Pacific Highway Upgrade – Sapphire to Woolgoolga

Operational Phase Fauna Crossing Monitoring Program ~ Year 1

Version 2 - Final Report

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Cover Photo: *A sugar glider (Petaurus breviceps) photographed using the Arrawarra Creek glide pole positioned between carriageways.*

Disclaimer:

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Table of Contents

List of Tables

List of Figures

List of Plates

1. Introduction

The upgrade of the Pacific Highway from Sapphire to Woolgoolga (S2W) involved construction of 25 km of dual carriageway from Campbell Close, Sapphire, to Arrawarra Beach Road, Arrawarra. The upgrade became operational in July 2014.

The Ministerial Conditions of Approval (MCoA) for the S2W upgrade included a requirement (MCoA 3.1) to prepare an Ecological Monitoring Program (EMP) to monitor the effectiveness of mitigation measures identified in MCoA 2.12(e). The EMP was developed and approved in 2009 and later amended to include data obtained during the construction phase (BEM 2014). The final version (version 4) was completed in February 2014 (BEM 2014).

The mitigation measures identified in MCoA 2.12(e) include "fauna crossing measures, including vegetated medians, fauna structures and associated fauna fencing to be installed as part of the project". The EMP focuses on nine mitigation measures and specifies sample sites, sample duration and methods. Measures relevant to the current study include to underpasses at ch.29200, ch.11500, ch.17500 and ch.17720, vegetated median between ch.29400 and ch.30000, rope bridge at Moonee (ch.10720) and glider poles at Arrawarra Creek (ch.31020) (BEM 2014). Other measures refer to pre-clearing and clearing procedures, installation of nest boxes, monitoring of frog pipes, protection of in-situ threatened flora and translocation areas for affected threatened flora (BEM 2014). The other measures are not the subject of the current report and are reported on elsewhere.

The following report presents results of year one operational phase monitoring conducted during 2015. The report includes information on the background, methods, discussion of the results and evaluation of mitigation measures against the potential indicators of success detailed in the EMP (BEM 2014).

1.1 Background

The EMP identifies several threatened species targeted by the mitigation measures addressed in this report. These include: common planigale *(Planigale maculata*), spotted-tail quoll (*Dasyurus maculatus*), rufous bettong (*Aepyprymnus rufescens*), long-nosed potoroo (*Potorous tridactylus*), brush-tailed phascogale (*Phascogale tapoatafa*) and eastern pygmy possum (*Cercartetus nanus*) use of fauna underpasses; and, squirrel glider (*Petaurus norfolcensis*) and yellow-bellied glider (*Petaurus australis*) use of the vegetated median, rope bridge and glide poles. Whereas threatened species are the focus of the mitigation measures, the aim of the EMP is "to allow the effectiveness of mitigation and offset measures to be assessed and allow for their modification if necessary" (BEM 2014). This includes selection of underpasses that varied somewhat from those previously monitored, such as pipes, underpasses that cross a vegetated median and a relatively long dedicated underpass.

The EMP further describes several potential indicators of success with which to assess the performance of fauna mitigation measures.

Indicators of success include:

- **Fauna underpasses:**
    - i. Low rates of use of fauna underpasses and adjacent habitats by feral predators;
    - ii. High levels of fauna underpass use by a wide variety of native fauna species;
    - iii. Evidence of use by dispersing individuals and different age cohorts;

iv. Use by cover-dependent species and species with low mobility;

v. Low incidences of fauna road strike mortality.

- **Vegetated median and aerial crossing structures:**

i. Evidence of regular use of the median vegetation by the target glider species;

ii. Evidence of use by dispersing individuals and different age cohorts;

iii. Use by glider species other than threatened species e.g. sugar glider, greater glider.

In January 2015, Sandpiper Ecological Surveys (Sandpiper) was contracted by Roads and Maritime Services NSW (RMS) to conduct year one operational phase monitoring of fauna mitigation measures and to assess their effectiveness. To improve the effectiveness of monitoring, some refinements were made to the timing and method of some monitoring techniques consistent with the intent of the EMP. Such refinements were agreed to by RMS and are described where appropriate in the methods section of the report.

Due to delays in awarding of contracts, commencement of year one monitoring began in early 2015, more than six months after the upgrade became operational. Further, initial inspection of the fauna underpass proposed for monitoring at ch.17720 (Reinforced Concrete (RC) twin box culverts, 2.4 x 1.5m) revealed that it was largely inundated and featured standing water at the entrance areas. After discussions with RMS, it was decided to instead monitor a fauna underpass at ch.29930 (RC box culvert, 3 x 3m), located near the northern end of the vegetated median.

