theft. Following theft (spring/summer 2021) and inundation (summer/autumn 2022) most Swift 3C's were replaced with Scoutguard SG560K and several Swift Enduros were replaced in-kind.

For box culverts, two cameras were mounted on the central post of the fauna furniture – one positioned to capture animals moving along the furniture and the other positioned approximately 400mm above ground level to capture animals moving along the floor (Plate 2). Both cameras were oriented east, and all cameras were housed in security cases with padlocks.

Cameras were set on high sensitivity and programmed to take 10 seconds of video on activation. They were scheduled to turn on at 1800hr and turn off at 0600hr. Cameras were inspected during the middle of each monitoring session to change batteries and SD cards. Cameras affected by false triggers were assessed and, if necessary re-oriented to reduce false triggers. During the interim and final download the battery status and number of videos taken was recorded for each camera.

Plate 2: Within each box culvert, cameras were installed on the centre post– one viewing along the rail and the other along the floor (left). Within pipes, cameras were installed on the upper edge of the obvert (to reduce inundation) and angled towards the floor.

3.4.4 Camera image analysis

Camera images were uploaded to a desktop computer and viewed using Windows Photo Viewer. Due to the large number of images the data recording was streamlined from previous monitoring in sections 1 and 2 (see Sandpiper Ecological 2021a). Data recorded in sections 3-11 during the 2021/22 sample period included: site, species, number of complete crossing east, number of complete crossings west and number of incomplete crossings. 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. Identification accuracy was scored as either definite (90%+ certainty), probable (75-90% certainty), or possible (60-75% certainty).

To determine the likelihood of a culvert 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 or exhibits no directional movement along floor/furniture.

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, 2018, 2019, 2023a).

To control for variation in camera 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.

Due to the large number of sites and species, data were condensed by allocating species to taxonomic groups and presenting complete crossings (cc) and incomplete crossings (ic) for each group in each monitoring period. Species allocated to each taxonomic group is presented in Table A1, Appendix A.

3.4.5 Scat, track and scratch searches

Scat and track searches within and at the entrance to crossing structures is a requirement of the threatened mammal monitoring program, and scat and scratch searches within crossing structures and a 100m radius from each entrance was a requirement of koala monitoring. For simplicity these surveys are herein referred to as scat and track surveys. Scat and track searches were conducted at each underpass on three occasions during the spring/summer 2021 (koala) monitoring period and on two occasions during the threatened mammal monitoring periods. For koalas, searches involved scanning the culvert floor and habitat within 100m of each underpass entrance for koala scats, predator scats and scratches on trees. Search effort was equivalent to 15 person-minutes/side. Fresh koala scats were collected placed in a cool esky and later transferred to a freezer for later DNA analysis. Any predator scats collected were sent to a recognised hair analyst for identification of mammal prey species. For threatened mammals, scat and track searches focused on the culvert floor and concrete apron and generally took 5 person minutes to complete.

3.4.6 Road mortality monitoring

Road mortality surveys were conducted quarterly during the 2021/22 monitoring period. Surveys were completed on 06/08/2021 (Q3), 10/11/2021 (Q4), 13/01/2022 (Q1) and 14/04/2022 (Q2). The car-based surveys entailed a driver and passenger/observer travelling both the northbound and southbound length of sections 1 -11. Additional surveys for koala were conducted in Q3 and Q4 along Wardell Road (Gulbay Lane to Thurgates Lane – 1.54 km), and along the existing Pacific Highway (Carlyle Street to the Coolgardie interchange – 3.3 km).

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 the Motion X-GPS application and the species recorded into a handheld voice recorder or directly to a notepad. 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/wire rope. 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.

Road mortality results were supplemented by other data sources including incidental observations from Sandpiper staff, TfNSW staff, and road mortality reports from Lismore-based Friends of the Koala (FOK). Koala vehicle strike in 2021/22 is explored in detail by Sandpiper Ecological (2023a).

4 Results

4.5 Crossing structure monitoring

4.5.1 Target species

Brush-tailed phascogale, long-nosed potoroo and koala were recorded in sections 3-11 in the spring 2021 to winter 2022 sample period (Tables A1-A3, Appendix A). Koala was recorded at sites K26 (9 x cc) and KWE1 (1 x cc), with the later site being a 1050mm wide by 15m long RCP on Wardell Road (Plate 3) and the former a 2.4m x 2.4m RCBC that was 66m in length (Figures 6 and 7). Koala movement was along the ground at both sites.

Phascogales were recorded making complete crossings at sites M16 (1 x cc), M18 (1 x cc), M26 (1 x c), M27 (1 x cc) and M29 (8 x cc) (Figures 2 & 4). Site M29 was used during the sum/aut and aut/winter 2022 sample periods, whilst sites M16, M18 and M27 were used in aut/wint only and site M26 in sum/aut only. Structures used by phascogales included two 1.2m diameter RCP (sites 16 and 18) and three RCBC (sites 26, 27 & 29). Only fauna furniture was used in RCBC and these structures ranged in size from 2.4x2.4 to 2.4x3m and in length from 40 to 51 metres. Long-nosed potoroo was recorded making one incomplete crossing at site M28 (a 1.8m x 2.4m x 66m RCBC) in aut/win 2022 (Figure 4).

Plate 3: A koala was recorded making a southward crossing through a 1050mm wide by 15m long pipe culvert under Wardell Road on 2 December 2021.

4.5.2 Species richness

Forty-three species and four unique genera were recorded using underpasses (Table 5). A list of all species, genera and groups recorded is presented in Table B1, Appendix B. Mammals were the most biodiverse group with 15 native and seven introduced species and a further two unique genera, *Antechinus* spp and *Melomys* spp. Five species of reptile were recorded, including two species of snake (carpet python and brown tree snake) and one species of lizard (land mullet). This was in addition to the commonly recorded eastern water dragon and lace monitor.

Amphibians were represented by the introduced cane toad and unidentified species of frog, which likely included members of the *Limnodynastes* and *Litoria* genera. Birds were well represented with 14 native species, two unique (native) genera and one introduced species. Bush turkey was the only species of bird that consistently uses underpasses for passage. Most other species use underpasses, particularly bridges with drainage lines, for foraging.

Table 5: Complete and incomplete crossings/week for various fauna groups recorded within sections 3-11 of W2B across all sample weeks in each of five monitoring periods in years one and two of the operational phase.

Fauna group	Native species	Introduced species	Unique (native) genera
Mammals	15	7	2
Reptiles	5		
Amphibians		1	
Birds	14	1	2

4.5.3 Introduced vs native fauna

Comparison of the mean number of complete crossings/week across all sample sites for native and introduced species shows that native fauna have been the dominant users of underpasses in all sample periods except autumn/winter 2021 (Figure 8). Complete crossings by native species have fluctuated over the five sample periods with a peak in mean crossings recorded in spr/sum 2021. Importantly, mean complete crossings by native species in sum/aut and aut/wint 2022 were higher than the same periods in 2021, although the mean number of complete crossings by introduced species declined from a peak in autumn/winter 2021.

The aut/wint 2021 peak in introduced species was due to high use by black rat which was recorded at 57% of sites sampled and had peak crossing rates of 15.2 at site 63, 11 at site 39, and 10.9 at site 46. A two-tailed t-test comparing black rat cc/week in aut/wint 2021 (n=75) and aut/wint 2022 (n=65) revealed a highly statistically significant difference of $P<0.001$. Mean cc/week by black rats across all sample sites in 2021 was 1.52 (sd 2.79) compared to a mean of 0.29 (sd 0.64) in 2022.

4.5.4 Introduced predators

Introduced predators (dog, fox, cat) have been recorded using underpasses during each sample event with visitation across all sample sites peaking at 1.18cc/week in spr/sum 2021 (Figure 4). Foxes have consistently been the most common introduced predator detected in underpasses with visitation increasing from sum/aut 2021 to a peak of 0.94 cc/week in spr/sum 2021 across all sample sites (Figure 5). Whilst visitation by foxes has fluctuated during 2022 samples it remained above the equivalent sample periods in 2021. By comparison, mean crossing rates by cats and dogs was substantially less than foxes (Figure 5). Dog visitation peaked in spr/sum 2021 with a mean of 0.17 cc/week and has gradually declined to a mean of 0.09 cc/week in aut/wint 2022. Visitation by cats peaked at 0.1 cc/week in aut/winter 2021 and gradually declined in each subsequent sample to 0.03 cc/week in aut/win 2022.

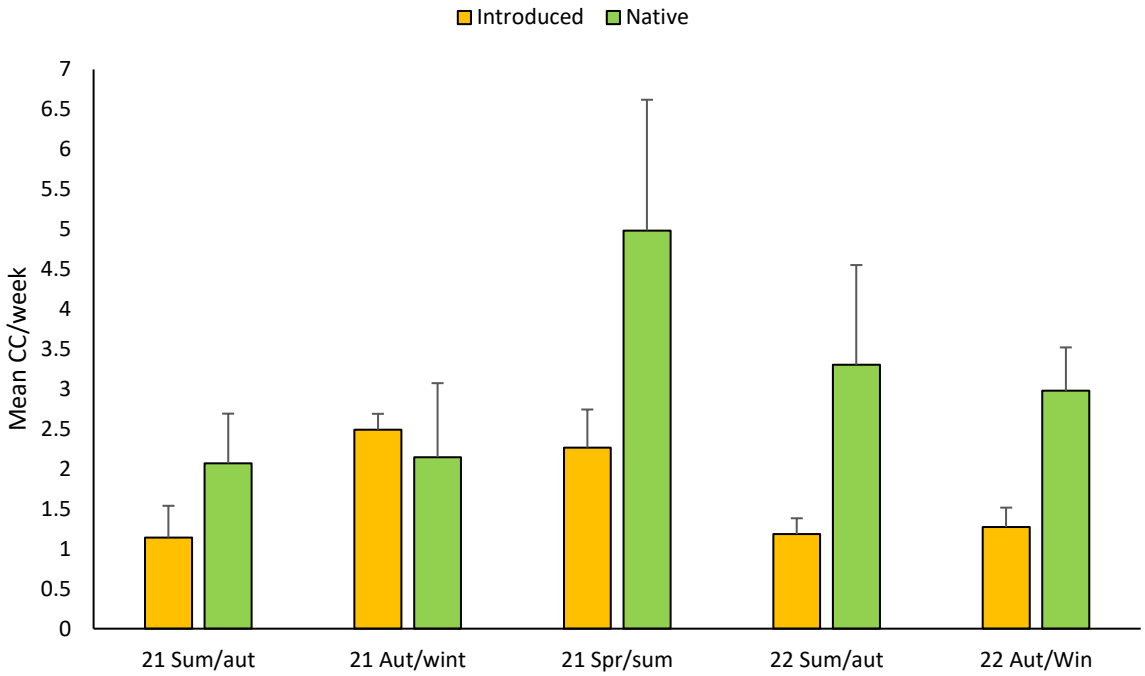

Figure 8: Mean crossings (+SD) recorded for introduced and native species at all sites in sections 3-11 of W2B.

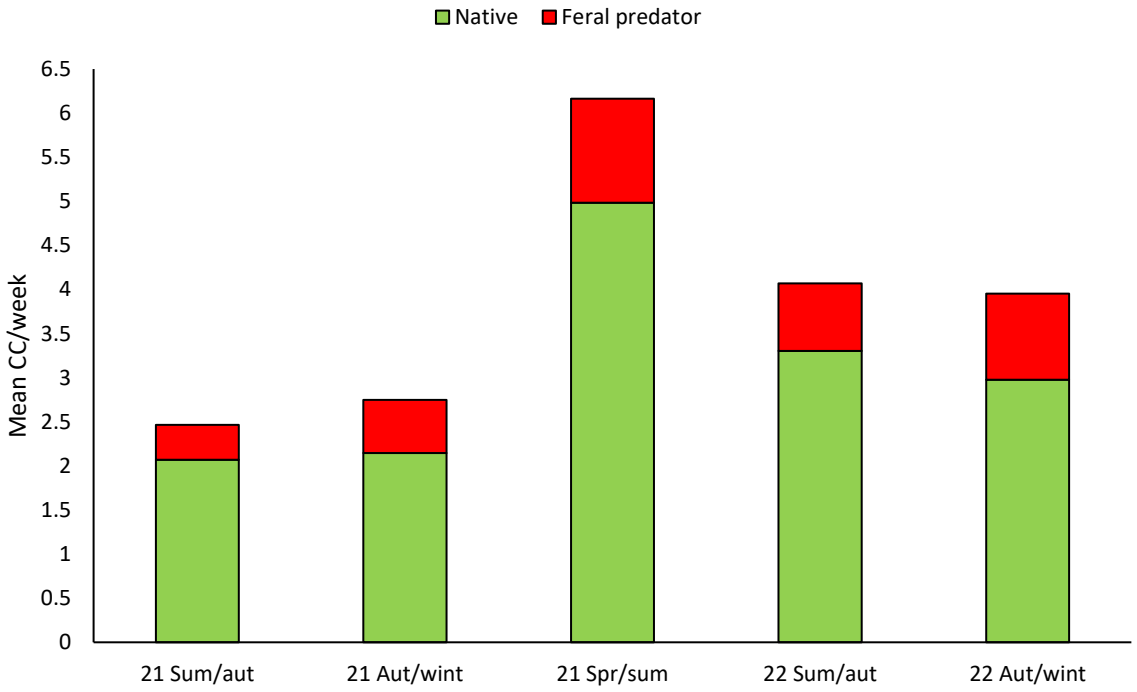

Figure 9: Comparison of the mean number of complete crossings/week across all sites by native species and feral predators in sections 3-11 of W2B.

