Fauna Underpass Monitoring 2022/2023

Oxley Highway to Kempsey, Pacific Highway Upgrade

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Cover photograph: Red-necked Wallaby in F26.40 (left), Echidna in F22.32 (middle) and two Short-eared Brushtail Possum recorded using fauna furniture in C4.46 (right) during late spring/summer surveys.

Executive summary

Context

This report documents findings of the 2022/2023 monitoring period, the final of three monitoring periods for the fauna underpasses, as required for the Oxley Highway to Kempsey (OH2K) Pacific Highway Upgrade Project (the Project), and specified in the Oxley Highway to Kempsey Ecological Monitoring Program (EMP, TfNSW 2022).

Aims

The aim of the fauna underpass monitoring program is to determine whether fauna are using the underpass structures to complete crossings under the Pacific Highway. The aim of this report is to determine if the Project is meeting the performance indicators of success for the mitigation measures, and provide corrective actions where required.

Methods

Fourteen underpasses were surveyed in accordance with the monitoring method specified in the EMP, specifically:

- Two remote cameras were placed within each underpass and left to record for a minimum of 60 consecutive days
- Ten hair tube traps were placed in and around the entrance to each underpass for 14 consecutive nights
- Sand plots were established in combined fauna underpasses and monitored for eight consecutive nights
- Scat searches were conducted within underpasses and adjoining habitat during sand plot surveys and camera deployment and retrieval.

Key Results

The key results of the 2022/2023 fauna underpass monitoring were as follows:

- A minimum of two of the fauna groups were recorded at all underpasses. Small ground-dwelling mammals were the most frequently recorded group at all underpasses, followed by macropods, arboreal mammals and reptiles (12 underpasses). Frogs were recorded using one underpass (C36.40).
- The three target threatened species listed on the *Environment Protection and Biodiversity Conservation Act* 1999 (EPBC Act), the Koala, the Giant Barred Frog and Spotted-tail Quoll, were not recorded using the underpasses in 2022/2023.
- One of the two non-EPBC Act target species, the Brush-tailed Phascogale was recorded using two of the underpasses (F20.54 and F22.32). Species identified as indicator species for the Brush-tailed Phascogale were recorded at all underpasses. Indicator species for the Green-thighed Frog (i.e. other frog species) were not recorded.
- Non-native predators including cats, dogs and foxes, were detected at 13 of 14 monitored underpasses (excluding C36.40). Three of the 14 monitored underpasses showed high use by non-native predators.
- To date, EPBC Act listed species, the Koala and Spotted-tailed Quoll, have been recorded at four and one underpass respectively.
- The 2022/2023 average weekly road kill decreased from that recorded during baseline monitoring from 8.0 to 3.6. Two road kill records were within 200 metres of monitored underpasses. There has not been an increase in road kill in proximity to monitored underpasses from baseline.

Conclusions

Performance measures are considered to have been met to date. The use of the underpasses by fauna, as measured and monitored according to the EMP, indicates that the underpasses allow fauna the opportunity for movement within home ranges, for dispersal and/or re-colonisation. The performance measure regarding use of underpasses by the Koala has been met at four underpasses and one underpass for the Spotted-tailed Quoll. Results indicate successful use by Indicator species for the Brush-tailed Phascogale. The performance indicator requiring a reduced incidence of road kill from baseline monitoring was met.

Management Implications

This report presents the results of the final of three monitoring events. Given the successful use by a range of native fauna from different fauna groups it is considered that the underpasses have been a successful mitigation measure allowing species to cross safely under the carriageway and maintain connectivity for adjacent habitat. Therefore, there are no further monitoring measures recommended beyond requirements of the EMP. However, maintenance of fauna fencing particularly within 200 m of underpasses is considered important in continued successful crossing by native fauna.

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1. Introduction

1.1 Context

The Oxley Highway to Kempsey (OH2K) section of the Pacific Highway Upgrade Project (the Project) was approved by the NSW Department of Environment and Planning in 2012 subject to various Ministers Conditions of Approval (MCoA) and a Statement of Commitments (SoC). A subsequent approval with additional conditions of consent (CoA) was granted in 2014 by the then Commonwealth Department of Environment (DoE) for Matters of National Environmental Significance (MNES) listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1995* (EPBC Act). The Ecological Monitoring Program (hereafter referred to as the EMP) (TfNSW 2022) combines these approval conditions and defines the mitigation and offsetting requirements for threatened species and ecological communities impacted by the Project.

Fauna underpasses were installed to reduce the impact, facilitate movement and maintain habitat connectivity for native fauna. These structures are to be monitored to assess their effectiveness in facilitating fauna movement*,* as required by the EMP.

1.1.1 Monitoring framework

The design, methods and performance indicators that define the fauna underpass monitoring program are specified in the EMP. The EMP specifies that monitoring be undertaken at 14 underpasses, including 10 dedicated fauna underpasses and four combined drainage/fauna culverts.

The EMP requires monitoring to occur in autumn and late spring/early summer in Years 4, 6 and 8 (operational phase) of the Project. The EMP specifies that additional monitoring may be required if underpasses are determined to be ineffective.

To date, these monitoring events have been conducted and reported as follows:

* Autumn 2018 and spring/summer 2018/2019: Year 4 surveys (Niche 2019a)
* Autumn 2020 and spring/summer 2020/2021: Year 6 surveys (Niche 2021a)
* Autumn 2022 and spring/summer 2022/2023: Year 8 surveys (current report).

This report represents the final of three reports required for the underpass monitoring – Year 8 autumn 2022 and spring/summer 2022/2023.

1.1.2 Background data

Underpass selection

The Project includes over 50 underpasses that may facilitate the passage of fauna, including bridges, dedicated fauna underpasses and combined drainage/fauna culverts. The EMP specifies that 14 underpasses be monitored based on the following criteria:

* All dedicated fauna underpasses will be monitored.
* Combined underpasses that are 50 metres or more in length, and located in proximity to intact native vegetation (fauna habitat) will be monitored.
* No combined culverts that are located in cleared, disturbed or modified areas will be monitored.
* No combined culverts that are located within 600 metres of another monitored underpass will be monitored.

- No incidental underpasses will be monitored (small culverts that are not intended to allow for the passage of fauna but may be used incidentally by small fauna).

Indicator species

The EMP provides a list of indicator and target (threatened) species to determine the successful use of fauna crossing structures. These species are those that have been previously recorded in proximity to the Project or are known to occur in the Project area and were considered as being potentially adversely affected by the Project. Section 2.2.4 of the EMP states: *"The effectiveness of wildlife crossings will be based on their use by fauna groups previously recorded in proximity to the Project (<one kilometre). It is assumed that the Project bisects the habitat of at least some individuals from each of the nominated fauna groups (Table 4). Fauna species known to occur within the Project area that may be potentially adversely affected by the upgrade are listed in Table 5. These species will indicate the successful usage of crossing structures."* Table 1 lists the five fauna groups that are to be used to assess the effectiveness of the underpasses, as well as the indicator and target species for each of the five groups. It should be noted that while this report discusses the target and indicator species nominated for each underpass, all performance indicators do not directly relate to the use of the underpasses by these fauna groups.

Table 1: Indicator species for fauna crossings (from Table 5 of the EMP)

Fauna group	Indicator species (known from area)	Target (threatened) species
Frogs	*Litoria* sp., *Limnodynastes* sp., *Crinia* sp., Giant Barred Frog	Green-thighed Frog, Giant Barred Frog
Small ground-dwelling mammals	Antechinus, rodents and bandicoots, Echidna, Spotted-tailed Quoll	Spotted-tailed Quoll, Brush-tailed Phascogale
Arboreal mammals	Brushtail Possum, Ringtail Possum	Brush-tailed Phascogale
Koala	Koala	Koala
Macropods	Swamp Wallaby, Red-necked Wallaby, Eastern Grey Kangaroo	N/A

1.1.3   Purpose of this report

This report details the findings obtained from the third operational monitoring event for the fauna underpasses. The aims of this report are to summarise the methods and results of the 2022/2023 monitoring and determine if performance measures are being met, as per the EMP.

1.2   Performance Measures

The EMP specifies the following performance measures for fauna underpasses:

- *Complete safe crossing by the targeted EPBC species, the Spotted-tailed quoll and Koala, at a sufficient frequency as defined in Section 1.5 of the EMP. This would ensure that the underpass performance measure would trigger the contingency measures in section 5 for underpass performance after each koala monitoring event to review / modify underpass furniture, habitat, monitoring and if required, agency discussions.*
- *For non-EPBC species (Brush-tailed Phascogale), the complete safe crossing of the nominated underpass by the target species or their indicator species on at least one occasion in order to demonstrate opportunity for dispersal and re-colonisation (excluding frogs which are unlikely to be detected using camera monitoring).*
- *For fauna groups, the complete safe crossing of the nominated underpass by one or more individuals on at least once occasion from each of the relevant fauna groups (small ground-dwelling mammals, arboreal mammals and macropods) to demonstrate opportunity for dispersal and re-colonisation*
- *Reduced incidence of road kill from baseline conditions.*

1.3   Monitoring Timing

Monitoring is to be undertaken in Years 4, 6 and 8 of the Project's operational phase in late autumn and late spring/early summer each monitoring year for a minimum of 60 days. The timing of monitoring coincides with breeding seasons and dispersal periods for target species, shown in Table 2.