2. Study Area

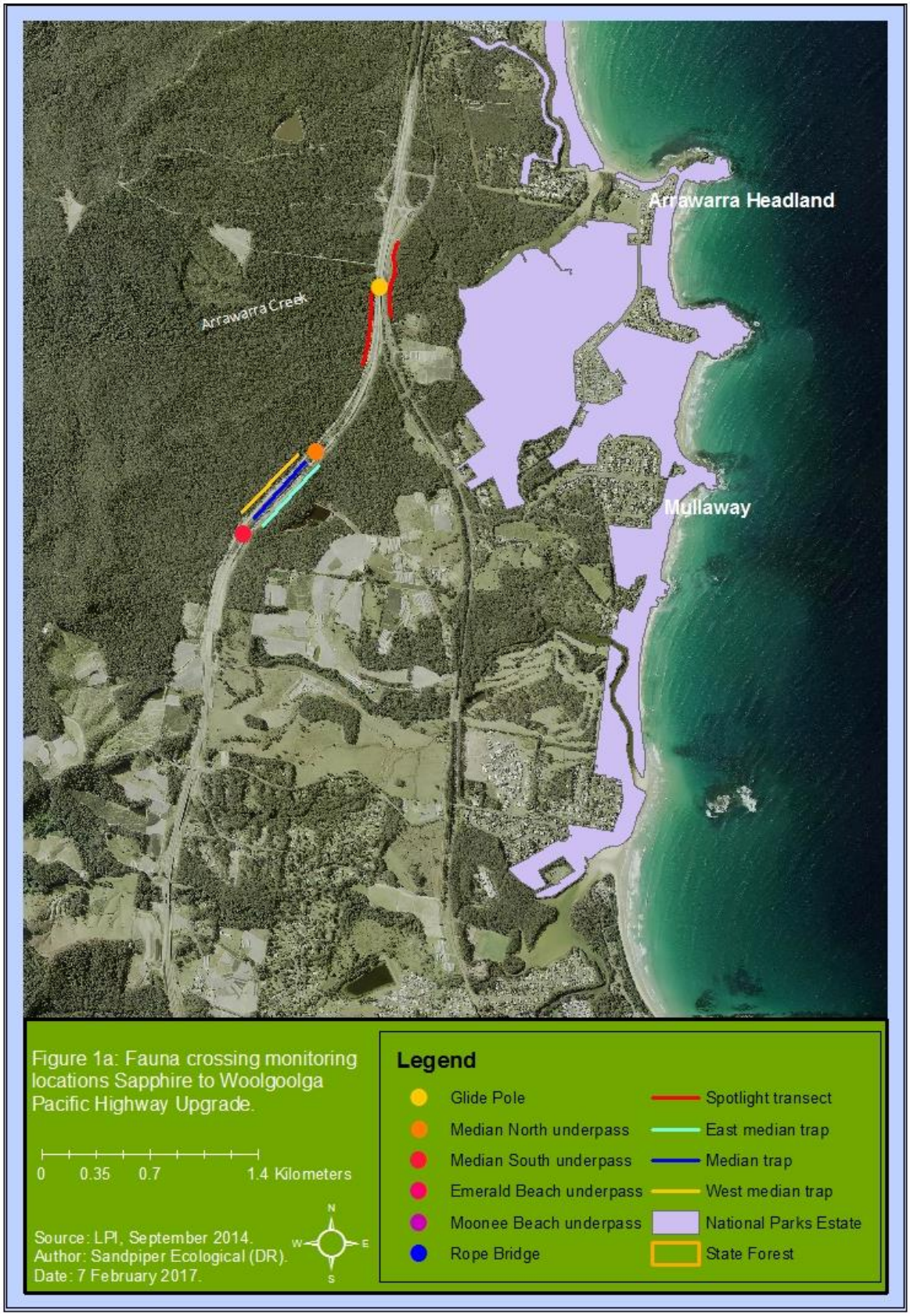
Monitoring sites ranged from the rope bridge at Moonee in the south (ch.10720) to the glide poles at Arrawarra creek in the north (ch.31000) (Table 1; Figure 1a&b). The study area included habitat within 500m either side of each crossing structure. For the vegetated median, the study area included the vegetated median and habitat within 500m either side of its length.