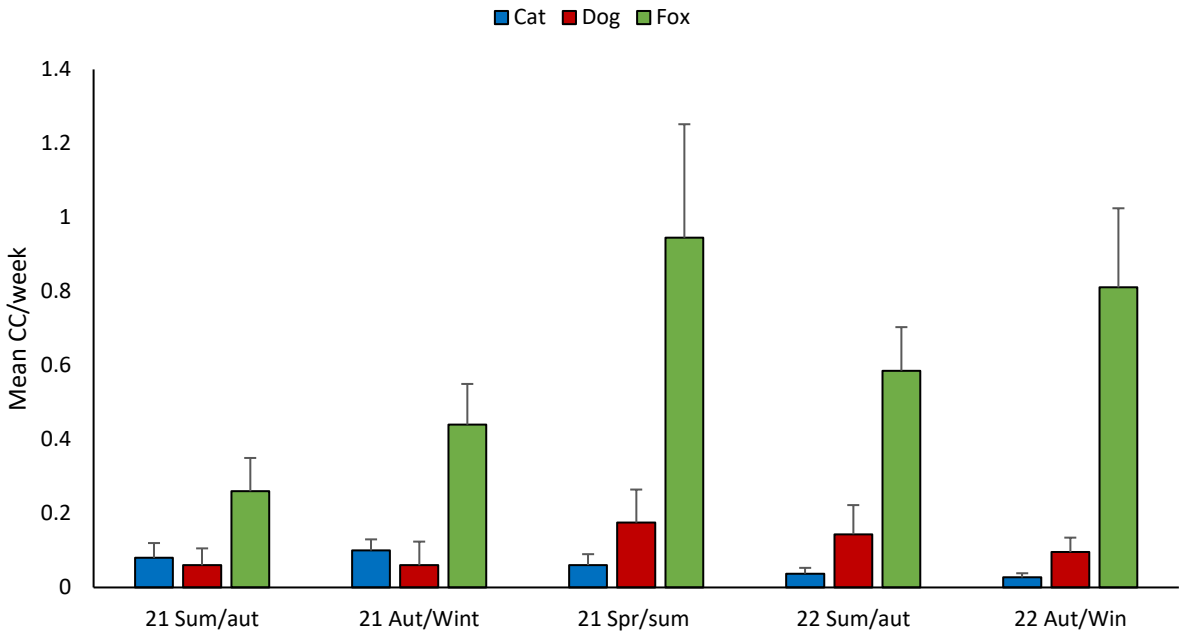

Figure 10: Mean number of crossings/week by cats, dogs and foxes in each of five sample periods in sections 3-11 of W2B.

In contrast to the mean crossing rates the number of sites visited by foxes peaked at 90% in aut/wint 2022, with a low of 58% in spr/sum 2021. The difference between the proportion of sites visited and mean crossing rate is due to particularly high crossing rates at some sites in spr/sum 2021 (Tables A1-A3, Appendix A). For example, mean crossing rates by foxes of 8.43cc/wk and 12.77 cc/wk were recorded at sites M73 and M74 respectively in spr/sum 2021. Peak weekly crossing rates in aut/wint 2022 were 4.98cc/wk and 3.07 cc/week at sites M74 and M63 respectively.

The number of sites visited by dogs was also converse to mean crossings/week with a peak of 21% of sites visited in aut/wint 2022, 18% in sum/aut 2022 and 16% in spr/sum 2021. The highest crossing rates in each of these years were: spr/sum 21 = 4.55cc/wk at site M25, sum/aut 22 = 3.91cc/wk at site M25 and aut/wint 22 = 1.96cc/wk at site M22. Dogs were only recorded at between 2 and 3 of the 29 sites sampled in sections 10 and 11.

4.5.5 Fauna furniture vs floor

Total crossings/week (all sites combined) for two scansorial (*Antechinus* spp. and black rat) and one arboreal (short-eared brushtail possum), species including an introduced species (black rat) was compared between fauna furniture and the ground (Figure 11). The comparison highlights the frequency with which fauna furniture is used, and the preference shown by native species to use furniture over the floor. In contrast, black rats used furniture and floor in similar rates during the 2022 samples and furniture at a much higher rate than the floor in spr/sum 2021. Despite frequent use by an introduced species the result emphasises the value of fauna furniture for native arboreal and scansorial species.

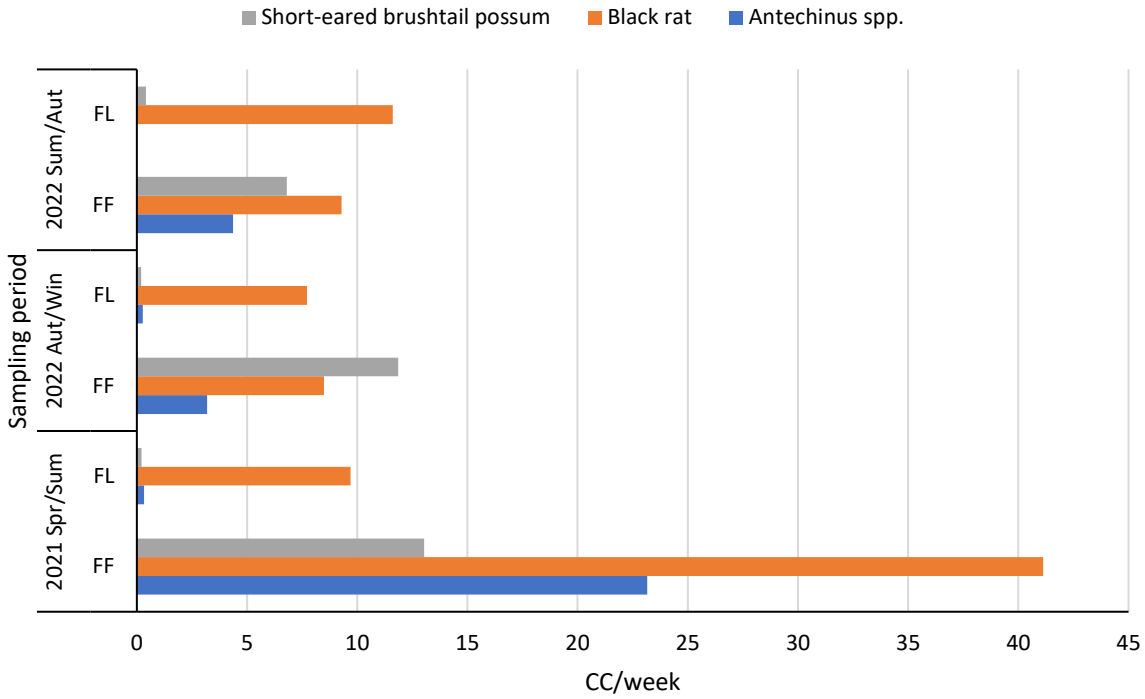

Figure 11: Comparison of complete crossings/week by three species of mammal using fauna furniture and the culvert floor.

4.5.2 Scat and scratch searches

Due to the different sample methods applied between the koala (spr/sum) and threatened mammal (sum/aut & aut/wint) sample periods data have not been compared. Key results are summarised below and raw data are presented in Table C1, Appendix C. In spr/sum 2021 koala scats were recorded adjacent to 12 of the 55 sites sampled. Nine of these sites were situated in section 10, with the remaining three sites (K26, 27 & 28) situated within Broadwater National Park between chainages 137400 and 139400. Within section 10 koala scats were clustered around Laws Point and Wardell Road. No evidence of koalas was recorded during the threatened mammal samples, which focussed on culverts only. Scat and track results were consistent with camera monitoring across all sample periods.

Table 6: Percentage of sample sites that different fauna groups were recorded during Scat/Scratch/Track surveys in spring/summer 2021 (56 sites), summer/autumn 2022 (70 sites) and autumn/winter 2022 (70 sites).

Group	Spring/summer	Summer/autumn	Autumn/winter
Amphibians		14.28	1.42
Bandicoots	7.14	15.71	10.00
Birds	1.78	17.14	12.85
Dasyuridae		2.85	1.42
Echidna	1.78	8.57	1.42
Feral predators	28.57	40.00	21.42
Frogs	1.78	15.71	
Introduced other	5.35	11.42	7.14
Koala	21.42		
Lizards	16.07	20	1.42
Macropods	82.14	41.42	30.00
Possums	19.64	10.00	1.42

Group	Spring/summer	Summer/autumn	Autumn/winter
Reptiles	10.71	21.42	4.28
Rodents	19.64	48.57	24.28
Snakes		1.42	

4.6 Road mortality

No target threatened mammals were identified during the survey period, however one possible greater glider (listed as vulnerable under the *EPBC Act 1999*) and one masked owl (listed as vulnerable under the *BC Act 2016*) were identified during the Q3 2021 survey (Table 7). A total of 268 vertebrates were recorded across the four samples from Q3 2021 to Q2 2022 (Table 6). This included 157 mammals, which comprised 59% of all individuals recorded. The mean rate of mammal road mortality over four quarters was 0.12 ± 0.01 /km.

The most common mammal taxa recorded was bandicoot species (n = 41), followed by unidentified medium mammals (n = 33) and unidentified small mammals (n = 19). In total, 28 macropods (inc. ten wallaby species, six swamp wallaby, four eastern grey kangaroo, four large macropod, two red-necked wallaby and two macropod species) were recorded. The remaining road-kills were comprised of birds (31%) and reptiles/amphibians (10%). The Q3 and Q4 surveys on Wardell Road and the old Pacific Highway in 2021 recorded five road mortalities, including one small mammal, two Australian magpie, one unidentified frog and one red fox (Table D2, Appendix D).

Table 7: Species of vertebrate fauna recorded during road-kill surveys throughout the operational phase of the W2B upgrade. * denotes threatened species.

Species	Q3 21	Q4 21	Q1 22	Q2 22	Total (all samples)
Short-beaked echidna	3	1	1	1	7
Spotted-tailed quoll*					1
Northern brown bandicoot			1	2	8
Bandicoot spp.	1	10	13	17	47
Common brushtail possum			1		3
Trichosurus spp.					2
Eastern grey kangaroo				4	8
Red-necked wallaby		1		1	4
Swamp wallaby	2	1	2	1	11
Wallaby spp.	3	1	2	4	14
Medium macropod					9
Med/large macropod					2
Large macropod	4				8
Macropod spp.		2			3
Greater glider*	1				1
Grey-headed flying-fox*					1
Little red flying-fox					3
Pteropus spp.	1		1	1	5
Microbat spp.	1			1	6
Rodent spp.		1	4		6
Small mammal	3	6	4	6	19
Medium mammal	7	13	7	6	41
Large mammal					1
Unidentified mammal	5				8
Total mammals	31	36	36	44	218
Little pied cormorant	1				1
Australian white ibis	1	1		1	3
Cattle egret				1	1
Silver gull			2		2
Australian wood duck	2	1			4

Species	Q3 21	Q4 21	Q1 22	Q2 22	Total (all samples)
Pacific black duck					1
Crested pigeon					1
Pigeon spp.			1		1
Tawny frogmouth	1		1	1	5
Australian magpie	1	1	2	7	18
Torresian crow		1			1
Pied butcherbird			1	1	2
Purple swamphen	1				2
Eastern barn owl	1				2
Masked owl*	1				1
Southern boobook	1				1
Laughing kookaburra	2		2	1	7
Fairy wren spp.					1
Yellow thornbill					1
Noisy friarbird					1
Pied currawong					1
Eastern yellow robin					1
Small bird		2	3	5	13
Medium bird			8	1	22
Unidentified bird	4	11	3	8	28
Total birds	16	17	23	26	121
Lace monitor		1	1	2	7
Eastern bearded dragon					1
Eastern blue-tongue lizard			1		1
Medium lizard					1
Carpet python	1		1		7
Eastern small-eyed snake					2
Yellow-faced whipsnake					1
Bandy-bandy			1		2
Large reptile					1
Medium reptile			2		2
Medium lizard			1		1
Unidentified reptile		2		3	5
Unidentified snake		2			6
Unidentified frog			2	1	3
Chelidae spp.		1		2	4
Total reptiles/amphibians	1	6	9	8	43
House mouse					2
European fox	1		1	1	5
Dog				1	3
Cat					3
European hare	5		1		8
Chicken					1
Cane toad		1	2	1	5
Total introduced species	6	2	4	3	28
Unidentified species			1		
Total fauna	54	60	73	81	411
Total mammals	37	36	38	44	238
Total kms surveyed	328	328	328	328	
Mammal kills/km	0.11	0.11	0.11	0.13	

5. Discussion

5.1 Use of crossing structures

Underpass monitoring in spring/summer 2021, summer/autumn 2022 and autumn/winter 2022 has provided additional data on the location, type and number of underpasses used by target species. Records of particular note include a koala making a complete crossing of a 1050mm diameter RCP at Wardell Road, and several crossings by brush-tailed phascogale in RCP and RCBC underpasses.

5.1.1 Koalas

Underpass use by koalas in sections 3-11 has been infrequent and crossing rates and number of sites used is less than comparable studies (see Sandpiper Ecological 2023b). To date, in sections 3-11 koalas have been recorded using two underpasses on Wardell Road (KWmid & KWeast1), and one underpass beneath the Pacific Motorway (site K26). K26 was used on nine occasions in spring/summer 2021, KWmid on four occasions in 2019 and 2020 and KWeast1 on one occasion. Use of the 1050mm diameter RCP on Wardell Road (KWeast1) is significant as it represents the smallest diameter structure confirmed to be used by a koala in NSW. The previous smallest known structure was the 2.4m wide x 1.2m high RCBC also on Wardell Road. Confirmation that koalas use small diameter structures means there is greater flexibility in providing connectivity beneath highways and local roads. The record also highlights the role that pipe culverts play in maintaining connectivity. One limitation of the Wardell Road records is that the structures were approximately 15m long which is substantially less than a standard crossing beneath a four-lane highway.

The absence of underpass use beneath the highway in the Laws Point and Wardell areas is concerning as these locations were identified as koala “hotspots” in the Koala Management Plan (see RMS 2016) and were considered to support resident individuals. Resident koalas continue to be recorded in the Laws Point area on both sides of the highway and a young male was recorded within 20m of site K36 at Laws Point and koala scats have been recorded with 10m of site K55 at Wardell.