Table 2: Breeding seasons and likely dispersal periods of threatened target species (from Table 13 of the EMP)

Scientific name	Common name	Breeding season	Likely dispersal period
Dasyurus maculatus	Spotted-tail Quoll	April to July	Spring and summer
Litoria brevipalmata	Green-thighed Frog	Late spring and summer	In association with rainfall events
Mixophyes iteratus	Giant Barred Frog	Late spring to early summer	In association with rainfall events
Phascogale tapoatafa	Brush-tailed Phascogale	May to July	Mid-summer
Phascolarctos cinereus	Koala	Spring and summer	Spring and summer

1.4   Reporting

Annual reporting of monitoring results will include:

- Detailed description of monitoring methodology
- Results of the monitoring period
- Discussion of results, including how the results compare against performance measures, if any modifications to timing or frequency of monitoring periods or monitoring methodology are required and any other recommendations
- If contingency measures should be implemented.

All reports prepared under the EMP will be submitted to the NSW Department of Planning and Environment (DPE) and the NSW Environment Protection Authority (EPA).

1.5   Limitations

Limitations relevant to the survey methodology that potentially impact on efficacy of the program include:

- Due to their small size and cryptic nature, frogs and smaller reptiles are difficult to detect within the underpasses using the current survey methods and thus if present, may have gone undetected.
- The EMP requires installation of sand plots at combined underpasses, which serve as combined drainage/fauna culverts. It was considered that sand plots established across the active drainage channel of the culvert would likely wash away. In consultation with Transport for NSW (TfNSW) it was therefore determined that sand plots would be established across the entire width of the underpass only if the drainage channel was not inundated with water.
- The EMP requires an assessment of the effectiveness of the underpasses for species listed under the Commonwealth EPBC Act, with 'effective' defined in Section 1.5 of the EMP as "*Result in the complete, safe crossing of the crossing by the targeted EPBC species at a sufficient frequency to ensure that habitat connectivity is maintained or improved from baseline conditions (determined by surveys condition 4a and information provided in the preliminary documentation), and ongoing population viability by providing opportunities for species dispersal and re-colonisation; and result in reduced incidence of road kill from baseline conditions (determined by surveys condition 4a and information provided in the preliminary Documentation*". The EMP does not define what "*sufficient frequency*" would be and baseline crossing frequencies are unknown and therefore cannot be used to assess the success of the underpasses. In addition, this monitoring program does not provide a means of

measuring dispersal and re-colonisation of species or population viability. The limitations of the EMP with regards to this performance measure are discussed in detail in Table 14.

2. Methods

2.1 Monitoring Sites

Monitoring was undertaken at 14 underpasses, including 10 dedicated fauna underpasses and four combined drainage/fauna culverts. Table 3 lists the fauna groups nominated in Table 12 of the EMP and shows the relevance of each of these groups at each of the underpasses (as specified in Table 12 of EMP). Target species (non-EPBC and EPBC listed species) have also been considered separately to their related fauna group as Table 12 of the EMP specifically nominates individual target species at certain underpasses. While the Brush-tailed Phascogale (*Phascogale tapoatafa*) was not specifically nominated within Table 12 of the EMP, it is listed in Table 13 of the EMP as a species targeted by underpasses and has therefore been included separately as a non-EPBC target species. Underpass F34.72 was erroneously omitted from Table 12 in the EMP; the text states all dedicated underpasses are to be monitored, therefore, after consultation with TfNSW, F34.72 was included in the monitoring. Fauna groups were therefore not nominated for F34.72 within the EMP. For the purpose of assessment, fauna groups/species nominated for the two closest underpasses (F33.40 and C36.4) have been included here as a guide for F34.72. The location of each monitored underpass is shown in Figure 1 and Figure 2. It should be noted that while this report discusses the target and indicator species nominated for each underpass, the performance indicators do not directly relate to the use of the underpasses as specified in Table 3 below. As such, the performance indicators are addressed as presented in the EMP.

Table 3: Monitored fauna underpasses and target species (adapted from Table 12 of the EMP).

Target fauna group/species	Indicator species	F1.04	F1.62	C4.46	C7.26	F9.70	F11.67	F20.54	F21.24	F22.32	F26.40	C32.35	F33.40	F34.72*	C36.40
Fauna group/species (target threatened species)															
Frogs (Green-thighed Frog)	*Litoria* sp., *Limnodynastes* sp., *Crinia* sp., Giant Barred Frog	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Small ground-dwelling mammals (Brush-tailed Phascogale)	*Antechinus* spp, rodents and bandicoots, Echidna, Spotted-tail Quoll	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Arboreal mammals (Brush-tailed Phascogale)	Brushtail Possum, Ringtail Possum		✓	✓	✓	✓	✓			✓			✓	✓	✓
Macropods	Swamp Wallaby, Red-necked Wallaby, Eastern Grey Kangaroo	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Reptiles		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Non-EPBC target species															
Green-thighed Frog	*Litoria* sp., *Limnodynastes* sp., *Crinia* sp., Giant Barred Frog												✓		✓
Brush-tailed Phascogale+	*Antechinus* spp, rodents and bandicoots, Echidna, Spotted-tail Quoll, Brushtail Possum, Ringtail Possum														
EPBC target species															
Giant Barred Frog	Giant Barred Frog														✓
Koala	Koala	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Spotted-tail Quoll	Spotted-tail Quoll				✓	✓	✓	✓	✓	✓	✓		✓	✓	✓

+ The Brush-tailed Phascogale was not previously nominated at any underpass in Table 12 of the EMP but has been included based on Table 13 of EMP. *Nominated fauna groups/species are based on the two closest underpasses and proximity of recorded Green-thighed Frog habitat.

2.2   Survey Method

Surveys were undertaken in accordance with the EMP. At each underpass the following survey techniques were used:

- Two motion-detecting cameras were installed in the middle of each underpass, one facing along the fauna furniture and one facing along the ground, where possible. Cameras were left operating for a minimum of 60 days in autumn and late spring/early summer.
- Sand plots at least one metre wide were established across the entire width of the raised cement footpath at each end of combined underpasses as drainage channels were inundated at the time of monitoring. Sand plots were monitored for eight nights in each monitoring period. Each morning, sand plots were checked, any tracks recorded and plots raked clean.
- Ten hair-tubes were attached to fauna furniture (where possible) or placed along the ground within each underpass and in adjoining habitat. Hair tubes were baited with a mixture of peanut butter, honey and oats and left for a minimum of 14 consecutive nights in each monitoring period. Hair samples were sent to Robyn Carter for analysis, and were identified to species level where possible.
- Scat searches were undertaken within underpasses and adjoining habitat during sand plot surveys and camera deployment and retrieval.

Legend:
- **C** combined underpass
- **D** dedicated underpass
- Project Boundary

Map labels:
- C36.40
- F34.72
- F33.40
- C32.35
- F26.40
- F22.32
- F21.24
- F20.54

km
0   0.5   1

GDA 1994 MGA Zone 56
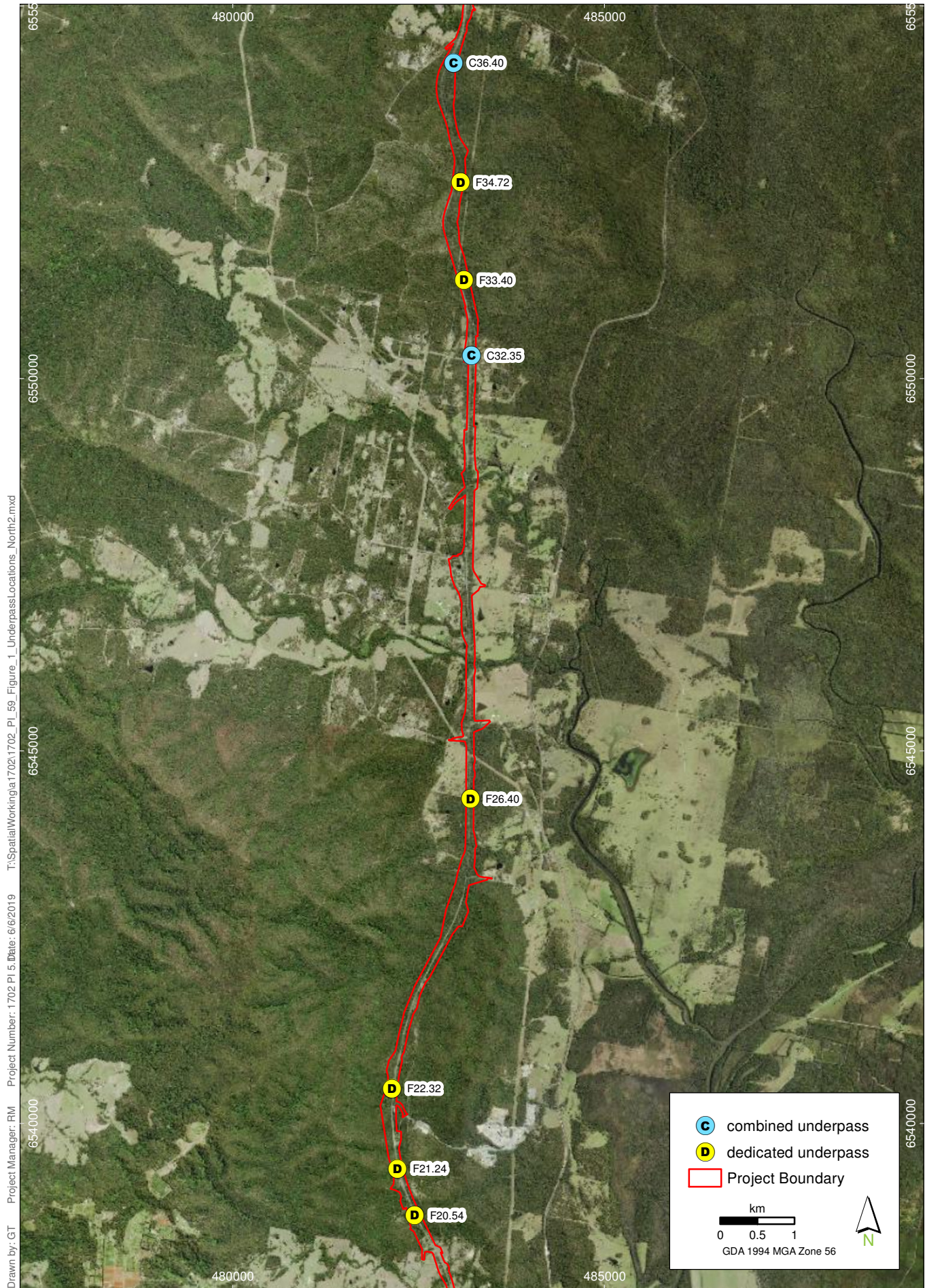
Fauna Underpass Locations - North