Habitat configuration differed greatly amongst the monitoring sites (Figure 1a&b; Plate 1-7). Habitat surrounding Emerald Beach and Moonee underpasses was highly fragmented, particularly on the west side, and Moonee east and Emerald Beach west adjoined cleared easements (Plate 2 & 3). The section of highway featuring the Arrawarra vegetated median and underpasses traversed Wedding Bells State Forest and was surrounded by contiguous forest (Figure 1a). The Arrawarra glide poles were contiguous with Wedding Bells State Forest to the west and a forested block to the east (Figure 1a). The rope bridge at Moonee connected fragmented but contiguous forest to the west with a large forest block to the east side of the highway (Figure 1b).

Habitat type adjoining crossing structures was mostly dry and moist open forest (Plates 1-7). Emerald Beach and Arrawarra north underpasses also featured areas of swamp forest. The distance between forest edge and underpass entrance ranged between 3.5m (Emerald Beach east) and 29.5m (Emerald Beach west)

Table 1: Location and habitat features of fauna mitigation structures. SF = swamp forest; MOF = moist open forest; DOF = dry open forest; Cl = cleared; E = east; W = west

Chainage	Location	Type	Adjoining Habitat (Distance (m) from structure to adjoining forest)
10720	Moonee	Rope bridge	E (8.5 to pole): DOF W (5 to pole): DOF/MOF
11500	Moonee	Fauna underpass	E (20.5): Cl/MOF/DOF W (10.5): MOF/DOF
17500	Emerald Beach	Fauna underpass	E (3.5): SF W (29.5): Cl/SF
29100-30200	Arrawarra	Vegetated median	E: SF/MOF/DOF W: SF/MOF/DOF
29380	Arrawarra south	Fauna underpass	E (15.8): DOF/MOF W (28.4): DOF/MOF
29930	Arrawarra north	Fauna underpass	E (20.8): SF/MOF/DOF W (17.6): SF/MOF/DOF
31000	Arrawarra creek	Glide poles	E (23.5): MOF/DOF W (36): MOF/DOF


Arrawarra Headland
Arrawarra Creek
Mullaway
Figure 1a: Fauna crossing monitoring locations Sapphire to Woolgoolga Pacific Highway Upgrade.
0 0.35 0.7 1.4 Kilometers
Source: LPI, September 2014.
Author: Sandpiper Ecological (DR).
Date: 7 February 2017.
N
W
E
S
Legend
Glide Pole
Median North underpass
Median South underpass
Emerald Beach underpass
Moonee Beach underpass
Rope Bridge
Spotlight transect
East median trap
Median trap
West median trap
National Parks Estate
State Forest


Emerald Beach
Moonee Beach
Figure 1b: Fauna crossing monitoring locations Sapphire to Woolgoolga Pacific Highway Upgrade.
0 0.35 0.7 1.4 Kilometers
N
W
E
S
Source: LPI, September 2014.
Author: Sandpiper Ecological (DR).
Date: 7 February 2017.
Legend
Glide Pole
Median North underpass
Median South underpass
Emerald Beach underpass
Moonee Beach underpass
Rope Bridge
Spotlight transect
East median trap
Median trap
West median trap
National Parks Estate
State Forest

Plate 1: Expanse of the 86m-long Moonee rope bridge (ch.10720) looking north (upper). Habitat adjoining rope bridge on the east (middle) and west (lower) side of the alignment.

Plate 2: Habitat adjoining Moonee underpass (ch.11500) on the east (upper) and west (lower) side of the alignment.

Plate 3: Habitat adjoining Emerald beach underpass (ch.17500) on the east (upper) and west (lower) side of the alignment.

Plate 4: Habitat adjoining Arrawarra underpass south (ch.29380) on the east (upper) and west (lower) side of the alignment and across the vegetated median (middle).

Plate 5: Habitat adjoining Arrawarra underpass north (ch.29930) on the east (upper) and west (lower) side of the alignment and across the vegetated median (middle).

Plate 6: Habitat adjoining Arrawarra vegetated median (ch.29100-30200) on the east/southbound (upper) and west/northbound (lower) side of the alignment. Adjoining habitat is on the left side of both pictures. (Image: Google Earth).

Plate 7: Habitat adjoining Arrawarra Creek glide poles (ch.31000) looking north. Cameras were installed on the central pole in the highway median.