The absence of underpass records is not due to camera setup, monitoring duration or time since construction. Results from the Warrell Creek to Nambucca Heads upgrade (WC2NH) underpass monitoring program, which has used the same camera setup and monitoring period, shows that koalas were using underpasses upon commencement of the operational phase and use has continued over the four years of monitoring. Although frequency of visits has varied the number of underpasses used at WC2NH has steadily increased over the monitoring period (Sandpiper Ecological 2023b).

Although continuous monitoring is required to conclude that koalas have not used underpasses, monitoring during the peak koala movement period (i.e., pre-dusk to post dawn) for seven months within a 12-month period provides some certainty that the results are accurate. In addition, the high density of monitoring sites between Woodburn and Coolgardie where there are 41 sites over 24 km further increases the likelihood of detection.

Low levels of use in sections 3-11 of W2B could be due to a combination of accessibility, home range behaviour and koala abundance. Whilst low koala abundance is likely to influence underpass use in some sections of 3-11 this is unlikely to be an issue north of the Richmond River where koala abundance has remained stable between 2017 and 2022 (see Sandpiper Ecological 2023a), and all available underpasses are monitored. Even in areas with low koala abundance use of underpasses has been confirmed using the methods applied in sections 3-11 (Sandpiper Ecological 2021a – NH2U, 2017b – Glenugie).

A combination of home range behaviour and underpass accessibility seem the likely reasons for low underpass use by koalas in section 10 and 11. Prior to construction, koalas were known to cross the alignment at both

Wardell/Meerschaum Vale and Laws Point. It is possible that the temporary barrier to movement created during construction has caused koalas to alter their home ranges and adult home ranges may now adjoin the alignment as was the case at Bonville in northern NSW (Lassau *et al.* 2008). At that site only juvenile koalas and dispersing individuals attempted to cross the highway. Conversely, de Oliveira *et al.* 2013 found no effect of linear infrastructure on koala movement at Redland Bay in south-east Queensland.

Numerous culvert entrances in sections 10 and 11 of W2B are obscured by dense pigeon grass (*Setaria* spp) which has dominated former grazing land and areas disturbed during construction. Pigeon grass forms dense swards that can be difficult for humans to move through. These swards likely inhibit movement and the ability of koalas to see underpasses. Whilst koalas are known to move through dense ground vegetation, such vegetation is often dominated by clumping species like saw sedge (*Gahnia* spp.) which often has open areas at ground level. Notwithstanding, there are some culverts at Laws Point that have open entrances on the western side, in areas known to be used by koalas. Targeted control of pigeon grass around culvert entrances was undertaken in mid-2022 and its effectiveness will be reported on in the 2022/23 annual report.

It is too early to conclude that koalas do not utilise underpasses within key parts of sections 3-11, although initial evidence is concerning given the number of sites sampled and proven effectiveness of the methods used. Monitoring in spr/sum 2022/23 found no evidence of underpass use by koalas in sections 3-11 (Sandpiper unpublished data). Results to date are contrary to most underpass monitoring programs conducted for Pacific Highway Upgrades.

5.1.2 Brush-tailed phascogale

In sections 3-11 phascogales have been recorded making complete crossings at seven underpasses, including three RCP and four RCBC. The preference shown by phascogales for using fauna furniture in each of the RCBC is consistent with records for other scansorial species such as *Antechinus stuartii* elsewhere (see Goldingay *et al.* 2018). The longest structure used to date by phascogales is a 53m RCP at site M18. Brush-tailed phascogale was also recorded making one complete crossing of a rope bridge at chainage 48050 (Sandpiper Ecological 2023a).

Lewis (2022) noted only limited correlation between the occurrence of phascogales at population monitoring sites and use of adjacent underpasses. This finding is likely due to differences in home range use, phascogale density and habitat resources between sites. This is like the different ways that gliders utilise aerial crossings (Soanes *et al.* 2015). A lack of consistency between population monitoring and underpass monitoring remains evident. Phascogales were recorded using two underpasses (M27 & M29) near population monitoring site 4A in 2022 yet no phascogales were recorded during population monitoring in 2021. Conversely, a moderate phascogale detection rate at Site 2A correlates with use of several nearby underpasses (i.e., M15, 16 & 18).

Brush-tailed phascogale records highlight two important components of any underpass connectivity program:

1. Spatial distribution of underpasses - the clustering of phascogale records highlights the importance of installing structures in suitable habitat.
2. Temporal component – inclusion of multiple seasons and years is essential to confirm underpass use by species that may undergo substantial fluctuations in abundance.

The pattern of records shows that phascogales will repeatedly use multiple adjoining structures where they occur in suitable habitat.

5.1.3 Long-nosed potoroo

Long-nosed potoroo was recorded at M28 adjacent to Bundjalung National Park. This site is analogous to population monitoring site 2A which had a 16.7% potoroo activity rate during monitoring in 2021 (Lewis 2022). The absence of potoroo records in underpasses in section 10 is likely due to a combination of habitat

distribution and access. Most potoroo habitat in section 10 is situated on the eastern side of the highway and there is no reason for potoroos to use underpasses. An exception occurs near chainage 148500 where potoroos occupy an isolated remnant. Underpass N$^{o.}$ M55 should facilitate movement between the western isolate and the Ngunya Jargoon Indigenous Protected Area. The absence of potoroo records at M55 may be due to the presence of dense sward of pigeon grass on the western side.

5.1.4 Rufous bettong

No rufous bettongs were recorded using underpasses between spring 2021 and winter 2022. This is surprising as five underpasses adjoin population monitoring sites 3A and 4A, which have high activity rates, and the species is known to utilise underpasses (Goldingay *et al.* 2022). Despite known use of underpasses, monitoring for the Glenugie Upgrade showed variable use with bettongs recorded using one of seven underpasses despite all being situated in known habitat (Sandpiper Ecological 2017). The pattern of use at Glenugie further emphasises the importance of having multiple structures available, particularly where there is no site-specific information on habitat use. The absence of bettong records during the 2021/22 monitoring period could be due to abundant food (i.e., grasses & herbs) associated with consecutive La-Nina weather events. It is likely that bettongs move shorter distances to forage when food is abundant.

5.2 Feral predators

Feral predators were recorded using underpasses throughout sections 3-11. Foxes were particularly prevalent being recorded at 90% of monitored structures in aut/winter 2022 and having visitation rates of up to 13 complete crossings per week at some sites. The data suggest some separation between dog and fox visitation with fox visits peaking in the northern part of the study area (i.e., sections 10 & 11) and dog visits peaking in section 3. This observation is consistent with the hypothesis that a higher abundance of wild dogs can suppress fox abundance (Johnson & VanDerWal 2009) and several studies that have found higher detection rates of wild dogs than foxes in the Glenugie area (see Sandpiper Ecological 2017) which covers part of section 3.

Whilst there is a complex interplay between dogs and foxes, at a basic level suppression of fox abundance by dogs is likely to benefit small prey such as phascogales (Cupples *et al.* 2011), which tend to be more common in areas with higher dog visitation. Conversely, the lower visitation rate of dogs in the primary koala areas of sections 9 and 10 means there is lower predation risk in those areas. Predation of koalas by wild and domestic dogs is well established (e.g., Lunney *et al.* 2004, 2007), however, there is no evidence that foxes predate adult koalas, and they tend to target smaller prey (Stobo-Wilson *et al.* 2021). Regardless, a single dog can predate multiple koalas and basing predation risk on underpass visitation rates could be misleading.

Underpass monitoring in sections 3-11 suggests there are seasonal differences in how foxes use underpasses. The number of sites used by foxes peaked during the breeding season (i.e., autumn/winter) and visitation at certain sites peaked in spring/summer when cubs were either in the den or at foot. This result is consistent with the wider ranging behaviour displayed by foxes during the breeding season and more restricted home range use by females after birth (Cavallini 1996).

Underpasses facilitate movement of feral predators, and cats and foxes were often recorded moving through underpasses with small mammal prey. No predation on target species at underpasses or evidence to support the prey-trap hypothesis was recorded. This is consistent with several studies that have found no evidence to support the pre-trap hypothesis (Little *et al.* 2002; Martinig *et al.* 2020; Goldingay *et al.* 2022). Should cats or foxes seek to predate fauna within an underpass the introduced black rat is a likely target due to its prevalence at several sites.

5.3 Road mortality

Road mortality of koalas is discussed in detail by Sandpiper Ecological (2023a) and has not been covered here. No target species of threatened mammal were recorded during road mortality surveys. This finding, combined with confirmed underpass use by all target species within sections 1-11, confirms the value of having a series of underpasses link with near continuous exclusion fence. The absence of road mortality of potoroos and bettongs also indicates that the modified exclusion fence design (i.e., stock fence with 1.2m tall chicken wire) used in sections 1-8 is effective in stopping threatened species of macropod from accessing the carriageway.

5.4 Performance indicators - koala

Compliance with performance indicators for koalas is summarised in Table 8. The analysis identified three issues, two of which relate to the vehicle strike near Devils Pulpit in September 2021. Actions taken to address that incident are discussed by Sandpiper Ecological (2023). The third issue relates to use of underpasses by koalas. Koala use of underpasses in sections 3-11 is below that recorded elsewhere (e.g., WC2NH) and more consistent with monitoring in areas of low koala density such as Glenugie, sections 1 and 2 and Nambucca Heads to Urunga. RMS (2016) identified sections 5, 8, 9 and 10 of W2B as supporting key populations of koala and population monitoring in sections 8, 9 and 10 has confirmed the presence of a stable resident population (Sandpiper Ecological 2023a). Given the number of underpasses monitored in these sections a higher occurrence of crossings is expected, particularly when koalas are known to utilise habitat adjoining the highway.

To date, none of the performance thresholds for koala crossing structures has been achieved. Although koalas have been recorded using four underpasses across sections 1-11 this is below what is anticipated given the number of underpasses sampled in areas with stable resident populations. In addition, two of these structures are situated on a local road that is approximately 15m wide, which is substantially shorter than a standard dual carriageway underpass. Low use in the 'key population areas' is likely due to a combination of altered home range behaviour following construction, favourable foraging conditions requiring shorter movements due to successive la-Nina years and difficulty accessing culverts due to long grass. The latter is a particular issue north of the Richmond River where many koala underpasses are situated. Underpass monitoring is showing structure use varies at spatio-temporal scales and the low usage recorded to date may be due to the combination of specific conditions prevailing in 2021/2022. Monitoring over a longer temporal scale is required to confirm how koalas use underpasses in sections 3-11.

Limitations associated with scat collection, namely persistent rain hampering collection of fresh scats and the selective nature of the collection method, means identification of individuals from genetic analysis has not occurred.

The performance threshold relating to visitation/usage rates of exotic predators, that is 2c) in Table 8, does not define "high" visitation. There is no standard measure of feral predator visitation to determine what is high. For this assessment visitation rates equal to or higher than 7/week (or 1 per day) are regarded as high. Rates of between nine and 13 complete crossings/week were recorded at some sites and feral predator control is warranted. This should involve engagement between TfNSW and Local Land Services to develop an appropriately scaled control program. Whilst feral predator control would benefit fauna in general the value to koalas is less evident, particularly given red fox, which has the highest visitation rates is not a noted predator of koalas. Targeting underpasses used by wild dogs in sections 3 and 10 would have positive benefit to koalas and rufous bettong.

Table 8: Assessment of performance indicators against monitoring results in sections 1-11 of W2B for koalas.

Performance indicator/mitigation goal	Performance threshold	Performance
1. Road mortality	a) No injury to an individual koala as a result of vehicle strike across all upgraded sections. b) Section 10: no koala road mortality within the fenced areas of the upgrade, on existing Pacific Highway or Wardell Road.	• A koala was reportedly struck by a vehicle near Devils Pulpit in September 2021. • No mortality of koalas recorded within the fenced sections of Wardell Road or the old Pacific Highway
2. Fauna crossing structures	a) Evidence of at least one completed crossing by koalas at targeted fauna crossing structures. b) Evidence of individual koalas using structures and/or breeding on either side of the highway, via scat analysis. c) No evidence of high visitation/usage rates by exotic predators.	• In 21/22 complete crossings recorded at KWeast1 (Wardell road) and K26 (Broadwater National Park). • In 2018-2020 complete crossings recorded at KWmid (Wardell Road) and K5 (section 1). • There is insufficient data to determine use by individual koalas and/or breeding on either side of the highway. • Visitation rates of feral predators equal to or greater than 7/week are classed as high. • High visitation rates were recorded at several underpasses in section 10.
3. Fauna exclusion fence	a) No breaches in fauna exclusion fence.	• Exclusion fence near Devils Pulpit was breached in September 2021.
4. Predator attack near fauna crossing structures	a) No koala deaths or injuries due to predator attack in the vicinity of fauna crossing structures.	• No evidence of koala deaths or injuries due to predator attack have been recorded.

5.5 Performance indicators – threatened mammals

Compliance with performance indicators for threatened mammals is summarised in Table 9. Data collected so far indicates that one potential issue of non-compliance relating to use of underpasses near long-nosed potoroo population monitoring sites 3A, 4A, 5A and 6A may arise. Monitoring in year 3 of the operational phase (i.e., 2023) is required before compliance (or non-compliance) with this performance threshold can be confirmed.

Table 9: Assessment of performance indicators against monitoring results in sections 1-11 of W2B for threatened mammals

Performance indicator/mitigation goal	Performance threshold	Performance
1. Maintain fauna exclusion fencing and connectivity structures for the life of the project.	a) Maintenance of fauna exclusion fencing at connectivity structures as part of routine highway maintenance to remove debris and replace damaged rope crossings. b) Monitor road-kill as part of the routine road maintenance and repair broken exclusion fencing or install new fencing where required.	• Damage to exclusion fence has been reported to TfNSW when detected and repairs have been completed in the appropriate timeframe.