Oxley Highway to Kempsey - PI 5.9 Fauna Underpass Monitoring

FIGURE 1

Imagery: (c) LPI 2013

Drawn by: GT

Project Manager: RM

Project Number: 1702 PI 5.9

Date: 6/6/2019

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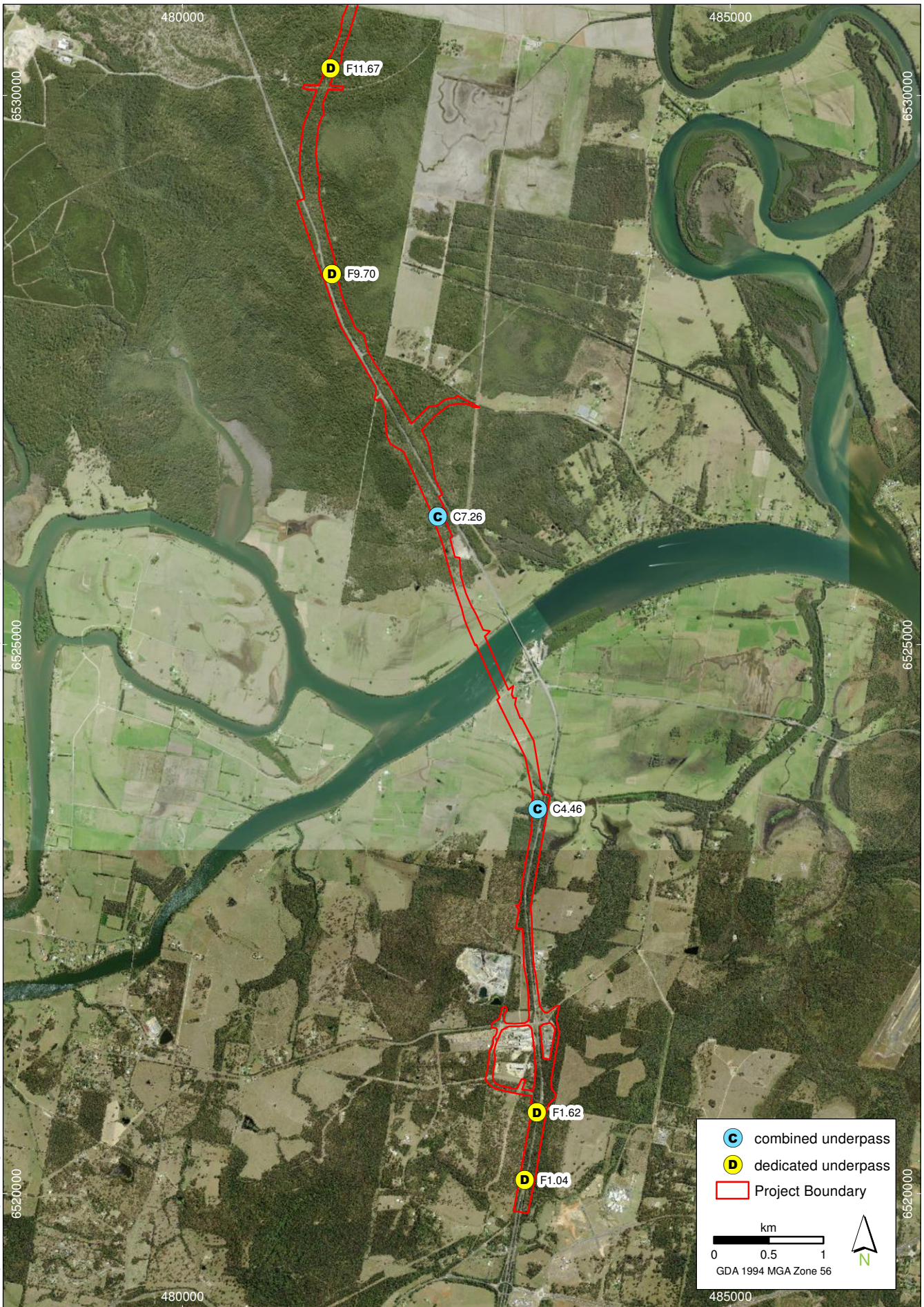
Fauna Underpass Locations - South

Oxley Highway to Kempsey - PI 5.9 Fauna Underpass Monitoring

FIGURE 2

Imagery: (c) LPI 2013

Legend:
- **C** combined underpass
- **D** dedicated underpass
- Project Boundary

Map labels: F11.67, F9.70, C7.26, C4.46, F1.62, F1.04

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Environment and Heritage

3. Results

3.1 2022/2023 Monitoring Summary

Detailed field data are provided in Annex 1 and Annex 2. Results of the different survey methods were combined to provide an overall assessment of the use of the monitored underpasses.

3.1.1 Monitoring periods

The 2022/2023 monitoring periods were as follows:

- Autumn 2022: 30 March 2022 – 1 and 7 June May 2022
- Late spring/early summer 2022/2023: 3-4 November 2022 – 4 January 2023.

Hair tube surveys were undertaken in the first two weeks of the monitoring period. Sand plots were monitored for eight nights in autumn (10 – 19 May 2022) and late spring/summer (8 – 16 December 2022). As the deployment periods were longer than the minimum 60 days, any species recorded outside of the 60 day monitoring period were considered as value adding data and included in the assessment of underpass use by fauna groups.

Camera details, including monitoring dates and durations, for autumn and spring/summer surveys are provided in Annex 1.

3.1.2 Remote cameras

Table 4 provides a summary of the fauna records for the monitored underpasses. Cameras captured a total of 1708 fauna records over the two monitoring periods. A proportion (12.1%) of records were unidentified, which consisting of partial and/or unclear images and could not be identified as either native or introduced fauna, including unidentified small mammals recorded as rodents. Of those records that were identified, 57.0% were identified as native fauna.

Table 4: 2022/2023 camera fauna record summary

Underpass	# fauna records	# natives	# non native	# unidentified	# introduced predator	% native	% introduced predator
F1.04	50	15	34	1	34	30.0	68.0
F1.62	120	83	35	2	34	69.2	28.3
C4.46	236	163	70	3	46	69.1	19.5
C7.26	16	2	12	2	5	12.5	31.3
F9.70	64	5	37	22	16	7.8	25.0
F11.67	88	23	49	16	16	26.1	18.2
F20.54	212	151	38	23	4	71.2	1.9
F21.24	279	172	45	62	4	61.6	1.4
F22.32	226	110	68	49	1	48.7	0.4
F26.40	165	114	45	6	1	69.1	0.6
C32.35	75	56	16	3	6	74.7	8.0
F33.40	115	58	49	8	2	50.4	1.7
F34.72	61	21	31	9	4	34.4	6.6
C36.40	1	0	0	1	0	0.0	0.0
TOTALS	1708	973	529	206	173	57.0	10.1

3.1.3 2022/2023 native fauna use of underpasses

Results of the different survey methods were combined to provide an overall assessment of the use of monitored underpasses by the nominated fauna groups, however only the small ground-dwelling mammals, arboreal mammals and macropods, i.e. not frogs or reptiles, factor into the determination of performance measure outcomes. While a specific means of determining a *"complete safe crossing"* by targeted EPBC species is not specified in the EMP, it is considered that animals captured on remote cameras within the underpass are using the underpass to complete successful crossings. Table 5 shows the use of underpasses by fauna groups and target species. Shaded squares indicate the underpasses where fauna groups/target species were nominated (Table 3). A summary of the use of underpasses by the respective fauna groups is as follows:

- Frogs: Scat recorded at one of the 14 nominated underpasses (C36.40).
- Small ground-dwelling mammals: recorded at all 14 nominated underpasses represented by rodents, antechinus, bandicoots and the Echidna.
- Arboreal mammals: recorded at seven of the nine nominated underpasses, and at five additional underpasses; represented by the Brushtail Possum.
- Macropods: recorded at 12 of the 14 nominated underpasses (excluding F1.04 and C36.40); represented by the Eastern Grey Kangaroo (*Macropus giganteus*), Red-necked Wallaby (*Macropus rufogriseus*) and Swamp Wallaby (*Wallabia bicolor*).
- Reptiles: recorded at 12 of the 14 nominated underpasses; represented predominantly by the Eastern Water Dragon (*Intellagama lesueurii*) and Lace Monitor (*Varanus varius*).