Performance indicator/mitigation goal	Performance threshold	Performance
2. Crossing structures for threatened mammals facilitates natural daily movements. Potoroo recorded using underpasses after three consecutive monitoring periods after installation	• Threatened mammals are not recorded using connectivity structures for three consecutive monitoring periods. • No Potoroo recorded using underpass structures at Site 3A, 4A, 5A, 6A post three consecutive monitoring periods after installation	• Use of crossings structures by the target species is complex and monitoring is confirming the manifold relationship between the number, type and distribution of structures and spatio-temporal variability in fauna populations and habitat use. • Results suggest that species are using underpasses as part of normal home range movement. Importantly, normal home range use does not equate to daily use and likely changes in response to breeding demands and foraging conditions. • No potoroos have been recorded using structures near population monitoring sites 3A, 4A, 5A and 6A. The absence of records at sites 5A and 6A is not surprising as there is no suitable potoroo habitat on the opposite side of the highway. • A single incomplete crossing by a long-nosed potoroo was recorded at site M28 during the spr/sum 2021, sum/aut 2022 and aut/wint 2022 monitoring periods.

5.6 Limitations

Monitoring between spring 2021 and winter 2022 was influenced by flooding of cameras and culverts, and theft of cameras. Collectively these issues compromised the efficacy of monitoring by reducing sampling effort at several sites and affecting accessibility for the target species. Some culverts were flooded for the entire monitoring period. These issues are likely to have influenced results by reducing visits by common species and the ability to detect occasional visits by rare species such as koala.

6. Conclusion and recommendations

This report has presented data for year 1 and 2 of the operational phase for threatened mammals and year one operational phase for koalas. Results are generally positive with underpasses being used by several target species. Monitoring is also revealing the manifold spatio-temporal relationship in the way that fauna use underpasses. The complexity of the relationship between the distribution of underpasses, target species abundance and the influence of environmental conditions on habitat use means that monitoring over several years is required to confirm the extent of underpass use.

There is some concern about the low usage of underpasses by koalas in sections 8, 9 and 10. Whilst this may be partly due to long grass blocking access to underpasses less movement due to good foraging conditions and re-adjustment of home ranges following highway construction may also be contributing factors. Notwithstanding, the results of similar monitoring programs elsewhere suggest that visitation rates should be higher and that results are not due to monitoring methods.

An emerging issue of non-conformance is the lack of visitation by long-nosed potoroos to underpasses in section 10. Some use of underpasses near population monitoring sites 3A and 4A is anticipated and access to the western side of the underpass near site 3A is blocked by dense pigeon grass.

The requirement for remedial actions due to non-conformance of underpass performance criteria for both koala and potoroo is linked to three consecutive years of monitoring. As monitoring has only occurred for two years remedial actions are not warranted at this stage. Issues regarding underpass use by koala and long-nosed potoroo will be addressed again in the final (year 3) report.

7. References

Cavallini, P. (1996). Ranging behaviour of red foxes during the mating and breeding season. *Ethology Ecology and Evolution:* **8,** 57-65.

Cupples, J. B., Crowther, M. S., Story, G., & Letnic, M. (2011). Dietary overlap and prey selectivity among sympatric carnivores: Could dingoes suppress foxes through competition for prey? *Journal of Mammalogy:* **92,** 590-600.

De Oliveira, S. M. Murray, P. J., de Villiers, D. L. & Baxter, G. S. (2013). Ecology and movement of urban koalas adjacent to linear infrastructure in coastal south-east Queensland. *Australian Mammalogy:* **36,** 45-54.

Goldingay, R., Taylor, B. and Parkyn, J. (2019). Movement of small mammals through a road underpass is facilitated by a wildlife railing. Australian Mammalogy 41(1), 142-146.

Goldingay, R. L., Rohweder, D. A., Taylor, B. D. & Parkyn, J. L. (2022). Use of road underpasses by mammals and a monitor lizard in eastern Australia and consideration of the prey-trap hypothesis. *Ecology and Evolution:* **12,** e9075.

Hulse, L. (2022). *Meta-population koala genetics of northern New South Wales*. Report prepared for Sandpiper Ecological Surveys.

Johnson, C. N. & VanDerWal, J. (2009). Evidence that dingoes limit abundance of a mesopredators in eastern Australian forests. *Journal of Applied Ecology:* **46,** 641-646.

Lassau, S. A., Ryan, B., Close, R., Moon, C., Geraghty, P., Coyle, A. & Pile, J. (2008). Home ranges and mortality of a roadside koala *Phascolarctos cinereus* population at Bonville, New South Wales pp 127-136 in Too Close for comfort: contentious issues in human-wildlife encounters, edited D. Lunney, A. Munn & W. Meikle. Royal Zoological Society of New South Wales, Mosman, NSW, Australia.

Lewis, B. D. (2022). *Woolgoolga to Ballina Pacific Highway Upgrade: threatened mammal construction monitoring 2020/21 – version 2*. Report prepared for Jacobs and Transport for NSW.

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

Martinig, A. R., Riaz, M. & Cassady, C. (2020). Temporal clustering of prey in wildlife passages provides no evidence of a prey-trap. *Scientific Reports:* **10,** 11489.

Menkhorst, P. and Knight, F. (2010). Field Guide to Mammals of Australia (3rd Ed.). Oxford University Press. Australia.

Menkhorst, P., Rogers, D., Clarke, R., Davies, J., Marsack, P. and Franklin, K. (2017). The Australian Bird Guide. CSIRO Publishing, Melbourne.

Lunney, D., Gresser, Mahon, P. and Matthews, A. (2004). Post-fire survival and reproduction of rehabilitated and unburnt koalas. *Biological Conservation* 120, 567-575.

Lunney, D., Gresser, S., O'Neill, L., Matthews, A. and Rhodes, J. (2007). The impact of fire and dogs on koalas at Port Stephens, NSW, using population viability analysis. *Pacific Conservation Biology* 13(3), 189-201.

Roads and Maritime Services NSW (2016). *Woolgoolga to Ballina Pacific Highway Upgrade – Koala Plan of Management Sections 1-11 (Version 4.4).*

New South Wales Roads and Maritime Services (2017). Woolgoolga to Ballina Pacific Highway Upgrade Threatened Mammal Management Plan (version 3.3). NSW RMS, Sydney.

Sandpiper Ecological Surveys (2017). *Pacific Highway Upgrade – Glenugie: Operational phase fauna crossing monitoring program years 1-3*. Report prepared for NSW Roads and Maritime Services.

Sandpiper Ecological (2018a). S2W Pacific Highway Upgrade: Operational Phase Fauna Crossing Monitoring, Year 3. Final Report (version 2). Report prepared for NSW Roads and Maritime Services.

Sandpiper Ecological (2019). *Nambucca Heads to Urunga (NH2U) Pacific Highway Upgrade: Operational Phase Fauna Monitoring, Year 1.* Report prepared for NSW Roads and Maritime Services.

Sandpiper Ecological (2020). *Woolgoolga to Ballina (W2B) Pacific Highway Upgrade - Koala Monitoring Program Year 3 (2019/20) - Final Report (Version 2).* Report prepared for Transport for NSW.

Sandpiper Ecological (2021a). Woolgoolga to Ballina Pacific Highway Upgrade – Threatened Mammal Monitoring Program, Operation Phase Connectivity Structure and Road Mortality Monitoring sections 1 and 2, annual report 2020-21 (Year 3). Report prepared for Transport for New South Wales.

Sandpiper Ecological (2023a). *Woolgoolga to Ballina (W2B) Pacific Highway Upgrade - Koala Monitoring Program Year 5 (2021/22) - Final Report (Version 2).* Report prepared for Transport for New South Wales.

Sandpiper Ecological (2023b). *Warrell Creek to Nambucca Heads (WC2NH) Pacific Highway Upgrade - Underpass Monitoring Report – Year Four Operational Phase.* Report prepared for NSW Roads and Maritime Services.

Sandpiper Ecological (2023c). Pacific Highway Upgrade Woolgoolga to Ballina sections 3-11: threatened gliders monitoring program, year 6 2022. Report prepared for Transport for New South Wales.

Stobo-Wilson, A. M., Murphy, B. P., Crawford, H. M., Dawson, S. J., Dickman, C. R., Doherty, T. S., Fleming, P. A., Gentle, M. N., Legge, S. M., Newsome, T. M., Palmer, R., Rees, M. W., Ritchie, E. G., Speed, J., Stuart, J., Thompson, E., Turpin, J. & Woinarski, J. C. Z. (2021). Sharing meals: predation on Australian mammals by the introduced European red fox compounds and complements predation by feral cats. *Biological Conservation:* **261,** 109284.

Swan, G., Shea, G. and Sadlier, R. (2004). A Field Guide to Reptiles of New South Wales. New Holland, Sydney.

W2B Planning Alliance (2012). *Upgrading the Pacific Highway: Woolgoolga to Ballina. Working Paper: Biodiversity Assessment, November 2012*. Final. Prepared by NSW Roads and Maritime Services, Aurecon and Sinclair Knight Merz.

Appendix A – Complete and incomplete crossings

Table A1: Complete (CC) and incomplete crossings (IC) recorded for each species/fauna group recorded at 79 underpasses during three monitoring periods in 2021 and 2022. TM = threatened mammal, Aut/Win = Autumn/Winter, Spr/Sum = Spring/Summer, Sum/Aut = Summer/Autumn, CC = Complete crossing, IC = Incomplete crossing. Ant = antechinus, BC = bandicoot spp., BR = black rat, BTS = brown tree snake, BtPhas = brush-tailed phascogale, BuR = bush rat, CT = cane toad, CBtP = common brushtail possum, EGK = eastern grey kangaroo, EWD = eastern water dragon, EH = European hare.

TM site no.	Koala site no.	Season	Year	Ant		BC		BR		BTS		BtPhas		BuR		CT		CP		Cat		CBtP		Cow		Dog		EGK		EWD		Echidna		EH	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
11		Aut/Win	2022																																
15	K12	Spr/Sum	2021	22.0	2.8	1.2	0.0	0.5	0.1											0.1	0.0														
		Aut/Win	2022	0.3	0.0	0.5	0.1	0.3	0.0					0.0	0.1					0.3	0.0														
		Sum/Aut	2022	1.7	0.3	0.2	0.0	0.3	0.1											0.1	0.0														
16		Aut/Win	2022	0.1	0.0							0.1	0.0	0.0	0.1																				
		Sum/Aut	2022	0.0	0.3	0.1	0.0																												
17		Aut/Win	2022																	0.1	0.0														
		Sum/Aut	2022	0.6	0.0																					0.1	0.0								
18		Aut/Win	2022			0.1	0.0	0.1	0.1			0.1	0.0			0.1	0.1			0.1	0.0											0.1	0.0		
		Sum/Aut	2022																																
19		Aut/Win	2022	0.2	0.1	0.1	0.0																							0.0	0.3	0.1	0.0		
		Sum/Aut	2022	0.5	0.1	1.6	0.0																	1.5	0.0	0.3	0.0	0.4	0.0			0.2	0.0		
20		Aut/Win	2022	2.7	0.1	0.5	0.0							0.1	0.0																	0.3	0.0		
		Sum/Aut	2022	1.6	0.7															0.0	0.1														
21	K13	Spr/Sum	2021																							0.1	0.0	0.1	0.0						
		Aut/Win	2022					0.1	0.0															2.7	0.4	0.3	0.0	0.4	0.0						
		Sum/Aut	2022																																
22	K14	Spr/Sum	2021	0.0	10.5	0.1	0.1	0.5	0.3											0.0	0.2					0.8	2.2	0.2	0.1						
		Aut/Win	2022	0.1	0.0			0.3	0.1															0.8	0.0	2.0	0.0	0.3	0.0	0.1	0.0				
		Sum/Aut	2022			0.1	0.0	0.6	0.1											0.3	0.0	0.1	0.0			3.3	0.0	0.3	0.0	0.0	0.1				
23	K15	Spr/Sum	2021																									0.3	0.0						
		Aut/Win	2022	0.6	0.1			0.9	0.1													0.1	0.0					0.3	0.1						
		Sum/Aut	2022	0.2	0.0			0.8	0.2							0.1	0.0											0.9	0.0						
24	K16	Spr/Sum	2021	0.2	0.0			0.0	0.1											0.4	0.0					0.2	0.0	0.7	0.0						
		Aut/Win	2022	1.0	0.0																					0.2	0.0	0.2	0.1						
		Sum/Aut	2022					0.7	0.1											0.1	0.0					0.1	0.0	0.6	0.0					0.1	0.0
25	K17	Spr/Sum	2021			0.1	0.0													0.0	0.1					4.6	1.1	0.3	0.2						
		Aut/Win	2022																							1.2	0.3								
		Sum/Aut	2022																							3.9	0.1								