Table 5: 2022/2023 native fauna use of underpasses

		Underpass number												
Target fauna group/species	Indicator species	F1.04	F1.62	C4.46	C7.26	F9.70	F11.67	F20.54	F21.24	F22.32	F26.40	C32.35	F33.40	F34.72*	C36.40
Fauna group/species (target threatened species)															
Frogs (Green-thighed Frog)	*Litoria* sp., *Limnodynastes* sp*., Crinia* sp*.,* Giant Barred Frog														Y (1)
Small ground-dwelling mammals (Brush-tailed Phascogale)	*Antechinus* spp*,* rodents and bandicoots, Echidna, Spotted-tail Quoll	Y (1)	Y (2)	Y (1)	Y (1)	Y (1)	Y (1)	Y (3)	Y (2)	Y (4)	Y (3)	Y (2)	Y (3)	Y (1)	Y (2)
Arboreal mammals (Brush-tailed Phascogale)	Brushtail Possum, Ringtail Possum	Y (2)	Y (2)	Y (2)	Y (1)		Y (1)	Y (1)	Y (2)	Y (2)	Y (2)	Y (1)		Y (1)	Y (1)
Macropods	Swamp Wallaby, Red-necked Wallaby, Eastern Grey Kangaroo		Y (3)	Y (2)	Y (1)	Y (1)	Y (2)	Y (2)	Y (1)	Y (2)	Y (3)	Y (1)	Y (2)	Y (1)	
Reptiles		Y (1)	Y (2)	Y (1)			Y (1)	Y (1)	Y (1)	Y (1)	Y (1)	Y (1)	Y (1)	Y (1)	Y (1)
Non-EPBC target species															
Green-thighed Frog	*Litoria* spp., *Limnodynastes* spp*., Crinia* spp*.,* Giant Barred Frog														
Brush-tailed Phascogale+	*Antechinus* spp*,* rodents and bandicoots, Echidna, Spotted-tail Quoll, Brushtail Possum, Ringtail Possum							Y (1)		Y (1)					
EPBC target species															
Giant Barred Frog	Giant Barred Frog														
Koala (Koala)	Koala														
Spotted-tail Quoll	Spotted-tail Quoll														

+ The Brush-tailed Phascogale was not previously nominated at any underpass in Table 12 of the EMP. Shaded cells are the nominated underpasses *Nominated fauna groups/species are based on the two closest underpasses. (#) = number of different species detected.

3.1.4 2022/2023 EPBC target species

Three of the five target threatened species (Table 1) are listed under the EPBC Act, including the Koala (*Phascolarctos cinereus*), Giant Barred Frog (*Mixophyes iteratus*) and Spotted-tailed Quoll (*Dasyurus maculatus*). These species were specifically nominated as target species at all, one and 10 of the underpasses respectively, however only the Koala and Spotted-tailed Quoll factor into the determination of performance measure outcomes.

The Koala was not recorded using any underpass during the 2022/2023 monitoring period. Neither the Giant Barred Frog or the Spotted-tailed Quoll were recorded within the underpasses during the 2022/2023 monitoring.

3.1.1 2022/2023 non-EPBC target species and presence of indicator species

Non-EPBC target threatened species include the Green-thighed Frog (*Litoria brevipalmata*) and Brush-tailed Phascogale, however only the Brush-tailed Phascogale factors into the determination of performance measure outcomes. The Brush-tailed Phascogale was recorded at two of the 14 underpasses (F20.54 and F22.32) during the 2022/2023 monitoring period, once in autumn and once in spring/summer.

Indicator species for the Brush-tailed Phascogale include those species included in the small ground-dwelling mammal fauna group and the arboreal mammal fauna group. While the Brush-tailed Phascogale

was not specifically nominated at individual underpasses, for the purpose of assessment, it is assumed that this species is a general target at all underpasses where the small ground-dwelling mammals and/or arboreal mammal fauna groups have been nominated, i.e. at all underpasses. Representatives of the small ground-dwelling fauna group were detected at all of the 14 underpasses with at least one indicator species at any underpass and representatives of the arboreal mammal group were recorded at seven of the nine nominated underpasses.

The Green-thighed Frog was specifically nominated as a species that may 'possibly' (TfNSW 2022) use F33.40 and C36.40. Indicator species for this target species include those species listed within the frog fauna group, however only amphibian scats were recorded at one underpass (C36.40) during the 2022/2023 monitoring periods. F33.40 is located approximately 150 metres (western side of carriageway) and 250 metres (eastern side of carriageway) south of Green-thighed Frog ponds constructed as part of the Project's mitigation requirements for this species, in proximity to a site where the species was recorded during targeted surveys (Site 16, Lewis 2013). However, no Green-thighed Frogs have been recorded at these ponds during the two monitoring events undertaken by Niche as part of the Project's Green-thighed Frog pond monitoring in 2016/2017 and 2018/2019 (Niche 2017a; Niche 2018a). It should be noted that it is unlikely that, if present, individuals from the identified Site 16 population would travel the required distance to F33.40 (Lemckert and Slatyer 2002). C36.40 is within 400 metres of a targeted survey site (Site 17, exact location not provided; Lewis 2013) identified as a likely location for the species and visited during targeted surveys. However, no Green-thighed Frogs were recorded at this site during the targeted surveys.

3.1.2   2022/2023 use of underpasses by non-native predators

Non-native predators including cats, dogs and foxes, were detected at 13 of the 14 monitored underpasses. Table 6 shows the non-native predators recorded using each underpass and the percentage of all identified fauna records that were non-native predators.

Based on previous underpass monitoring outcomes (Sandpiper Ecological 2015, Sandpiper Ecological 2017) and in consultation with North Coast Local Land Services (Biosecurity Manager, *pers. comm.* 2017), it was considered that visitation by non-native predators equating to greater than 25 per cent of visitations to the underpass or visitations by non-native predators on more than 25 per cent of the days monitored, constitutes high use by non-native predators.

Three of the 14 monitored underpasses showed high use by non-native predators, notably cats and foxes. The highest use was recorded at the following four underpasses: F1.04, F1.62, and C7.26 with visitation by non-native predators accounting for 68.0%, 28.3% and 31.3% of visitations respectively. Visitation by dogs was low in comparison.

Table 6: 2022/2023 exotic predator use of underpasses

Species	Underpass number													
	F1.04	F1.62	C4.46	C7.26	F9.70	F11.67	F20.54	F21.24	F22.32	F26.40	C32.35	F33.40	F34.72	C36.40
Fox (*Vulpes vulpes*)	30	21	46	0	2	4	3	1	1	1	6	1	2	0
Cat (*Felis catus*)	4	13	0	0	0	0	0	1	0	0	0	1	0	0
Dog (*Canis familiaris/dingo*)	0	0	0	5	14	12	1	2	0	0	0	0	2	0
Percentage of visitations	**68.0**	**28.3**	19.5	**31.1**	25.0	18.2	1.9	1.4	0.4	0.6	8.0	1.7	6.6	0.0

Bold indicates visitation rate by exotic predators > 25% of all visitations.

3.2 Cumulative Use

Combined results from the 2018/2019, 2020/2021 and 2022/2023 monitoring events are presented below.

3.2.1 Cumulative native fauna use of underpasses

Table 7 shows the cumulative use of underpasses by fauna groups and target species to date. All but one of the fauna groups (frogs), have been recorded using all of fourteen underpasses. A summary of the use of underpasses by the respective fauna groups is as follows:

- Frogs: Scat recorded at one of the 14 nominated underpasses (C36.40).
- Small ground-dwelling mammals: recorded at all nominated underpasses; represented by rodents, antechinus, bandicoots, the Echidna and the Spotted-tailed Quoll.
- Arboreal mammals: recorded at all nine nominated underpasses, and at five additional underpasses; represented by the Brushtail Possum and the Koala.
- Macropods: recorded at all 14 nominated underpasses; represented by the Eastern Grey Kangaroo, Red-necked Wallaby and Swamp Wallaby.
- Reptiles: recorded at all 14 nominated underpasses; represented predominantly by the Eastern Water Dragon and Lace Monitor.

Table 7: Cumulative fauna use of underpasses - 2018/2019, 2020/2021 and 2022/2023

Target fauna group/species	Indicator species	F1.04	F1.62	C4.46	C7.26	F9.70	F11.67	F20.54	F21.24	F22.32	F26.40	C32.35	F33.40	F34.72*	C36.40
Fauna group/species (target threatened species)															
Frogs (Green-thighed Frog)	*Litoria* sp., *Limnodynastes* sp., *Crinia* sp., Giant Barred Frog														Y
Small ground-dwelling mammals (Brush-tailed Phascogale)	*Antechinus* spp, rodents and bandicoots, Echidna, Spotted-tail Quoll	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Arboreal mammals (Brush-tailed Phascogale)	Brushtail Possum, Ringtail Possum	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Macropods	Swamp Wallaby, Red-necked Wallaby, Eastern Grey Kangaroo	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Reptiles		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Non-EPBC target species															
Green-thighed Frog	*Litoria* spp., *Limnodynastes* spp., *Crinia* spp., Giant Barred Frog														
Brush-tailed Phascogale+	*Antechinus* spp, rodents and bandicoots, Echidna, Spotted-tail Quoll, Brushtail Possum, Ringtail Possum							Y		Y					
EPBC target species															
Giant Barred Frog	Giant Barred Frog														
Koala (Koala)	Koala					Y	Y					Y	Y		
Spotted-tail Quoll	Spotted-tail Quoll														Y

+ The Brush-tailed Phascogale was not specifically nominated at any underpass in Table 12 of the EMP. Shaded cells are the nominated underpasses *Nominated fauna groups/species are based on the two closest underpasses.

3.2.2 Cumulative EPBC Act listed target species

As outlined in section 3.3, three target species are listed under the EPBC Act including the Koala, Giant Barred Frog and Spotted-tailed Quoll, however only the Koala and Spotted-tailed Quoll factor into the determination of performance measure outcomes. To date, the Koala and the Spotted-tailed Quoll have been recorded using five underpasses during the 2018/2019 and 2020/2021 monitoring periods; the Koala has been detected using F9.70, F11.67, C32.35 and F33.40, and the Spotted-tailed Quoll has been detected using C36.40. Details of these records are provided in Table 8 and discussed below. The Giant Barred Frog has not been detected using any underpasses.