TM site no.	Koala site no.	Season	Year	Ant		BC		BR		BTS		BtPhas		BuR		CT		CP		Cat		CBtP		Cow		Dog		EGK		EWD		Echidna		EH	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
26	K18	Spr/Sum	2021					0.1	0.1																			0.2	0.0								
		Aut/Win	2022					0.8	0.2																			0.1	0.0								
		Sum/Aut	2022					0.8	0.1			0.1	0.0			0.0	0.1																				
27	K19	Spr/Sum	2021			1.2	0.0	1.6	0.2																			0.2	0.0								
		Aut/Win	2022			0.0	0.2					0.2	0.0															0.2	0.2								
		Sum/Aut	2022			1.3	0.1									0.0	0.6			0.8	0.0							0.1	0.0								
28		Aut/Win	2022			0.8	0.0																					0.1	0.0					0.1	0.0		
		Sum/Aut	2022			0.2	0.1									0.0	0.1											0.2	0.0					0.1	0.0		
29	K20	Spr/Sum	2021	0.2	0.1	0.5	0.0	0.0	0.3																												
		Aut/Win	2022									0.3	0.0																								
		Sum/Aut	2022	0.2	0.0							0.3	0.0																								
30	K21	Spr/Sum	2021			0.1	0.0	0.9	0.2											0.3	0.0					0.4	0.1	0.6	0.6	0.0	0.3	0.1	0.0		
		Aut/Win	2022																									0.3	0.0								
		Sum/Aut	2022					0.1	0.0																			0.3	0.0			0.1	0.0				
31		Aut/Win	2022																															0.1	0.0		
		Sum/Aut	2022			0.6	0.2											0.1	0.0									0.2	0.2								
32		Aut/Win	2022			0.1	0.0	0.1	0.0											0.1	0.0																
		Sum/Aut	2022					0.2	0.2											0.0	0.2																
33		Aut/Win	2022	0.5	0.1																																
		Sum/Aut	2022			0.2	0.0																									0.2	0.0				
34		Aut/Win	2022																											0.1	0.0						
		Sum/Aut	2022			0.1	0.0																														
35	K22	Spr/Sum	2021			0.2	0.0																			1.4	0.0										
		Aut/Win	2022																							0.6	0.1	0.1	0.0					0.0	0.1		
		Sum/Aut	2022																							0.5	0.0										
36		Sum/Aut	2022			0.1	0.0																														
37	K23	Spr/Sum	2021	0.0	0.1			0.1	0.3																												
		Aut/Win	2022			0.0	1.8	0.4	0.6											0.0	0.1	0.0	0.1									0.0	0.2				
		Sum/Aut	2022			0.7	0.1	1.1	0.3																	0.0	0.1					0.2	0.1				
	K24	Spr/Sum	2021																	1.4	0.0							17.5	0.0								
38	K25	Spr/Sum	2021					0.1	0.0											0.0	0.1							45.7	0.4								
		Sum/Aut	2022			0.4	0.0																					44.8	4.0								
39	K26	Spr/Sum	2021			1.6	0.0	4.3	0.5											0.2	0.0							3.3	0.4			0.2	0.0				
		Aut/Win	2022					0.4	0.0											0.2	0.0	0.4	0.0					1.3	0.0			0.2	0.0				
		Sum/Aut	2022	0.2	0.0			1.8	0.2											0.2	0.0							2.6	0.0								
40	K27	Spr/Sum	2021			0.2	0.0	0.1	0.0																			0.0	0.9								
		Aut/Win	2022			0.1	0.0	0.2	0.0											0.0	0.4							0.5	2.6								

TM site no.	Koala site no.	Season	Year	Ant		BC		BR		BTS		BtPhas		BuR		CT		CP		Cat		CBtP		Cow		Dog		EGK		EWD		Echidna		EH	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
		Sum/Aut	2022																									1.8	0.5			0.3	0.0		
41	K28	Spr/Sum	2021																																
		Aut/Win	2022																																
		Sum/Aut	2022	0.0	0.1															0.3	0.0							0.0	0.1						
42	K29	Spr/Sum	2021	0.1	0.2															0.8	0.0							3.0	0.0						
		Aut/Win	2022																	0.5	0.0							3.9	0.1						
		Sum/Aut	2022					0.1	0.0											0.1	0.0							0.5	0.0						
43	K30	Spr/Sum	2021			1.1	0.0	4.7	0.2																							0.4	0.0		
		Aut/Win	2022			0.3	0.0																									0.1	0.0		
		Sum/Aut	2022			0.5	0.0	0.1	0.1																			0.3	0.0			0.1	0.0		
44	K31	Spr/Sum	2021													0.0	0.2																	0.2	0.3
		Aut/Win	2022	0.2	0.0	0.0	0.1	1.1	1.6											0.4	1.1							0.2	0.0			0.1	0.0	0.3	0.1
		Sum/Aut	2022			0.5	0.0	0.4	0.0							0.5	0.2			0.3	0.0											0.1	0.0	0.1	0.0
45	K32	Spr/Sum	2021					1.7	0.3					0.1	0.0			0.1	0.0									0.0	0.1						
		Aut/Win	2022					2.9	0.6									0.0	0.1			3.8	0.1					0.1	0.0						
		Sum/Aut	2022																											0.1	0.0				
46		Aut/Win	2022					0.2	0.4																			0.1	0.0						
		Sum/Aut	2022																									0.2	0.0					0.1	0.0
47	K33	Spr/Sum	2021			0.1	0.1	0.4	0.0							0.1	0.1											3.0	1.2					0.8	0.0
		Aut/Win	2022																							0.4	0.0	3.2	0.0						
		Sum/Aut	2022																									1.0	0.0					0.1	0.0
48	K34	Spr/Sum	2021			1.1	0.0			0.0	0.3											5.2	0.4					0.6	0.0			0.1	0.0	1.8	0.1
		Aut/Win	2022			0.1	0.0	0.1	0.0													3.2	0.1					1.8	0.0			0.1	0.0		
49	K35	Spr/Sum	2021																							0.0	0.1								
		Aut/Win	2022																																
		Sum/Aut	2022																							0.4	0.0								
50	K36	Spr/Sum	2021			0.2	0.0	1.5	0.3																			0.1	0.0						
		Aut/Win	2022	0.3	0.0			2.3	0.2																							0.1	0.0		
		Sum/Aut	2022	0.2	0.0			0.3	0.1																										
51	K37	Spr/Sum	2021	0.8	0.0			0.4	0.1									0.0	0.1									0.1	0.0			0.3	0.0		
		Aut/Win	2022													0.0	0.1											0.5	0.0			0.1	0.0		
		Sum/Aut	2022	0.2	0.0			0.6	0.1							0.1	0.0															0.1	0.0		
52	K38	Spr/Sum	2021	0.3	0.0																														
		Aut/Win	2022					0.5	0.1																			0.1	0.0						
		Sum/Aut	2022	0.2	0.1	0.2	0.0																												
53	K39	Spr/Sum	2021					0.2	0.2																			0.2	0.0			0.1	0.0		
	K39	Spr/Sum	2021																																

TM site no.	Koala site no.	Season	Year	Ant		BC		BR		BTS		BtPhas		BuR		CT		CP		Cat		CBtP		Cow		Dog		EGK		EWD		Echidna		EH	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
		Aut/Win	2022					0.9	0.4																	0.1	0.0					0.1	0.0		
		Sum/Aut	2022	0.3	0.0			0.3	0.0																										
54	K40	Spr/Sum	2021					0.6	0.0																										
		Aut/Win	2022																																
		Sum/Aut	2022					0.1	0.0																										
55	K41	Spr/Sum	2021			0.7	0.0																							0.3	0.0				
		Aut/Win	2022					0.1	0.1																										
		Sum/Aut	2022					0.1	0.0							0.1	0.0																		
56	K42	Spr/Sum	2021					0.4	0.1																	0.5	0.2	0.8	0.4	0.1	0.1	0.2	0.0		
		Aut/Win	2022					0.8	0.2																	0.3	0.0	0.3	0.0	0.1	0.0				
		Sum/Aut	2022					0.4	0.0																			0.1	0.0			0.2	0.0		
57	K43	Spr/Sum	2021					0.2	0.0	0.1	0.0																	0.2	0.0						
		Aut/Win	2022											0.0	0.1													0.2	0.0						
		Sum/Aut	2022					0.4	0.1																			0.3	0.0						
58	K44	Spr/Sum	2021			0.1	0.0	0.2	0.0																							0.1	0.0		
		Sum/Aut	2022					0.2	0.0																										
59	K45	Spr/Sum	2021					0.9	0.4																							0.1	0.0		
		Aut/Win	2022																											0.1	0.0	0.1	0.0		
		Sum/Aut	2022					1.2	0.9																							0.2	0.0		
60	K46	Spr/Sum	2021			0.9	0.0													0.1	0.0							0.1	0.0						
		Aut/Win	2022			0.1	0.0																	2.8	0.0										
		Sum/Aut	2022					0.2	0.0																										
61	K47	Spr/Sum	2021																									0.1	0.0						
		Aut/Win	2022																	0.1	0.0									0.2	0.0				
		Sum/Aut	2022					0.4	0.0																										
62		Aut/Win	2022					1.2	0.3																										
		Sum/Aut	2022					1.0	0.0																										
63	K49	Spr/Sum	2021					0.7	0.3																			0.2	0.0						
		Aut/Win	2022			0.1	0.0	2.9	0.4																			0.5	0.0						
		Sum/Aut	2022					2.3	0.2																										
64		Aut/Win	2022																	0.1	0.0														
65	K51	Spr/Sum	2021					6.0	0.7																										
		Sum/Aut	2022																																
66	K52	Spr/Sum	2021					6.4	0.3	0.0	0.1																								
		Sum/Aut	2022																																
67	K53	Spr/Sum	2021			0.4	0.1	1.3	0.0									0.1	0.0													0.1	0.0		
		Aut/Win	2022					0.2	0.3																										

TM site no.	Koala site no.	Season	Year	Ant		BC		BR		BTS		BtPhas		BuR		CT		CP		Cat		CBtP		Cow		Dog		EGK		EWD		Echidna		EH	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
		Sum/Aut	2022			0.1	0.0	1.3	0.2																			0.1	0.0								
68	K54	Spr/Sum	2021					4.1	0.6									0.0	0.1									0.1	0.0								
	K54	Spr/Sum	2021																																
		Aut/Win	2022																																
		Sum/Aut	2022																																
69	K55	Spr/Sum	2021			0.3	0.3																			1.0	0.0								
		Sum/Aut	2022					0.3	0.0																	0.2	0.0					0.1	0.0		
70	K56	Spr/Sum	2021					0.6	0.1																	0.7	0.0								
		Aut/Win	2022																																
		Sum/Aut	2022																																
71	K57	Spr/Sum	2021					0.1	0.1																										
		Aut/Win	2022																													0.2	0.0		
		Sum/Aut	2022																																
72	K58	Spr/Sum	2021					0.5	0.2															1.6	0.0										
		Aut/Win	2022			0.1	0.0	0.0	0.1															0.1	0.5										
		Sum/Aut	2022					0.2	0.7																										
73	K59	Spr/Sum	2021					10.5	2.0																										
		Aut/Win	2022					1.9	0.4																										
		Sum/Aut	2022					2.4	0.1																										
74	K60	Spr/Sum	2021					2.5	0.3							0.0	0.1																		
		Aut/Win	2022																							0.1	0.0					0.2	0.0		
		Sum/Aut	2022					0.2	0.0																										
75		Aut/Win	2022					0.0	0.1																										
		Sum/Aut	2022					0.3	0.1																										
76	K61	Spr/Sum	2021					1.3	0.4																										
77	K62	Spr/Sum	2021					0.6	0.0																										
78	K63	Spr/Sum	2021					0.3	0.1	0.0	0.1																					0.3	0.1		
		Aut/Win	2022					0.1	0.2													0.5	0.0									0.4	0.0		
		Sum/Aut	2022					3.6	0.3											0.2	0.0														
79	K64	Spr/Sum	2021					0.1	0.0							0.0	0.1			0.1	0.0														
		Aut/Win	2022																							1.2	0.0								
		Sum/Aut	2022																																
36		Aut/Win	2022																									2.0	0.0						
K		Aut/Win	2022																																
N1		Aut/Win	2022	0.0	0.2																			1.2	0.0	0.1	0.0	0.1	0.0						
		Sum/Aut	2022	0.6	0.0																					0.6	0.0								
N2		Aut/Win	2022	0.4	0.1			0.1	0.1													1.2	0.1					0.6	0.0						

TM site no.	Koala site no.	Season	Year	Ant		BC		BR		BTS		BtPhas		BuR		CT		CP		Cat		CBtP		Cow		Dog		EGK		EWD		Echidna		EH	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
		Sum/Aut	2022					0.2	0.0													5.4	0.0														
N3		Aut/Win	2022																			3.8	0.4					0.4	0.0						
		Sum/Aut	2022																																
N4		Aut/Win	2022			0.1	0.0															3.5	0.2					0.1	0.0						
		Sum/Aut	2022																			3.0	0.0												
N5		Aut/Win	2022	0.4	0.0	0.2	0.0	0.3	0.3																										
		Sum/Aut	2022					0.6	0.0																										
N6		Sum/Aut	2022																					0.2	0.0										
N7		Sum/Aut	2022	0.2	0.0																														
	KWE1	Spr/Sum	2021																																
	KWE2	Spr/Sum	2021																																
	Kwmid	Spr/Sum	2021			0.0	0.4																												
	Kwmid	Spr/Sum	2021																																

Table A2: Complete (CC) and incomplete crossings (IC) recorded for each species/fauna group recorded at 79 underpasses during three monitoring periods in 2021 and 2022. TM = threatened mammal,Aut/Win = Autumn/Winter, Spr/Sum = Spring/Summer, Sum/Aut = Summer/Autumn, CC = Complete crossing, IC = Incomplete crossing. HM = house mouse, LM = lace monitor, Liz = lizard spp., LNB = long-nosed bandicoot, Mac = macropod spp., FFM = fawn-footed melomys, NBB = northern brown bandicoot, PfW = pretty face wallaby, Pyth = python spp., Rattus = rattus spp.