Three of the four underpasses used by the Koala are dedicated fauna underpasses with installed fauna furniture. The fourth underpass used by the Koala (C32.35) is a combined drainage/fauna culvert without installed fauna furniture. All Koalas were recorded on the ground. The Spotted-tailed Quoll was detected using a nominated combined drainage/fauna culvert heading in a westerly direction on the raised fauna footpath.

The Giant Barred Frog was specifically nominated as a species that may 'possibly' (TfNSW 2022) use C36.40. Given the constructed state of C36.40, the intermittent water flow within the underpass and in the drainage line connecting to the underpass, and the absence of habitat within the underpass to facilitate movement (including shelter such as leaf litter, vegetation, rocks and logs), it is considered unlikely that this species would use this underpass. The nearest baseline record is from Maria River, approximately 500 metres to the north (Lewis 2014). Giant Barred Frog monitoring for the Project has shown that this species is traversing the Pacific Highway within the monitored waterways under bridges (Niche 2018b).

As mentioned, it is considered that animals captured on remote cameras within the underpass are using the underpass to complete successful crossings. Koalas have therefore been recorded completing safe crossings at four of the 14 underpasses for which it is a target species, and the Spotted-tail Quoll has been recorded completing a safe crossing at one of 10 underpasses for which it is a target species.

Table 8: Cumulative EPBC Act listed species recorded in underpasses

Season	Underpass	Date	Time	Species	Position	Direction
Autumn	C36.40	28/05/2018	2:43:37	Spotted-tailed Quoll	Ground	West
Spring/summer	F33.40	23/11/2018	5:41:47	Koala	Ground	East
Spring/summer	F11.67	24/11/2018	23:16:54	Koala	Ground	East
Spring/summer	F9.70	16/12/2018	11:06:19	Koala	Ground	East
Spring/summer	C32.35	29/11/2020	7:13:29	Koala	Ground	West

3.2.3 Cumulative non-EPBC Act listed target species and presence of indicator species

Non-EPBC target threatened species include the Green-thighed Frog and Brush-tailed Phascogale, however only the Brush-tailed Phascogale factors into the determination of performance measure outcomes.

Indicator species for the Brush-tailed Phascogale include those species within the small ground-dwelling mammal fauna group and the arboreal mammal fauna group. Representatives of the small ground-dwelling fauna group were detected at all underpasses with at least two indicator species at any underpass. Representatives of the arboreal mammal group were recorded at eight of the nine nominated underpasses indicating relatively high use of the underpasses by these fauna groups.

Indicator species for the Green-thighed Frog include those species listed within the frog fauna group, however no amphibians were detected at any of the underpasses during the 2018/2019 and 2020/2021. During the 2022/2023 monitoring periods the presence of amphibians at C36.40 was recorded based on scat detected.

3.2.4 Cumulative use of underpasses by non-native predators

Non-native predators including cats, dogs and foxes, have been detected at all of the fourteen monitored underpasses. Table 9 shows the non-native predators recorded using each underpass and Table 10 shows the percentage of all identified fauna records that were non-native predators. The majority (11 of 14) of the monitored underpasses showed high use by non-native predators during at least one monitoring period. At least two of the three different non-native predators have been recorded at each underpass, with all three recorded at 12 of 14 underpasses. Non-native predator use at underpasses has increased at five of the monitored underpasses since 2018/2019 monitoring and at two of the underpasses since 2020/2021.

Table 9: Cumulative frequency of exotic predator use of underpasses (number of records)

Species	Underpass number													
	F1.04	F1.62	C4.46	C7.26	F9.70	F11.67	F20.54	F21.24	F22.32	F26.40	C32.35	F33.40	F34.72	C36.40
Fox (*Vulpes vulpes*)	**84**	**54**	**57**	**56**	**30**	12	9	4	**18**	**31**	7	**54**	6	4
Cat (*Felis catus*)	9	18	9	9	10	1	9	**6**	4	5	**33**	27	**26**	**25**
Dog (*Canis familiaris/dingo*)	1	0	1	10	15	**19**	**10**	4	3	13	0	2	**28**	2

Bold indicates exotic predator which occurs most frequently at each underpass.

Table 10: Cumulative exotic predator use of underpasses to (percentage of all fauna recorded)

Species	Underpass number													
	F1.04	F1.62	C4.46	C7.26	F9.70	F11.67	F20.54	F21.24	F22.32	F26.40	C32.35	F33.40	F34.72	C36.40
2018/2019	**53.1**	**43.3**	14.5	12.7	21.0	1.8	20.8	20.0	8.0	**36.6**	**30.0**	**35.2**	**34.7**	**27.8**
2020/2021	**28.6**	**46.2**	7.6	**79.7**	**31.6**	**29.4**	17.0	5.3	**75.0**	20.0	**54.9**	**41.9**	**35.9**	**39.4**
2022/2023	**68.0**	**28.3**	19.5	**31.1**	25.0	18.2	1.9	1.4	0.4	0.6	8.0	1.7	6.6	0.0

Bold indicates visitation rate by exotic predators > 25% of all visitations.

3.3 Road Kill

3.3.1 Weekly road kill rate

As part of the road kill monitoring component of the Project, road kill surveys were undertaken in April 2022 (autumn), October 2022 (spring) and January 2023 (summer), involving weekly surveys of the entire length of the Project for four weeks in each season. Detailed reporting of these surveys is presented in Niche (2023).

There were a total of 43 road kill records for the spring, summer and autumn 2022/2023 road kill monitoring events, including 20 in autumn, 11 in spring and 12 in summer. Baseline surveys were undertaken prior to the commencement of construction for 12 weeks in spring 2013, summer 2014 and autumn 2014. Monitoring took place weekly for four weeks in each of the seasons as required by the EMP. Baseline surveys recorded 96 animals as road kill during the three monitoring events, representing 33 species and an average weekly road kill for spring, summer and autumn of 9.5, 11.8 and 3.3 respectively. Table 11 shows the average weekly road kill for across all years, stages of the Project and seasons to date.

Spring and summer weekly road kill rates were lower in the 2022/2023 monitoring period than during baseline surveys (2.8 *cf* 9.5 and 3.0 *cf* 11.8 respectively), while autumn 2023 was higher than baseline for the same period (5.0 *cf* 3.3). The overall average weekly road kill rate (calculated for the same three seasons) was similar during the baseline surveys and for the first year of operation (8.0 and 7.7 respectively), however the road kill rate for the last three years of operational monitoring has been lower (3.8 in 2019/2020, 5.8 in 2020/2021 and 3.6 in 2022/2023).

3.3.2 Road kill within 200 metres of monitored fauna underpasses

Table 12 shows the road kill records within 200 metres of monitored underpasses during 2022/2023, 2020/2021, 2018/2019 and baseline monitoring events. There were a total of two road kill records within 200 metres of monitored underpasses during 2022/2023 monitoring (F33.40 and C32.35), decreased from the three road kill records during the 2021/2022, 2020/2021 and 2018/2019 surveys respectively. Baseline road kill surveys included five road kill within 200 metres of monitored underpasses including F1.04, F34.72, F22.32 and C7.26.

3.3.3 Threatened species road kill

Table 13 lists the threatened species identified as road kill throughout the Project to date. One Koala was identified in October 2020, within a partially fenced area of the highway on the northbound left lane near Barry's Creek. TfNSW inspected the area of the Koala road strike within days to review the fencing integrity. Minor tree limbs were removed from fauna fencing in the general area, but it was considered unlikely that these provided a potential access point. No holes or issues with the fencing were identified during the inspection. The individual likely entered the motorway from the unfenced intersection at Mingaletta Road or fallen tree limbs on the fauna fence near the U-turn bay at Barry's Creek, crossed from the southbound lane to the northbound land where it was hit.

The baseline monitoring report (Lewis 2014) states that, based on baseline Koala road kill records, "*the baseline count for road kill should be set at 1 individual per 8 weeks*". Koala road kill has therefore not increased from the baseline count.

There have been no threatened species road kill recorded since the 2020/2021 monitoring period.

Table 11: Average weekly road kill rate for all monitoring to date

Monitoring period		Spring (n)	Summer (n)	Autumn (n)	Winter (n)	Annual (n)
Baseline	2013/2014	9.5 (4)	11.8 (4)	3.3 (4)	No surveys	8.0 (12)
Construction phase	2015/2016 (all surveys)	4.2 (13)	5.8 (14)	6.7 (13)	4.1 (12)	5.0 (52)
	2015/2016 (4 weeks)	2.75 (4)	6.5 (4)	6.5 (4)	3.0 (4)	
	2016/2017 (all surveys)	3.3 (13)	2.6 (13)	2.0 (12)	2.2 (14)	2.3 (52)
	2016/2017 (4 weeks)	4.0 (4)	1.5 (4)	1.5 (4)	2.5 (4)	
	2017/2018 (all surveys)	2.9 (9)	No surveys*	No surveys*	3.3 (4)	3.0 (13)
	2017/2018 (4 weeks)	1.5 (4)	No surveys*	No surveys*	3.3 (4)	
12-week post-opening	2017/2018 (all sections combined)					4.5 (12)
Operational	2018/2019	11.3 (4)	6.8 (4)	5.0 (4)	No surveys	7.7 (12)
Operational	2019/2020	5.3 (4)	3.8 (4)	2.5 (4)	No surveys	3.8 (12)
Operational	2020/2021	5.8 (4)	6.0 (4)	5.5 (4)	No surveys	5.8 (12)
Operational	2022/2023	2.8 (4)	3.0 (4)	5.0 (4)	No surveys	3.6 (12)

n = number of survey weeks; * = construction partially complete

Table 12: Road kill within 200 metres of monitored fauna underpasses and distance from underpass