Tmam site no.	Koala site no.	Season	Year	Fox		Fox/Dog		Frog spp.		HM		Koala		LM		Liz		LNB		Mac		FFM		NBB		Potoroo		PfW		Pyth		Rattus	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
11		Aut/Win	2022																														
15	K12	Spr/Sum	2021															0.1	0.2													0.3	0.3
		Aut/Win	2022															1.2	0.7													0.2	0.0
		Sum/Aut	2022															0.7	0.1			0.1	0.1	0.2	0.0							0.3	0.2
16		Aut/Win	2022							0.0	0.2																					0.0	0.2
		Sum/Aut	2022																													0.2	0.1
17		Aut/Win	2022																													0.0	0.1
		Sum/Aut	2022																														
18		Aut/Win	2022	0.1	0.1			0.0	0.1	0.1	0.0													0.1	0.0							0.1	0.1
		Sum/Aut	2022	0.1	0.0																												
19		Aut/Win	2022															0.7	0.1													1.2	0.1
		Sum/Aut	2022	0.4	0.1					0.1	0.0					0.0	0.1							0.5	0.0							1.0	0.5
20		Aut/Win	2022															0.8	0.1					0.1	0.0							1.0	0.2
		Sum/Aut	2022							0.1	0.1																					0.2	0.1
21	K13	Spr/Sum	2021																														
		Aut/Win	2022	0.5	0.1																												

Tmam site no.	Koala site no.	Season	Year	Fox		Fox/Dog		Frog spp.		HM		Koala		LM		Liz		LNB		Mac		FFM		NBB		Potoroo		PfW		Pyth		Rattus	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
		Sum/Aut	2022																													0.0	0.4
22	K14	Spr/Sum	2021	0.0	0.1													0.1	0.4	0.0	0.8											0.7	3.8
		Aut/Win	2022	0.3	0.1	0.1	0.0													0.1	0.0			0.1	0.1							0.8	0.1
		Sum/Aut	2022	0.1	0.0																											2.3	0.8
23	K15	Spr/Sum	2021																														
		Aut/Win	2022	0.7	0.0															0.3	0.0											0.1	0.1
		Sum/Aut	2022																													0.4	0.0
24	K16	Spr/Sum	2021	0.2	0.0															0.6	0.0												
		Aut/Win	2022	0.5	0.0															0.9	0.0											0.3	0.0
		Sum/Aut	2022	0.1	0.0															0.4	0.0											0.1	0.0
25	K17	Spr/Sum	2021																														
		Aut/Win	2022	0.1	0.0																											0.1	0.0
		Sum/Aut	2022	0.1	0.0																												
26	K18	Spr/Sum	2021																													0.2	0.0
		Aut/Win	2022																													6.6	0.8
		Sum/Aut	2022																													3.4	0.9
27	K19	Spr/Sum	2021											0.2	0.1																	0.1	0.2
		Aut/Win	2022											0.4	0.0			1.0	0.0														
		Sum/Aut	2022																													0.2	0.0
28		Aut/Win	2022															0.1	0.0	0.1	0.0					0.0	0.1						
		Sum/Aut	2022											0.2	0.0									0.2	0.0								
29	K20	Spr/Sum	2021															0.2	0.0													0.1	0.0
		Aut/Win	2022																													0.1	0.1
		Sum/Aut	2022															0.1	0.0													0.2	0.0
30	K21	Spr/Sum	2021											0.0	0.4					0.9	0.2			0.0	0.1							0.6	0.3
		Aut/Win	2022															0.3	0.1													0.1	0.0
		Sum/Aut	2022											0.1	0.0																	0.9	0.0
31		Aut/Win	2022	0.1	0.0																											0.1	0.0
		Sum/Aut	2022	0.8	0.0																											0.4	0.0
32		Aut/Win	2022	0.0	0.1													0.1	0.0													0.3	1.9
		Sum/Aut	2022	0.2	0.2					0.2	0.0							0.2	0.0													0.2	0.4
33		Aut/Win	2022	0.1	0.0			0.0	0.0									0.1	0.0													0.4	0.1
		Sum/Aut	2022	0.3	0.0													0.1	0.0													0.1	0.0
34		Aut/Win	2022	0.1	0.0													0.2	0.1	0.1	0.0											0.3	0.1
		Sum/Aut	2022	0.4	0.0					0.2	0.2											0.1	0.0									0.1	0.0
35	K22	Spr/Sum	2021	0.1	0.1																												
		Aut/Win	2022	0.2	0.0																												

Tmam site no.	Koala site no.	Season	Year	Fox		Fox/Dog		Frog spp.		HM		Koala		LM		Liz		LNB		Mac		FFM		NBB		Potoroo		PfW		Pyth		Rattus	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
		Sum/Aut	2022																														
36		Sum/Aut	2022																														
37	K23	Spr/Sum	2021					0.2	0.1	0.0	0.5							0.7	0.1	0.0	0.1			0.1	0.0							3.0	0.9
		Aut/Win	2022	0.0	0.1					0.0	0.1							0.9	2.4	0.8	0.1			0.0	0.3							0.1	0.0
		Sum/Aut	2022							0.2	0.0							3.7	0.7													0.4	0.0
	K24	Spr/Sum	2021																														
38	K25	Spr/Sum	2021	0.0	0.1													0.2	0.0														
		Sum/Aut	2022	0.0	0.2													0.2	0.0					0.2	0.0			0.4	0.0				
39	K26	Spr/Sum	2021	1.0	0.0							0.9	0.0					0.7	0.0	0.1	0.0											2.2	1.0
		Aut/Win	2022	3.0	0.0															0.3	0.0											2.2	0.2
		Sum/Aut	2022	2.4	0.2																											0.4	0.4
40	K27	Spr/Sum	2021	0.5	0.1													0.0	0.1														
		Aut/Win	2022	0.2	2.1													0.2	0.1													0.3	0.1
		Sum/Aut	2022	0.5	0.2																											0.2	0.0
41	K28	Spr/Sum	2021																														
		Aut/Win	2022	0.4	0.2																												
		Sum/Aut	2022	0.0	0.1													0.2	0.0													0.0	0.1
42	K29	Spr/Sum	2021																													0.2	0.0
		Aut/Win	2022	0.2	0.2													0.0	0.1													0.1	0.0
		Sum/Aut	2022																														
43	K30	Spr/Sum	2021	0.0	0.1																											2.8	0.5
		Aut/Win	2022																														
		Sum/Aut	2022															0.1	0.0													1.3	2.4
44	K31	Spr/Sum	2021							0.1	0.1																					0.1	0.3
		Aut/Win	2022	0.1	0.0					0.0	2.1							0.1	0.1	0.1	0.0			0.0	0.1							0.8	0.3
		Sum/Aut	2022	0.4	0.0			0.1	0.1	0.1	0.0							0.2	0.0					0.2	0.0							2.5	0.6
45	K32	Spr/Sum	2021																											0.0	0.1	0.7	0.0
		Aut/Win	2022	0.5	0.1															0.1	0.0											6.6	1.2
		Sum/Aut	2022																														
46		Aut/Win	2022																														
		Sum/Aut	2022																					0.0	0.1								
47	K33	Spr/Sum	2021															0.2	0.1	1.1	0.5											0.1	0.0
		Aut/Win	2022	2.1	0.0													0.1	0.0	4.0	0.1											0.3	0.0
		Sum/Aut	2022																														
48	K34	Spr/Sum	2021															0.1	0.0					0.2	0.1					0.0	0.1	0.1	0.1
		Aut/Win	2022	0.5	0.0													0.7	0.0					0.3	0.0							0.1	0.0
49	K35	Spr/Sum	2021	0.1	0.1																												

Tmam site no.	Koala site no.	Season	Year	Fox		Fox/Dog		Frog spp.		HM		Koala		LM		Liz		LNB		Mac		FFM		NBB		Potoroo		PfW		Pyth		Rattus	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
		Aut/Win	2022	0.9	0.1															0.1	0.0												
		Sum/Aut	2022	0.3	0.0																												
50	K36	Spr/Sum	2021	0.1	0.0																											0.6	0.2
		Aut/Win	2022	0.8	0.0																											0.3	0.0
		Sum/Aut	2022	0.4	0.0																											0.7	0.1
51	K37	Spr/Sum	2021	0.1	0.0																											0.0	0.1
		Aut/Win	2022	0.9	0.2																									0.1	0.0	4.3	0.8
		Sum/Aut	2022	0.7	0.0																												
52	K38	Spr/Sum	2021	0.1	0.0																												
		Aut/Win	2022	0.4	0.0													0.4	0.0	0.2	0.0											0.4	0.1
		Sum/Aut	2022	0.5	0.0																											0.0	0.1
53	K39	Spr/Sum	2021	0.3	0.1																												
	K39	Spr/Sum	2021																													0.4	0.0
		Aut/Win	2022	0.2	0.0																											0.4	0.1
		Sum/Aut	2022	1.7	0.0																											0.6	0.0
54	K40	Spr/Sum	2021	1.1	0.0																											0.2	0.0
		Aut/Win	2022	0.4	0.0																											0.2	0.0
		Sum/Aut	2022	1.0	0.0																												
55	K41	Spr/Sum	2021																														
		Aut/Win	2022	1.1	0.2															1.2	0.0											0.2	0.0
		Sum/Aut	2022	0.3	0.0																											0.3	0.0
56	K42	Spr/Sum	2021	1.3	0.6																											1.0	0.3
		Aut/Win	2022	1.0	0.1																												
		Sum/Aut	2022	0.3	0.0																											0.1	0.0
57	K43	Spr/Sum	2021	0.6	0.0															0.1	0.0											5.1	1.4
		Aut/Win	2022	0.1	0.1															1.8	0.1											1.0	0.4
		Sum/Aut	2022	1.4	0.1																											0.9	0.2
58	K44	Spr/Sum	2021	0.6	0.0															1.0	0.0											0.7	0.1
		Sum/Aut	2022	0.2	0.0																											0.3	0.0
59	K45	Spr/Sum	2021	0.8	0.1					0.2	0.1									1.0	0.0											3.3	1.8
		Aut/Win	2022	0.7	0.1															1.5	0.0											2.1	1.0
		Sum/Aut	2022	1.3	0.2					0.4	0.0																					0.6	0.3
60	K46	Spr/Sum	2021	0.1	0.0																			0.1	0.1							0.2	0.1
		Aut/Win	2022	1.5	0.0					0.1	0.0							0.1	0.0					0.1	0.0							0.0	0.2
		Sum/Aut	2022							0.2	0.0			0.1	0.0																		
61	K47	Spr/Sum	2021	0.4	0.0																											0.4	0.1
		Aut/Win	2022	0.1	0.1																											0.1	0.5

Tmam site no.	Koala site no.	Season	Year	Fox		Fox/Dog		Frog spp.		HM		Koala		LM		Liz		LNB		Mac		FFM		NBB		Potoroo		PfW		Pyth		Rattus	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
		Sum/Aut	2022	0.6	0.0																												
62		Aut/Win	2022	0.1	0.0																											1.0	0.5
		Sum/Aut	2022	0.1	0.0																											0.1	0.0
63	K49	Spr/Sum	2021	0.4	0.0																											0.4	0.0
		Aut/Win	2022	3.1	0.0															0.4	0.0											2.7	0.2
		Sum/Aut	2022	3.1	0.0																											0.8	0.6
64		Aut/Win	2022	0.1	0.0																											0.0	0.3
65	K51	Spr/Sum	2021	1.8	0.5																											4.4	0.4
		Sum/Aut	2022	1.8	0.2																											18.5	1.4
66	K52	Spr/Sum	2021	0.1	0.0																											7.7	1.4
		Sum/Aut	2022	0.4	0.0																											0.2	0.4
67	K53	Spr/Sum	2021	0.6	0.3													0.5	0.0	0.5	0.0											3.6	1.6
		Aut/Win	2022	0.2	0.0																											0.2	0.0
		Sum/Aut	2022	0.3	0.0					0.2	0.2																					4.3	1.8
68	K54	Spr/Sum	2021	0.2	0.0											0.0	0.3															3.4	0.9
	K54	Spr/Sum	2021																													0.8	0.2
		Aut/Win	2022	0.3	0.0																											0.5	0.3
		Sum/Aut	2022																													2.0	0.3
69	K55	Spr/Sum	2021	0.7	0.0															0.3	0.0											5.3	0.3
		Sum/Aut	2022	0.3	0.0					0.0	0.1									0.2	0.0											0.3	0.3
70	K56	Spr/Sum	2021	0.4	0.0																											0.0	0.1
		Aut/Win	2022	0.9	0.1															1.3	0.0											4.2	1.4
		Sum/Aut	2022	1.4	0.0															0.1	0.0											0.1	0.1
71	K57	Spr/Sum	2021	1.1	0.4																												
		Aut/Win	2022	1.7	0.1																												
		Sum/Aut	2022	0.3	0.0																												
72	K58	Spr/Sum	2021	1.2	0.6																											2.3	0.1
		Aut/Win	2022	0.9	0.2																											1.2	1.4
		Sum/Aut	2022																														
73	K59	Spr/Sum	2021	8.4	0.9																											14.6	3.1
		Aut/Win	2022	0.4	0.1																											2.2	0.4
		Sum/Aut	2022	0.5	0.0																											0.7	0.8
74	K60	Spr/Sum	2021	12.8	3.8																											4.3	4.2
		Aut/Win	2022	5.0	0.0																											4.7	0.1
		Sum/Aut	2022	2.8	0.1																											0.9	0.3
75		Aut/Win	2022	1.1	0.0																											0.1	1.7
		Sum/Aut	2022	0.2	0.0																											0.3	0.0

Tmam site no.	Koala site no.	Season	Year	Fox		Fox/Dog		Frog spp.		HM		Koala		LM		Liz		LNB		Mac		FFM		NBB		Potoroo		PfW		Pyth		Rattus	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
76	K61	Spr/Sum	2021	4.9	0.0																												
77	K62	Spr/Sum	2021																													0.2	0.0
78	K63	Spr/Sum	2021	5.6	0.3																											1.0	0.9
		Aut/Win	2022	2.8	0.0																											3.0	2.1
		Sum/Aut	2022	5.4	0.1					0.3	0.0																					1.7	0.3
79	K64	Spr/Sum	2021	0.2	0.3																											0.1	0.0
		Aut/Win	2022	3.8	0.0																												
		Sum/Aut	2022	1.0	0.0																											0.1	0.0
36		Aut/Win	2022																														
K		Aut/Win	2022	12.6	0.0											0.0	0.2																
N1		Aut/Win	2022	2.1	0.0																											0.1	0.0
		Sum/Aut	2022	1.6	0.0																											0.2	0.0
N2		Aut/Win	2022	0.5	0.2																											0.2	0.2
		Sum/Aut	2022	1.6	0.0																											0.6	0.2
N3		Aut/Win	2022	0.1	0.0																												
		Sum/Aut	2022															0.2	0.0														
N4		Aut/Win	2022	0.1	0.0															0.6	0.0											0.2	0.1
		Sum/Aut	2022	1.0	0.0																												
N5		Aut/Win	2022	2.0	0.1									0.5	0.0			0.4	0.2													0.4	0.9
		Sum/Aut	2022	2.2	0.0					0.2	0.0							0.2	0.0														
N6		Sum/Aut	2022																													0.4	0.0
N7		Sum/Aut	2022							0.2	0.0																						
	KWE1	Spr/Sum	2021	1.1	0.2							0.1	0.0					0.1	0.0														
	KWE2	Spr/Sum	2021	0.3	0.1													0.2	0.1														
	Kwmid	Spr/Sum	2021	1.0	0.7																											0.0	0.1
	Kwmid	Spr/Sum	2021	4.0	4.4			0.0	0.1							0.0	0.0																

Table A3: Complete (CC) and incomplete crossings (IC) recorded for each species/fauna group recorded at 79 underpasses during three monitoring periods in 2021 and 2022. TM = threatened mammal, Aut/Win = Autumn/Winter, Spr/Sum = Spring/Summer, Sum/Aut = Summer/Autumn, CC = Complete crossing, IC = Incomplete crossing. RnW = red-necked wallaby, SeBtp = short-eared brushtail possum, SR = swamp rat, Tri = trichosurus spp., W spp. = wallaby spp., WR = water rat.

Tmam site no.	Koala site no.	Season	Year	RnW		SeBtP		Snake spp.		SR		SW		Tri		W spp.		WR	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
11		Aut/Win	2022													0.2	0.0		
15	K12	Spr/Sum	2021																
		Aut/Win	2022																
		Sum/Aut	2022																
16		Aut/Win	2022															0.1	0.2
		Sum/Aut	2022															0.1	0.0
17		Aut/Win	2022																
		Sum/Aut	2022					0.1	0.0										
18		Aut/Win	2022											0.1	0.0			0.1	0.0
		Sum/Aut	2022											0.1	0.0				
19		Aut/Win	2022																
		Sum/Aut	2022							0.0	0.1								
20		Aut/Win	2022																
		Sum/Aut	2022															0.5	0.0
21	K13	Spr/Sum	2021																
		Aut/Win	2022																
		Sum/Aut	2022																
22	K14	Spr/Sum	2021													0.1	1.4		
		Aut/Win	2022															0.3	0.1
		Sum/Aut	2022													0.1	0.0	0.4	0.1
23	K15	Spr/Sum	2021																
		Aut/Win	2022													2.0	0.1		
		Sum/Aut	2022	0.6	0.1											1.8	0.0		
24	K16	Spr/Sum	2021	0.1	0.0											1.2	0.0		
		Aut/Win	2022													0.6	0.0		
		Sum/Aut	2022													0.3	0.0		
25	K17	Spr/Sum	2021																
		Aut/Win	2022																
		Sum/Aut	2022																
26	K18	Spr/Sum	2021	0.2	0.0														
		Aut/Win	2022																
		Sum/Aut	2022																
27	K19	Spr/Sum	2021													0.2	0.0		
		Aut/Win	2022																
		Sum/Aut	2022																
28		Aut/Win	2022																

Tmam site no.	Koala site no.	Season	Year	RnW		SeBtP		Snake spp.		SR		SW		Tri		W spp.		WR	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
		Sum/Aut	2022																
29	K20	Spr/Sum	2021													1.7	0.0		
		Aut/Win	2022																
		Sum/Aut	2022													0.1	0.0		
30	K21	Spr/Sum	2021	0.3	0.0							0.8	0.1			0.1	0.0		
		Aut/Win	2022	1.0	0.1							0.9	0.0			0.5	0.1	0.1	0.0
		Sum/Aut	2022													1.0	0.0		
31		Aut/Win	2022			1.0	0.1	0.0	0.1										
		Sum/Aut	2022			0.1	0.0							0.2	0.0				
32		Aut/Win	2022											0.0	0.1			0.0	1.6
		Sum/Aut	2022											0.2	0.0			4.3	0.2
33		Aut/Win	2022			3.9	0.1					1.9	0.1			0.2	0.0		
		Sum/Aut	2022			0.6	0.2					1.6	0.3						
34		Aut/Win	2022			0.1	0.0					2.0	0.0			0.2	0.0		
		Sum/Aut	2022			1.0	0.0					0.8	0.0						
35	K22	Spr/Sum	2021	1.7	0.2							0.1	0.0			0.3	0.5		
		Aut/Win	2022									0.2	0.0			0.3	0.0		
		Sum/Aut	2022													0.2	0.0		
36		Sum/Aut	2022																
37	K23	Spr/Sum	2021															0.0	0.3
		Aut/Win	2022									1.9	0.1						
		Sum/Aut	2022																
	K24	Spr/Sum	2021			1.0	0.0					25.6	0.0						
38	K25	Spr/Sum	2021									21.7	0.1			6.0	0.2		
		Sum/Aut	2022									20.0	1.4			14.2	0.4		
39	K26	Spr/Sum	2021			10.5	0.0					0.5	0.1						
		Aut/Win	2022			3.5	0.2					1.3	0.0	3.6	0.0				
		Sum/Aut	2022			2.2	0.1					2.0	0.0	5.1	0.0	0.6	0.0		
40	K27	Spr/Sum	2021									0.3	0.0						
		Aut/Win	2022									0.2	1.3						
		Sum/Aut	2022									0.0	0.1			0.3	0.0		
41	K28	Spr/Sum	2021									0.0	0.7						
		Aut/Win	2022									0.4	0.1			0.4	0.0		
		Sum/Aut	2022									0.9	0.1			0.4	0.2		
42	K29	Spr/Sum	2021									0.9	0.1						
		Aut/Win	2022					0.1	0.0			5.2	0.2					0.2	0.0

Tmam site no.	Koala site no.	Season	Year	RnW		SeBtP		Snake spp.		SR		SW		Tri		W spp.		WR	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
		Sum/Aut	2022									1.0	0.0						
43	K30	Spr/Sum	2021															0.2	0.0
		Aut/Win	2022									0.1	0.0			0.1	0.0		
		Sum/Aut	2022																
44	K31	Spr/Sum	2021																
		Aut/Win	2022													0.0	0.1		
		Sum/Aut	2022									0.4	0.0						
45	K32	Spr/Sum	2021																
		Aut/Win	2022															0.4	0.0
		Sum/Aut	2022																
46		Aut/Win	2022															0.3	0.1
		Sum/Aut	2022									0.0	0.1						
47	K33	Spr/Sum	2021									20.1	2.8						
		Aut/Win	2022	1.3	0.0							8.9	0.1			3.2	0.0		
		Sum/Aut	2022					0.1	0.0			4.1	0.1			2.0	0.0		
48	K34	Spr/Sum	2021			0.1	0.0					3.1	0.5						
		Aut/Win	2022			0.7	0.0	0.1	0.0			6.1	0.3	3.2	0.2				
49	K35	Spr/Sum	2021					0.0	0.1			0.2	0.0						
		Aut/Win	2022													0.1	0.0		
		Sum/Aut	2022					0.1	0.0							0.1	0.0		
50	K36	Spr/Sum	2021			0.0	0.1					0.1	0.0						
		Aut/Win	2022			0.5	0.0					0.9	0.0						
		Sum/Aut	2022																
51	K37	Spr/Sum	2021																
		Aut/Win	2022									0.1	0.0						
		Sum/Aut	2022																
52	K38	Spr/Sum	2021									1.6	0.2						
		Aut/Win	2022	0.9	0.0							5.8	0.2			1.7	0.0		
		Sum/Aut	2022									4.0	0.1			0.7	0.1		
53	K39	Spr/Sum	2021									1.8	0.2						
	K39	Spr/Sum	2021																
		Aut/Win	2022	0.2	0.0							0.8	0.0			0.2	0.0		
		Sum/Aut	2022									7.9	0.4			0.2	0.0		
54	K40	Spr/Sum	2021																
		Aut/Win	2022	0.1	0.0											1.0	0.0		
		Sum/Aut	2022									0.9	0.0						

Tmam site no.	Koala site no.	Season	Year	RnW		SeBtP		Snake spp.		SR		SW		Tri		W spp.		WR	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
55	K41	Spr/Sum	2021									10.0	0.3			0.7	0.0		
		Aut/Win	2022	0.6	0.0							3.0	0.0			3.8	0.0	0.3	0.1
		Sum/Aut	2022									6.0	0.1					0.3	0.1
56	K42	Spr/Sum	2021	1.0	0.1							0.3	0.1						
		Aut/Win	2022									0.4	0.0						
		Sum/Aut	2022									1.1	0.0						
57	K43	Spr/Sum	2021					0.1	0.0			7.6	2.4			1.1	0.9		
		Aut/Win	2022	3.1	0.0							10.9	0.4			3.0	0.1		
		Sum/Aut	2022									9.6	0.1			0.4	0.0		
58	K44	Spr/Sum	2021									2.3	0.0						
		Sum/Aut	2022									0.4	0.0						
59	K45	Spr/Sum	2021					0.0	0.1			3.8	0.3			0.1	0.0		
		Aut/Win	2022									4.9	0.6			0.7	0.0		
		Sum/Aut	2022									4.2	0.2			0.4	0.0		
60	K46	Spr/Sum	2021									1.0	0.4						
		Aut/Win	2022									1.4	0.0			1.8	0.0	0.1	0.0
		Sum/Aut	2022									2.8	0.5						
61	K47	Spr/Sum	2021									2.8	0.2					0.5	0.0
		Aut/Win	2022	0.1	0.0							0.2	0.1						
		Sum/Aut	2022									1.6	0.0					0.8	0.0
62		Aut/Win	2022																
		Sum/Aut	2022																
63	K49	Spr/Sum	2021									0.3	0.0						
		Aut/Win	2022									0.1	0.0						
		Sum/Aut	2022									0.3	0.0			0.1	0.0		
64		Aut/Win	2022																
65	K51	Spr/Sum	2021																
		Sum/Aut	2022																
66	K52	Spr/Sum	2021																
		Sum/Aut	2022																
67	K53	Spr/Sum	2021	0.1	0.1							4.3	0.1					0.2	0.2
		Aut/Win	2022	0.1	0.0							3.3	0.0			0.5	0.0		
		Sum/Aut	2022	0.1	0.0							1.1	0.2						
68	K54	Spr/Sum	2021					0.1	0.2			0.1	0.0					0.1	0.1
	K54	Spr/Sum	2021																
		Aut/Win	2022					0.1	0.0									0.1	0.0

Tmam site no.	Koala site no.	Season	Year	RnW		SeBtP		Snake spp.		SR		SW		Tri		W spp.		WR	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
		Sum/Aut	2022																
69	K55	Spr/Sum	2021													1.3	0.0		
		Sum/Aut	2022									0.2	0.0					0.1	0.0
70	K56	Spr/Sum	2021													0.1	0.0		
		Aut/Win	2022					0.0	0.1			0.4	0.0			0.9	0.1		
		Sum/Aut	2022									0.4	0.0						
71	K57	Spr/Sum	2021													0.1	0.1		
		Aut/Win	2022													0.1	0.0		
		Sum/Aut	2022																
72	K58	Spr/Sum	2021					0.1	0.1										
		Aut/Win	2022			0.2	0.1											0.0	0.1
		Sum/Aut	2022																
73	K59	Spr/Sum	2021			0.1	0.0									0.1	0.0		
		Aut/Win	2022																
		Sum/Aut	2022			0.1	0.0												
74	K60	Spr/Sum	2021											0.1	0.1				
		Aut/Win	2022											0.1	0.0				
		Sum/Aut	2022																
75		Aut/Win	2022			0.3	0.0							0.7	0.0			1.0	0.8
		Sum/Aut	2022			0.1	0.0							1.4	0.0			1.2	0.0
76	K61	Spr/Sum	2021											0.0	0.4				
77	K62	Spr/Sum	2021																
78	K63	Spr/Sum	2021			2.5	0.3												
		Aut/Win	2022			2.1	0.7					0.1	0.0						
		Sum/Aut	2022			2.7	0.3							1.2	0.0				
79	K64	Spr/Sum	2021			0.2	0.1												
		Aut/Win	2022									0.1	0.1	0.1	0.0				
		Sum/Aut	2022			0.6	0.1											0.3	0.0
36		Aut/Win	2022									0.5	0.1			0.6	0.0		
K		Aut/Win	2022											1.2	0.0	0.4	0.0		
N1		Aut/Win	2022									0.2	0.0						
		Sum/Aut	2022									0.4	0.0			0.2	0.0		
N2		Aut/Win	2022	0.5	0.0									0.3	0.0	1.2	0.0		
		Sum/Aut	2022	0.4	0.0									2.8	0.0				
N3		Aut/Win	2022																
		Sum/Aut	2022																

Tmam site no.	Koala site no.	Season	Year	RnW		SeBtP		Snake spp.		SR		SW		Tri		W spp.		WR	
				CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC	CC	IC
N4		Aut/Win	2022	0.4	0.0							0.4	0.0	3.9	0.0				
		Sum/Aut	2022	1.0	0.0							0.0	0.0	2.8	0.0				
N5		Aut/Win	2022									0.4	0.0						
		Sum/Aut	2022													1.4	0.0		
N6		Sum/Aut	2022																
N7		Sum/Aut	2022																
	KWE1	Spr/Sum	2021			0.6	0.0					0.9	0.4	0.0	0.1	0.3	0.3		
	KWE2	Spr/Sum	2021			0.5	0.0					1.6	1.4			0.0	0.4		
	Kwmid	Spr/Sum	2021																
	Kwmid	Spr/Sum	2021			0.0	0.3					0.1	0.0	0.4	0.6	0.1	0.2		

Appendix B – Species richness and taxonomic groups

Table B1: Species total complete and incomplete crossings per week during 3 sample periods (koala 2021, tmam 2022 x2) operational monitoring W2B.