Monitoring event	Season	Species	Native/ introduced	Fauna category	Underpass	Distance (metres)
2022/2023	Summer	Bandicoot	Native	Small Mammal	F33.40	135
2022/2023	Summer	Small mammal	Unknown	Small Mammal	C32.35	98
2020/2021	Autumn	Bandicoot	Native	Medium mammal	C32.35	14.6
2020/2021l	Autumn	Snake	Native	Reptile	F11.67	34.6
2020/2021l	Autumn	Snake	Native	Reptile	F11.67	35.4
2020/2021l	Summer	Kookaburra	Native	Bird	C7.26	57.1
2018/2019	Spring	Medium Mammal	unknown	Medium ground dwelling mammal	C32.35	136.8
2018/2019	Summer	Medium Mammal	unknown	Medium ground dwelling mammal	F21.24	31.9
2018/2019	Summer	Kangaroo	native	Large ground dwelling mammal	C32.35	54.3
Baseline	Autumn	Brushtail Possum	native	Arboreal Mammal	F1.04	67.0
Baseline	Spring	Lace Monitor	native	Reptile	F34.72	77.8
Baseline	Spring	Koala	native	Arboreal Mammal	F22.32	117.3
Baseline	Summer	Eastern Grey Kangaroo	native	Large ground dwelling mammal	C7.26	150.4
Baseline	Summer	Red-necked Wallaby	native	Large ground dwelling mammal	F22.32	150.5

Table 13: Threatened species road kill to date

Monitoring type (report)	Monitoring period	Threatened species identified as road kill (number recorded)
Baseline (Lewis 2014)	2013-2014	• Koala (1*) • Grey-headed Flying Fox (2)
Clearing (Niche 2015)	2014-2015	• Koala (4) • Grey-headed Flying Fox (1) • Masked Owl (2) • Spotted-tail Quoll (1)
Construction (Niche 2016)	2015-2016	• Koala (1)
Construction (Niche 2017b)	2016-2017	• Koala (2)
Construction (Niche 2018c)	2017-2018	Nil
Operational (Niche 2019b)	2018-2019	• Koala (1)
Operational (Niche 2020)	2020-2021	• Brush-tail Phascogale (1)
Operational (Niche 2021b)	2020-2021	• Koala (1)

* = An additional three Koala road kill were recorded between August 2013 and February 2014, outside of the monitoring period.

4. Discussion

4.1 Performance Measures

A summary and discussion of the 2022/2023 fauna underpass monitoring results in relation to the performance measures is provided in Table 14.

Table 14: Performance measures

Performance measure	Discussion
Complete safe crossing by the targeted EPBC species, the Spotted-tailed quoll and Koala, at a sufficient frequency as defined in Section 1.5 of the EMP. This would ensure that the underpass performance measure would trigger the contingency measures in section 5 for underpass performance after each koala monitoring event to review / modify underpass furniture, habitat, monitoring and if required, agency discussions.	**This performance measure is considered to have been met.** Section 1.5 of the EMP defines an 'effective' crossing as: "*Result in the complete, safe crossing of the crossing by the targeted EPBC species at a sufficient frequency to ensure that habitat connectivity is maintained or improved from baseline conditions (determined by surveys condition 4a and information provided in the preliminary documentation), and ongoing population viability by providing opportunities for species dispersal and re-colonisation; and result in reduced incidence of road kill from baseline conditions (determined by surveys condition 4a and information provided in the preliminary Documentation*". The crossing frequency required to determine effective habitat connectivity for each EPBC species and baseline crossing frequencies are unknown. As such, it is not possible to determine if fauna are crossing with 'sufficient frequency' and therefore it is not possible to use this metric to assess the success of the underpasses. In addition, the monitoring program does not provide a means of measuring dispersal and re-colonisation of species. However, it is considered that the monitoring scope permits comment on the use of underpasses as demonstrating *opportunity* for dispersal and reduction in road kill. This performance measure has therefore been assessed in this manner for each of the three EPBC Act listed species. To date, the Koala and Spotted-tailed Quoll have been recorded during the monitoring. The Koala was recorded in both the 2018/2019 and 2020/2021 monitoring periods whilst the Spotted-tailed Quoll has only been recorded on one occasion in 2018/2019. The Koala was recorded using one underpass in 2020/2021 and three underpasses in 2018/2019, each on a single occasion. These events all occurred within the spring/summer monitoring event, which may reflect seasonal movement patterns of the species. The detection of this species within a number of underpasses may be considered as demonstration of 'successful crossing at a sufficient frequency' as the records demonstrates that the underpasses provide opportunity for dispersal. In addition, the baseline road kill monitoring report (Lewis 2014) states that, based on baseline Koala road kill records, "*the baseline count for road kill should be set at 1 individual per 8 weeks*". Koala road kill has therefore not increased from the baseline count. The Spotted-tailed Quoll has only been recorded on one occasion in 2018/2019 within a single underpass. Given the low densities and cryptic nature of this species, it is considered unlikely that this species would be detected at all of the nominated underpasses. Spotted-tailed Quoll monitoring (two events of 21 consecutive nights using 36 cameras over 2,700 ha and repeated within three different areas) within the Project Area has not resulted in the detection of this species. In addition, one event during 2022/2023 monitored 14 fauna crossing locations within three broad monitoring areas for not less than three months from 1 June to 14 September 2022, also resulting in no detection of the species. The detection of this species within an underpass may be considered as demonstration of 'successful crossing at a sufficient frequency' as the record demonstrates that the underpass provides opportunity for dispersal, and there have been no incidences of road kill recorded for this species since construction.
For non-EPBC species (Brush-tailed Phascogale), the complete safe crossing of the nominated underpass by the target species or their indicator species on at least one occasion in order to demonstrate opportunity for dispersal and re-colonisation (excluding frogs which are unlikely to be detected using camera monitoring).	**This performance measure has been met.** The Brush-tailed Phascogale was recorded using two of the 14 underpasses during 2022/2023 monitoring periods. The species was recorded on one occasion in underpasses F20.54 and F22.32, in autumn and summer, respectively. Indicator species (small ground-dwelling mammals and/or arboreal mammals) for the Brush-tailed Phascogale were recorded using all 14 underpasses in 2022/2023.

Performance measure	Discussion
For fauna groups, the complete safe crossing of the nominated underpass by one or more individuals on at least once occasion from each of the relevant fauna groups (small ground-dwelling mammals, arboreal mammals and macropods) to demonstrate opportunity for dispersal and re-colonisation.	**This performance measure has been met.** All underpasses have records of crossings by representatives from all of the three specified fauna groups, as follows: • Small ground-dwelling mammals: recorded at all nominated underpasses; represented by rodents, antechinus, bandicoots, the Echidna and the Spotted-tailed Quoll. • Arboreal mammals: recorded at all nine nominated underpasses, and at five additional underpasses; represented by the Brushtail Possum and the Koala. • Macropods: recorded at all 14 nominated underpasses; represented by the Eastern Grey Kangaroo, Red-necked Wallaby and Swamp Wallaby.
Reduced incidence of road kill from baseline conditions.	**This performance measure has been met.** The annual average weekly road kill rate has decreased from baseline to 2022/2023 operational monitoring (8.0 in baseline *cf. 3.6* in 2022/2023).

5. Recommendations

5.1 Contingency Measures

The EMP lists potential problems and contingency measures for various components of the monitoring program. Those that are related to the underpass monitoring program are listed and discussed in Table 15.

Table 15: Contingency measures

Potential problem	EMP contingency measure	Discussion of proposed measure
No recorded presence of indicator species from the nominated classes in underpasses.	Commence review/modification of fauna furniture associated with underpasses within two weeks of results reported by ecologist.	Four of the five fauna groups have been detected at all monitored underpasses. Frogs have been detected using only one underpass during monitoring events, however monitoring methods do not favour their detection. **This contingency measure is not considered relevant.**
No recorded presence of cover- dependent species or fauna species with low mobility in underpasses.	Commence review/modification of habitat (i.e. vegetation composition and structure; type and abundance of natural habitat features) adjoining the underpass within two weeks of results reported by ecologist.	All three relevant fauna groups have been detected using all 14 underpasses. Frogs have been detected using only one underpass during monitoring events, however monitoring methods do not favour their detection. **This contingency measure is not considered relevant.**
Increased incidence of road kill from baseline conditions, in proximity to underpasses, particularly target species.	Commence review/modification of frequency and/or timing of monitoring periods within two weeks of results reported by ecologist.	Overall annual weekly road kill rates have decreased compared to baseline monitoring. Two road kill fauna were recorded during 2022/2023 monitoring within 200 metres of monitored underpasses (F33.40 and C32.35) and five road kill fauna were recorded within 200 metres of four different underpasses during baseline monitoring (F1.04, F34.72, F22.32 and C7.26). There has not been an increase in road kill in proximity to monitored underpasses. No target species (the Koala) was recorded as road kill during the 2022/2023 monitoring period. The baseline monitoring report (Lewis 2014) states that, based on baseline Koala road kill records, "*the baseline count for road kill should be set at 1 individual per 8 weeks*". Koala road kill has not increased from the baseline count. **This contingency measure is not considered relevant.**
Inferior results compared to baseline surveys for the EPBC species, relevant to reference site monitoring.	If it is not reasonable or feasible to redesign/modify the underpass, discussions with EPA, DP&I and DoTE will be undertaken to determine if additional biodiversity offsets are required within 1 month of above reviews being completed.	Comparison of underpass records with EPBC species reference site monitoring may be undertaken only at a superficial level due to the different means of data collection of the different monitoring components. Koalas were recorded along the entire length of the Project during baseline surveys (Lewis 2014). The Koala was recorded using four underpasses in areas where the Koala was recorded during the baseline surveys (Niche 2019c). The Spotted-tailed Quoll was not recorded during baseline surveys (Niche 2018d) but was recorded using one nominated underpass during the 2018/2019 fauna underpass monitoring. The Giant Barred Frog has been recorded traversing the Project under constructed bridges at locations where it was recorded during baseline surveys (Niche 2018b), but not using the nominated underpass, which is considered unlikely to provide suitable habitat for this species. **This contingency measure is not considered relevant.**

5.2   Recommendations

Given the successful use by a range of native fauna from different fauna groups it is considered that the underpasses have been a successful mitigation measure allowing species to cross safely under the carriageway and maintain connectivity for adjacent habitat. Underpasses are a key mitigation measure in reducing the impact of the highway as a major barrier to native fauna. Therefore, there are no further monitoring measures recommended beyond requirements of the EMP. However, maintenance of fauna fencing particularly within 200 m of underpasses is considered important in continued successful crossing by native fauna.