Common name	Sum of CC/week	Sum of IC/week
Short-beaked echidna	5.958	0.339
Antechinus spp.	36.608	15.799
Brush-tailed phascogale	1.054	0
Koala	0.941	0
Long-nosed bandicoot	16.022	5.580
Northern brown bandicoot	2.241	0.767
Bandicoot species	19.83	3.62
Common brushtail possum	30.289	1.288
Short-eared brushtail possum	35.005	2.492
Trichosurus spp.	27.37	1.32
Long-nosed potoroo	0	0.065
Eastern grey kangaroo	149.816	12.050
Pretty face wallaby	0.4	0
Red-necked wallaby	13.570	0.537
Swamp wallaby	246.435	17.378
Wallaby spp.	61.569	5.108
Macropod spp.	19.924	1.771
Water rat	11.562	3.820
Melomys spp.	0.187	0.094
Bush rat	0.139	0.242
Swamp rat	0	0.094
Rattus spp.	171.875	56.768
House mouse	2.730	3.570
Black rat	96.465	19.581
Cat	7.602	2.249
Dog	25.489	4.236
Fox	145.193	19.789
Fox/Dog	0.065	0
European Hare	3.695	0.548
Cow	10.928	0.808
Small mammal	0.28	0.17
Med mammal	0.66	0.06
Land mullet	0	0.094
Lizard spp.	0	0.194
Eastern water dragon	0.70	0.81
Agamidae spp.	0	0.256

Common name	Sum of CC/week	Sum of IC/week
Lace monitor	1.573	0.46
Brown tree snake	0.070	0.437
Carpet python	0.34	0.35
Snake spp.	0.745	0.612
Cane toad	0.976	1.517
Frog spp.	0.251	0.35
Black duck	0.991	1.785
Wood duck	0.085	0.859
White-faced heron	0	0.085
Ardea spp.	1.350	0.441
Pied cormorant	0	0.365
Cormorant spp.	0	0.085
Brown goshawk	0.070	0
Unidentified raptor	0.159	0.070
Tyto spp.	0	0.088
Bush turkey	9.25	2.401
Pheasant coucal	0	0.179
Azure Kingfisher	0	0.256
Forest kingfisher	0	0.085
Laughing kookaburra	0	0.265
Kingfisher spp.	0	0.077
Wonga pigeon	0.066	0.354
Peacock	2.792	0.535
Welcome swallow	0	0.395
Willie wagtail	0	0.875
Torresian crow	0	0.169
Unidentified bird	0.18	0.255
Unknown	0.089	0

Appendix C - Scat and track results

Table C1: Scat and track survey results for sections 3-11 in spr/sum 2021, sum/aut 2022 and aut/wint 2022. K = koala sample site number. All other numbers are threatened mammal sample sites.

Sample period	Species	Scat & scratch & track
Spr/Sum 21	Bandicoot	KWE12, k21, k26, k57
Spr/Sum 21	Brushtail possum	K19, k23, k34, k41, k61, k62
Spr/Sum 21	Cattle	k13
Spr/Sum 21	dog	k20, k28
Spr/Sum 21	Eastern grey kangaroo	K13, k18, k25, k27, k28, k29, k34, k39, k45, k46, k47
Spr/Sum 21	Echidna	k44
Spr/Sum 21	Fox	K12, k21, k44, k47, k48, k51, k53, k54, k56, k59, k60, k61, k63, k64

Sample period	Species	Scat & scratch & track
Spr/Sum 21	Frog	k56
Spr/Sum 21	Goanna	K13, k14, k16, k18, k20, k21, k38, k62
Spr/Sum 21	Horse	k14
Spr/Sum 21	Koala	KWE12, Kwmid, k26, k27, k28, k36, k37, k38,k40, k45, k46, k55
Spr/Sum 21	lizard	k61
Spr/Sum 21	microbat	k41
Spr/Sum 21	Possum	K12, k14, k21, k40, k63
Spr/Sum 21	Reptile	k27
Spr/Sum 21	Rodent	K12, k16, k21, k26, k29, k34, k40, k53, k56, k57, k61
Spr/Sum 21	Small reptile	k26, k30, k40, k53, k54
Spr/Sum 21	swamp wallaby	k25, k26, k27, k28, k34, k36, k44, k51, k56, k61
Spr/Sum 21	Toad	k27
Spr/Sum 21	Wallaby	KWE12, Kwmid, K12, K13, k14, k16, k17, k18, k19, k20, k21, k22, k24, k25, k26, k27, k28, k29, k30, k34, k36, k37, k38, k39, k40, k41, k42, k43, k44, k45, k46, k47, k48, k49, k52, k53, k54, k55, k56, k57, k59, k60, k61, k63, k64
Sum/aut 22	Amphibian	54, 55, 58, 63, 73, 78, 79
Sum/aut 22	Antechinus	15, 17
Sum/aut 22	Bandicoot	15, 27, 29, 30, 35, 36, 42, 48, 50, 54, 55
Sum/aut 22	Bird	55, 56, 57, 58, 62
Sum/aut 22	Brushtail possum	N4, 23, 30, 39, 58, 63
Sum/aut 22	Canid	66, 71
Sum/aut 22	Cat	44, 74
Sum/aut 22	Cattle	21, N1, 72
Sum/aut 22	Common brushtail possum	17
Sum/aut 22	Dog	N1, 22, 30, 51, 53, 60, 63, 69, 78
Sum/aut 22	Echidna	50, 51, 52, 54, 58, 65
Sum/aut 22	EG	21, 24, 42, 47, 48
Sum/aut 22	Fox	15, N1, 24, 26, 31, 35, 42, 45, 47, 48, 50, 51, 58, 62, 63, 69, 72, 73, 74, 79
Sum/aut 22	Frog spp	15, 20, N3, 23, 25, 27, 39, 47, 48, 76, 79
Sum/aut 22	Goanna	50, 55, 69, 74
Sum/aut 22	Horse	18, 22
Sum/aut 22	Lace monitor	N1, N3, 30, 50
Sum/aut 22	Large reptile	45
Sum/aut 22	Lizard	N2, 62, 76
Sum/aut 22	Medium lizard	36
Sum/aut 22	Medium reptile spp.	16, 17, 22, 31, 35, 42, 50
Sum/aut 22	Microbat	15, 24, 26, 36, 50, 51
Sum/aut 22	Peacock	50, 51
Sum/aut 22	Reptile spp.	N3, 62, 79
Sum/aut 22	Rodent	15, 16, 17, N4, 22, 23, 26, 28, 30, 31, 33, 35, 36, 37, 39, 42, 46, 50, 51, 54, 55, 56, 58, 61,62, 63, 65, 66, 68, 69, 73, 74, 77, 78
Sum/aut 22	Small reptile spp.	19, 20, N3, 30, 41, 45
Sum/aut 22	Snake	N1
Sum/aut 22	Swallow	26, 27
Sum/aut 22	Swamp wallaby	38, 52, 60

Sample period	Species	Scat & scratch & track
Sum/aut 22	Toad	27, 31, 62
Sum/aut 22	Wallaby spp.	15, 18, N3, 23, 24, 33, 35, 39, 42, 45, 47, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 63, 65, 66, 67, 70
Sum/aut 22	Water dragon	30, 42
Aut/win 22	Amphibian	63
Aut/win 22	Antechinus	29
Aut/win 22	Bandicoot	N3, 15, 29, 50, 60, 67, 74
Aut/win 22	Brush-tailed possum	N2
Aut/win 22	Cane toad	26, 28
Aut/win 22	Canid	22, 24
Aut/win 22	Cattle	N1, 58, 72
Aut/win 22	Dog	N1, 70, 79
Aut/win 22	Echidna	50
Aut/win 22	EG	21, 39, 41, 51
Aut/win 22	Fox	N1, N4, N5, 37, 52, 54, 61, 63, 66, 70, 74, 75, 79
Aut/win 22	Medium lizard spp.	25
Aut/win 22	Microbat	23, 32, 33, 34, 36, 50, 55
Aut/win 22	Reptile	70
Aut/win 22	Rodent	15, N2, N5, 23, 24, 26, 28, 29, 36, 37, 39, 50, 53, 60, 62, 63, 66
Aut/win 22	Small reptile	21, 79
Aut/win 22	Swamp wallaby	55
Aut/win 22	Wallaby	N3, N4, 24, 39, 40, 41,52, 53, 54, 56, 57, 59, 60, 61, 67, 70, 73
Aut/win 22	Water bird	22, 43

Appendix D – Road mortality data

Table D1: Road mortality data for sections 1 & 2 (Q3 2028 to Q2 2022) and 3-11 (Q3 2021 to Q2 2022). * denotes threatened species.

Species	Q3 18	Q4 18	Q1 19	Q2 19	Q3 19	Q4 19	Q1 20	Q2 20	Q3 20	Q4 20	Q1 21	Q3 21	Q4 21	Q1 22	Q2 22	Total
Short-beaked echidna	1											3	1	1	1	7
Spotted-tailed quoll*	1															1
Northern brown bandicoot			1	2	1				1					1	2	8
Bandicoot spp.	1								1	1	3	1	10	13	17	47
Common brushtail possum	1			1										1		3
Trichosurus spp.	1						1									2
Eastern grey kangaroo	1				1					1	1				4	8
Red-necked wallaby				1				1					1		1	4
Swamp wallaby	1	1			1	1					1	2	1	2	1	11
Wallaby spp.	1	2					1					3	1	2	4	14
Medium macropod	2				3	2		1			1					9
Med/large macropod											2					2
Large macropod		1	1				2					4				8
Macropod spp.				1									2			3
Greater glider*												1				1
Grey-headed flying-fox*					1											1
Little red flying-fox											3					3
Pteropus spp.											2	1		1	1	5
Microbat spp.	4											1			1	6
Rodent spp.	1												1	4		6
Small mammal												3	6	4	6	19
Medium mammal				1					1		6	7	13	7	6	41
Large mammal								1								1
Unidentified mammal	2		1									5				8
Total mammals	17	4	3	6	7	3	4	3	3	2	19	31	36	36	44	218
Little pied cormorant												1				1
Australian white ibis												1	1		1	3
Cattle egret															1	1
Silver gull														2		2
Australian wood duck	1											2	1			4
Pacific black duck								1								1
Crested pigeon								1								1
Pigeon spp.														1		1
Tawny frogmouth				1	1							1		1	1	5
Australian magpie	2							1			4	1	1	2	7	18
Torresian crow													1			1
Pied butcherbird														1	1	2
Purple swamphen							1					1				2
Eastern barn owl	1											1				2
Masked owl*												1				1
Southern boobook												1				1
Laughing kookaburra	1									1		2		2	1	7
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		2	3	5	13
Medium bird				2				1			10			8	1	22
Unidentified bird			1		1							4	11	3	8	28
Total birds	6		1	5	2		1	5		1	18	16	17	23	26	121
Lace monitor	1		1								1		1	1	2	7

Species	Q3 18	Q4 18	Q1 19	Q2 19	Q3 19	Q4 19	Q1 20	Q2 20	Q3 20	Q4 20	Q1 21	Q3 21	Q4 21	Q1 22	Q2 22	Total
Eastern bearded dragon			1													1
Eastern blue-tongue lizard														1		1
Medium lizard											1					1
Carpet python			1			1					3	1		1		7
Eastern small-eyed snake				1							1					2
Yellow-faced whipsnake			1													1
Bandy-bandy				1										1		2
Large reptile							1									1
Medium reptile														2		2
Medium lizard														1		1
Unidentified reptile													2		3	5
Unidentified snake	1			1							2		2			6
Unidentified frog														2	1	3
Chelidae spp.								1					1		2	4
Total reptiles/amphibians	2		4	3		1	1				8	1	6	9	8	43
House mouse	2															2
European fox							1		1			1		1	1	5
Dog								1	1						1	3
Cat					1					1	1					3
European hare					1				1			5		1		8
Chicken											1					1
Cane toad											1		1	2	1	5
Total introduced species	2				2		1	1	3	1	3	6	2	4	3	28
Unidentified species														1		
Total fauna	27	4	8	14	11	4	7	10	6	4	48	54	60	73	81	411
Total mammals	19	4	3	6	9	3	4	4	6	3	20	37	36	38	44	238
Total kms surveyed	11	11	11	12	57.4	57.4	57.4	57.4	57.4	57.4	328	328	328	328	328	
Mammal kills/km	1.73	0.36	0.27	0.5	0.16	0.05	0.07	0.07	0.10	0.05	0.06	0.11	0.11	0.11	0.13	

Table D2: Road mortalities recorded during Q3 and Q4 2021 surveys along Wardell Road and the old Pacific Highway. Records are pooled for the two surveys.

Species	2021/22	
	Wardell Rd	Old Pac Hway
Mammals		
Short beaked Echidna		
Bandicoot spp.		
Red-necked wallaby		
Swamp wallaby		
Wallaby spp.		
Large macropod		
Macropod spp.		
Greater glider		
Pteropus spp.		
Microbat spp.		
Rodent spp.		
Small mammal	1	
Medium mammal		
Unidentified mammal		
Total mammal	1	
Birds		
Little pied cormorant		
Australian white ibis		

Species	2021/22	
	Wardell Rd	Old Pac Hway
Australian wood duck		
Tawny frogmouth		
Australian magpie	2	
Toressian crow		
Purple swamphen		
Eastern barn owl		
Masked owl		
Southern boobook		
Laughing kookaburra		
Small bird		
Unidentified bird		
Total birds	2	
Introduced species		
European fox	1	
European hare		
Cane toad		
Total introduced species	1	
Total fauna	5	0
Total kms travelled	3.08 km	6.6 km
Roadkill/km	1.62	0