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Annex 1 – 2022/2023 camera results

Table 16: 2022/2023 remote camera records – F1.04, F1.62, C4.46, C7.26, F9.70, F11.67 and F20.54

Underpass	F1.04		F1.62		C4.46		C7.26		F9.70		F11.67		F20.54	
Fauna group / Species	autumn	spring/ summer	autumn	spring/ summer	autumn	spring/ summer	autumn	spring/ summer	autumn	spring/ summer	autumn	spring/ summer	autumn	spring/ summer
Small ground-dwelling mammals														
Antechinus sp.					Y (3)	Y (2)			Y (1)					Y (1)
Bandicoot				Y (4)										Y (6)
Northern Brown Bandicoot (*Isoodon macrourus*)				Y (1)										
Long-nosed Bandicoot (*Perameles nasuta*)				Y (3)										Y (2)
Echidna (*Tachyglossus aculeatus*)														Y (1)
Spotted-tailed Quoll (*Dasyurus maculatus*)*														
Rattus fuscipes														
Rattus rattus					Y (10)	Y (12)		Y (7)	Y (15)	Y (6)	Y (4)	Y (29)	Y (29)	Y (5)
Rattus spp.														
Rodent/Marsupial	Y (1)		Y (1)			Y (2)		Y (2)	Y (18)	Y (4)	Y (4)	Y (12)	Y (19)	Y (4)
Arboreal mammals														
Brushtail Possum			Y (7)	Y (1)	Y (36)	Y (36)	Y (2)						Y (27)	Y (21)
Common Brushtail Possum (*Trichosurus vulpecula*)		Y (15)	Y (2)		Y (5)	Y (44)								
Short-eared Brushtail Possum (*Trichosurus caninus*)			Y (16)	Y (1)	Y (8)	Y (9)							Y (31)	Y (17)
Brush-tailed Phascogale (*Phascogale tapoatafa*)													Y (1)	
Koala														
Koala (*Phascolarctos cinereus*)*														

Underpass	F1.04		F1.62		C4.46		C7.26		F9.70		F11.67		F20.54	
Fauna group / Species	autumn	spring/ summer	autumn	spring/ summer	autumn	spring/ summer	autumn	spring/ summer	autumn	spring/ summer	autumn	spring/ summer	autumn	spring/ summer
Macropods														
Eastern Grey Kangaroo (*Macropus giganteus*)			Y (2)	Y (22)	Y (1)				Y (1)	Y (2)	Y (1)	Y (5)	Y (2)	Y (9)
Macropod sp.			Y (1)	Y (14)								Y (2)		Y (1)
Swamp Wallaby (*Wallabia bicolor*)				Y (1)										
Red-necked Wallaby (*Macropus rufogriseus*)				Y (2)										Y (7)
Wallaby			Y (2)	Y (2)							Y (4)		Y (1)	
Reptiles														
Blue-tongue Lizard (*Tiliqua scincoides*)														
Eastern Water Dragon (*Intellagama lesueurii*)					Y (5)									
Lace Monitor (*Varanus varius*)				Y (2)	Y (1)	Y (13)						Y (6)		Y (23)
Snake														
Other														
Microbat										Y (1)				Y (1)
Unk Mammal				Y (1)										
Rattus rattus														
Raven (*Corvus* sp.)														
Wood Duck (*Chenonetta jubata*)														
Fox (*Vulpes vulpes*)	Y (30)		Y (7)	Y (14)		Y (46)			Y (2)		Y (4)		Y (3)	
Deer				Y (1)		Y (2)								
Cat (*Felis catus*)	Y (3)	Y (1)	Y (9)	Y (4)										
Wild Dog (*Canis lupus*)							Y (5)		Y (14)		Y (1)	Y (11)		Y (1)
Swallow														

Y = detected; (n) = number of records; * = EPBC target species

Table 17: 2022/2023 remote camera records – F21.24, F22.32, F26.40, C32.35, F33.40, F34.72 and C36.40

Underpass	F21.24		F22.32		F26.40		C32.35		F33.40		F34.72		C36.40	
Fauna group / Species	autumn	spring/summer	autumn	spring/summer	autumn	spring/summer	autumn	spring/summer	autumn	spring/summer	autumn	spring/summer	autumn	spring/summer
Small ground-dwelling mammals														
Antechinus sp.	Y (2)	Y (29)	Y (3)	Y (5)		Y (7)								
Bandicoot	Y (4)		Y (2)	Y (1)		Y (5)		Y (2)	Y (10)	Y (2)				
Northern Brown Bandicoot (*Isoodon macrourus*)				Y (1)										
Long-nosed Bandicoot (*Perameles nasuta*)	Y (1)								Y (2)	Y (3)				
Echidna (*Tachyglossus aculeatus*)				Y (1)		Y (1)				Y (1)				
Spotted-tailed Quoll (*Dasyurus maculatus*)*														
Black Rat (*Rattus rattus*)	Y (1)	Y (40)	Y (9)	Y (58)	Y (21)	Y (23)	Y (10)		Y (18)	Y (29)	Y (5)	Y (22)		
Rattus sp.	Y (7)	Y (19)	Y (17)	Y (25)						Y (6)		Y (4)		
Rodent/Marsupial	Y (11)	Y (23)	Y (1)	Y (6)		Y (6)	Y (3)			Y (2)		Y (3)		
Arboreal mammals														
Brushtail Possum	Y (46)	Y (26)	Y (14)	Y (27)	Y (13)	Y (4)		Y (1)			Y (4)			
Common Brushtail Possum (*Trichosurus vulpecula*)	Y (10)	Y (12)	Y (14)	Y (1)		Y (10)					Y (3)	Y (4)		
Short-eared Brushtail Possum (*Trichosurus caninus*)	Y (30)	Y (5)	Y (1)	Y (1)	Y (2)									
Brush-tailed Phascogale (*Phascogale tapoatafa*)				Y (1)										
Koala														
Koala (*Phascolarctos cinereus*)*														
Macropods														
Grey Kangaroo (*Macropus giganteus*)	Y (1)				Y (1)	Y (11)								
Macropod sp.		Y (1)	Y (3)		Y (3)				Y (3)	Y (1)	Y (1)			
Swamp Wallaby (*Wallabia bicolor*)			Y (3)	Y (2)		Y (16)			Y (11)	Y (16)				

Underpass	F21.24		F22.32		F26.40		C32.35		F33.40		F34.72		C36.40	
Fauna group / Species	autumn	spring/ summer	autumn	spring/ summer	autumn	spring/ summer	autumn	spring/ summer	autumn	spring/ summer	autumn	spring/ summer	autumn	spring/ summer
Wallaby			Y (3)	Y (1)	Y (1)	Y (1)				Y (4)	Y (6)			
Red-necked Wallaby (*Macropus rufogriseus*)				Y (1)		Y (5)				Y (1)			Y (1)	
Reptiles														
Blue-tongue Lizard (*Tiliqua scincoides*)														
Eastern Water Dragon (*Intellagama lesueurii*)					Y (2)									
Lace Monitor (*Varanus varius*)		Y (3)		Y (24)		Y (25)				Y (1)		Y (1)		
Unk Skink														
Other														
Microbat	Y (1)		Y (1)			Y (1)	Y (1)					Y (1)		
Rattus rattus														
Unk Mammal														
Raven (*Corvus* sp.)														
Wood Duck (*Chenonetta jubata*)														
Fox (*Vulpes vulpes*)	Y (1)		Y (1)			Y (1)	Y (6)		Y (1)		Y (2)			
Hare (*Lepus 27uropaeus*) / Rabbit (*Oryctolagus cuniculus*)														
Cat (*Felis catus*)	Y (1)								Y (1)					
Wild Dog (*Canis lupus*)		Y (2)										Y (2)		
Unk Bird					Y (5)		Y (13)					Y (1)		
Lewin's Honeyeater														
Superb Fairy Wren														
Welcome Swallow							Y (39)							

Y = detected; (n) = number of records; * = EPBC target species

Table 18: Autumn 2022 camera details

Underpass	Camera	Operating for entire period (Y/N)	Install date	Retrieve date	Operational days	Location	Direction facing (E/W)	Number of fauna records	Notes
F1.04	156	Y	30/03/2022	7/06/2022	67	Top	W	4	
F1.04	162	Y	30/03/2022	7/06/2022	67	Bottom	W	29	
F1.62	399	Y	30/03/2022	7/06/2022	67	Top	E	34	
F1.62	422	Y	30/03/2022	7/06/2022	67	Bottom	W	20	
C4.46	443	Y	30/03/2022	7/06/2022	67	Top	E	69	
C4.46	870	Y	30/03/2022	7/06/2022	67	Bottom	E	0	
C7.26	127	Y	30/03/2022	1/06/2022	61	Bottom	E	5	
C7.26	380	Y	30/03/2022	1/06/2022	61	Top	E	2	
F9.7	383	Y	30/03/2022	1/06/2022	61	Bottom	E	17	
F9.7	423	Y	30/03/2022	1/06/2022	61	Top	W	34	
F11.67	387	Y	30/03/2022	1/06/2022	61	Top	E	8	
F11.67	425	Y	30/03/2022	1/06/2022	61	Bottom	E	23	
F20.54	120	Y	30/03/2022	1/06/2022	61	Top	E	68	
F20.54	415	Y	30/03/2022	1/06/2022	61	Bottom	E	6	
F21.24	125	Y	30/03/2022	1/06/2022	61	Top	W	1	
F21.24	442	Y	30/03/2022	1/06/2022	61	Bottom	E	117	
F22.32	175	Y	30/03/2022	1/06/2022	61	Bottom	E	11	
F22.32	431	Y	30/03/2022	1/06/2022	61	Top	E	59	
F26.4	194	Y	31/03/2022	1/06/2022	60	Bottom	E	5	
F26.4	373	Y	31/03/2022	1/06/2022	60	Top	E	36	
C32.35	80	Y	31/03/2022	1/06/2022	60	Bottom	W	33	
C32.35	435	N	31/03/2022	1/06/2022	48	Bottom	E	0	19/5/2022 last photo
F33.4	72	Y	31/03/2022	1/06/2022	60	Bottom	E	28	
F33.4	432	N	31/03/2022	1/06/2022	22	Top	E	19	Camera 427 replaced after found not to be triggering on 11/5

F34.72	134	Y	31/03/2022	1/06/2022	60	Bottom	E	11	
F34.72	377	Y	31/03/2022	7/06/2022	66	Top	E	10	
C36.4	65	Y	31/03/2022	1/06/2022	60	Bottom	W	1	
C36.4	378	N	31/03/2022	1/06/2022	60	Bottom	E	0	Camera error taking videos.

Table 19: Spring/summer 2022/2023 camera details

Underpass	Camera #	Operating for entire period (Y/N)	Install date	Retrieve date	Operational days	Location	Direction facing (E/W)	Number of fauna records	Notes
F1.04	433	N	4/11/2022	3/01/2023	40	Bottom	W	17	
F1.04	447	N	4/11/2022	3/01/2023	35	Top	W	0	
F1.62	430	Y	4/11/2022	3/01/2023	60	Top	W	62	
F1.62	178	Y	4/11/2022	3/01/2023	60	Bottom	W	4	
C4.46	424	Y	4/11/2022	3/01/2023	60	Bottom	W	107	
C4.46	870	Y	4/11/2022	3/01/2023	60	Top	W	60	
C7.26	432	Y	3/11/2022	3/01/2023	60	Bottom	E	0	
C7.26	426	Y	3/11/2022	3/01/2023	60	Top	W	9	
F9.7	194	Y	3/11/2022	3/01/2023	60	Bottom	W	2	
F9.7	167	Y	3/11/2022	3/01/2023	60	Top	W	11	
F11.67	85	Y	3/11/2022	3/01/2023	60	Bottom	W	10	
F11.67	423	Y	3/11/2022	3/01/2023	60	Top	E	47	
F20.54	156	Y	3/11/2022	3/01/2023	60	Bottom	E	49	
F20.54	174	Y	3/11/2022	3/01/2023	60	Top	W	89	
F21.24	443	Y	3/11/2022	3/01/2023	60	Top	E	158	
F21.24	127	Y	3/11/2022	3/01/2023	60	Bottom	E	3	
F22.32	125	Y	3/11/2022	3/01/2023	60	Bottom	E	33	
F22.32	382	Y	3/11/2022	3/01/2023	60	Top	W	123	
F26.4	65	Y	3/11/2022	3/01/2023	60	Bottom	E	64	

Underpass	Camera #	Operating for entire period (Y/N)	Install date	Retrieve date	Operational days	Location	Direction facing (E/W)	Number of fauna records	Notes
F26.4	369	Y	3/11/2022	3/01/2023	60	Top	E	60	
C32.35	397	Y	3/11/2022	3/01/2023	60	Bottom	E	42	
F33.4	72	Y	3/11/2022	3/01/2023	60	Bottom	E	22	
F33.4	374	Y	3/11/2022	3/01/2023	60	Top	E	46	
F34.72	134	Y	3/11/2022	3/01/2023	60	Bottom	E	6	
F34.72	422	Y	3/11/2022	3/01/2023	60	Top	E	34	
C36.4	141	Y	3/11/2022	3/01/2023	60	Bottom	W	0	
C36.4	378	N	3/11/2022	3/01/2023	43	Top	E	0	

Annex 2 – 2022/2023 scat, track and hair-tube results

Table 20: 2022/2023 sand plot survey results

Species	C4.46	C7.26	C32.35	C36.40
Fox		Y	Y	
Rodent	Y	Y	Y	Y
Echidna				
Cat		Y	Y	Y
Dog		Y	Y	
Brushtail Possum				Y
Koala				
Bandicoot	Y		Y	Y
Lace Monitor		Y		
Water Dragon			Y	
Macropod		Y		
Reptile	Y	Y		Y
Mammal				

Y = detected

Table 21: 2022/2023 tracks and scats results

Species	F1.04	F1.62	C4.46	C7.26	F9.70	F11.67	F20.54	F21.24	F22.32	F26.40	C32.35	F36.4
Bird			T	T					T			
Macropod		Y				T	T	T	T			
Possum						T						
Microbat								I		I	I/C	I
Rodent			C/T		T	T/C	T			C	C	C
Frog												C
Cat/Fox		T		T					T			
Dog					T	T			T		C	
Deer	T											

I = observed, C = scat, T = track

Table 22: 2022/2023 hair tube results

Season	Monitoring year	Underpass	Location	number of tubes	Hair tube deploy date	Hair tube retrieve date	Tubes with hair (samples sent for ID)	Species idenditifed
Autumn	2022	F1.04	OH2K	10	30/03/2022	12/05/2022	1	*Rattus* sp.
Autumn	2022	F1.62	OH2K	10	30/03/2022	12/05/2022	1	Human
Autumn	2022	C4.46	OH2K	10	30/03/2022	12/05/2022	11	*Trichosurus* sp.
Autumn	2022	C7.26	OH2K	10	30/03/2022	11/05/2022	3	*Rattus rattus, Rattus* sp.
Autumn	2022	F9.70	OH2K	10	30/03/2022	10/05/2022	0	NA
Autumn	2022	F11.67	OH2K	10	30/03/2022	10/05/2022	8	*Rattus rattus*
Autumn	2022	F20.54	OH2K	10	30/03/2022	10/05/2022	2	*Rattus rattus, Trichosurus* sp.
Autumn	2022	F21.24	OH2K	10	30/03/2022	11/05/2022	9	*Trichosurus* sp.
Autumn	2022	F22.32	OH2K	10	30/03/2022	11/05/2022	5	*Rattus rattus, Trichosurus* sp.
Autumn	2022	F26.40	K2K	10	30/03/2022	10/05/2022	2	*Rattus* sp., *Trichosurus* sp.
Autumn	2022	C32.35	K2K	10	30/03/2022	10/05/2022	3	*Rattus rattus, Rattus* sp.
Autumn	2022	F33.40	K2K	10	30/03/2022	11/05/2022	7	*Rattus rattus, Rattus* sp.
Autumn	2022	F34.72	K2K	10	30/03/2022	10/05/2022	12	*Trichosurus* sp.
Autumn	2022	C36.40	K2K	10	30/03/2022	11/05/2022	3	Human, *Rattus* sp., *Trichosurus* sp.
Summer	2022	F1.04	OH2K	10	4/11/2022	9/12/2022	2	*Trichosurus* sp.
Summer	2022	F1.62	OH2K	10	4/11/2022	9/12/2022	1	*Trichosurus* sp.
Summer	2022	C4.46	OH2K	10	4/11/2022	9/12/2022	8	*Rattus rattus, Trichosurus* sp.
Summer	2022	C7.26	OH2K	10	3/11/2022	7/12/2022	0	NA
Summer	2022	F9.70	OH2K	10	3/11/2022	7/12/2022	2	Macopod
Summer	2022	F11.67	OH2K	10	3/11/2022	7/12/2022	7	*Rattus rattus, Rattus* sp.
Summer	2022	F20.54	OH2K	10	3/11/2022	7/12/2022	1	*Trichosurus* sp.
Summer	2022	F21.24	OH2K	10	3/11/2022	7/12/2022	7	*Trichosurus* sp.
Summer	2022	F22.32	OH2K	10	3/11/2022	7/12/2022	6	*Rattus rattus, Rattus* sp.
Summer	2022	F26.40	K2K	10	3/11/2022	7/12/2022	0	NA
Summer	2022	C32.35	K2K	10	3/11/2022	7/12/2022	3	*Trichosurus* sp., *Perameles nasuta*
Summer	2022	F33.40	K2K	10	3/11/2022	7/12/2022	1	*Wallabia bicolor*
Summer	2022	F34.72	K2K	10	3/11/2022	7/12/2022	7	*Rattus* sp., *Trichosurus* sp.
Summer	2022	C36.40	K2K	10	3/11/2022	7/12/2022	0	NA

Season	Monitoring year	Underpass	Location	number of tubes	Hair tube deploy date	Hair tube retrieve date	Tubes with hair (samples sent for ID)	Species idenditifed

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