3. Methods

3.1 Underpasses

3.1.1 Design features

Underpasses varied in their design and function (Table 2; Plate 8-11). All underpasses were positioned in drainage lines except Arrawarra south, which was positioned mid-slope. Emerald Beach underpass functions as a combined drainage/fauna structure and was constructed as a series of eleven 1.2m diameter RC pipes. Arrawarra and Moonee were dedicated RC box culverts and ranged in opening size from 2.4m x 3.0m (Moonee) to 3.0m x 3.0m (Arrawarra) (Table 2). Dedicated culverts featured a wooden post and rail running the length of the underpass and extending beyond the entrances by up to 10m. Moonee and Emerald Beach underpasses were 102.4m and 74.5m long respectively. Arrawarra underpasses were 19m - 21.8m long split underpasses separated by 31.8m - 38.4m of vegetated median. All underpasses were dry during monitoring except some Emerald Beach pipes featured up to 50mm of standing water.

Table 2: Design features of fauna underpasses. SB = south bound carriageway; NB = northbound carriageway; VM = vegetated median.

Chainage	Location	Type	Function	Length (m)	No. & Size (# x W x H(m))
11500	Moonee	RCBC	Dedicated	102.4	1 x 3 x 2.4
17500	Emerald Beach	RCP	Combined	74.5	11 x 1.2 diam.
29380	Arrawarra south	RCBC RCBC	Dedicated	21.4 (NB) 31.8 (VM) 21.4 (SB)	1 x 3 x 3 1 x 3 x 3
29930	Arrawarra north	RCBC RCBC	Dedicated	19 (NB) 38.4 (VM) 21.8 (SB)	1 x 3 x 3 1 x 3 x 3

Plate 8: Moonee underpass (ch.11500) viewed from the east (upper) and from the west entrance (lower).

Plate 9: Emerald Beach underpass (ch.17500) viewed from the east (upper) and west (lower).

Plate 10: Arrawarra underpass south (ch.29380) viewed from the east (upper), across the vegetated median (middle) and from west (lower).

Plate 11: Arrawarra underpass north (ch.29930) viewed from the east (upper), across the vegetated median (middle) and from west (lower).

3.1.2 Monitoring fauna using underpasses

The EMP recommends monitoring of four underpasses and their entrances using sand pads, hair funnels/tubes, cameras, scat and track searches and artificial ground cover. These methods can be more effectively covered by using cameras installed in each underpass and a series of cameras and bait stations installed in adjoining forest. Cameras with bait stations provide a good indication of ground fauna in an area and are superior in cost and results to hair funnels/tubes, sand pads, scat and track searches and artificial ground cover (e.g. Paull et al. 2012).

Monitoring was undertaken at the four underpasses using Reconyx HC500 infra-red (IR) cameras. To confirm complete crossings by fauna, a camera was installed at each end of the single cell underpasses (i.e. Arrawarra north & south, Moonee). Cameras were mounted to the side wall opposite the wooden rail, ~1.5m above floor level and ~2m inside the entrance and facing inwards (Plate 12). Cameras were housed in purpose-built security cases. At the Emerald Beach site, the pipe series is almost 20m across, well beyond the field of view of a single camera. Monitoring of single pipes was impractical because the site featured 11 pipes. Instead, the two cameras were used to achieve full coverage of the entire entrance area of one side. As such, two cameras were positioned at the east side only. Each camera was positioned at either end of the pipe series facing across the entrance area (Plate 12).

Plate 12: Single cell underpasses were monitored at each end with a Reconyx HC500 camera housed in a security case and mounted to the side wall opposite the wooden rail (e.g. Moonee underpass, Left). For the pipe series at Emerald Beach, a camera was mounted on the wing wall at each end of the pipe series and directed across the entrance area of the east side (Right).

Underpass monitoring occurred over two eight week periods, autumn and spring 2015 (Table 3). Cameras were set on high sensitivity and to take 5 pictures/activation with no delay between activations. Images were saved onto an 8GB memory card and batteries and memory cards were checked during the middle of the monitoring period. All cameras were active/functioning for the full duration of each monitoring period (Table 3).

Table 3: Fauna underpass camera monitoring effort. Days active are for 2 cameras/underpass.

Method	Autumn 2015		Spring 2015	
	Period	Days active	Period	Days active
Moonee	26/3 - 21/5/15	56/56	4/9 - 30/10/15	58/58
Emerald Beach	26/3 - 21/5/15	56/56	4/9 - 30/10/15	58/58
Arrawarra south	26/3 - 21/5/15	56/56	4/9 - 30/10/15	58/58
Arrawarra north	24/3 - 21/5/15	58/58	4/9 - 30/10/15	58/58

3.1.3 Sampling fauna in adjacent habitat

Camera bait stations were installed on either side of each underpass to sample fauna in adjoining habitat. Two bait stations were each positioned at ~45^0 to and ~50m from each culvert entrance. Each station featured a Scoutguard KG680V infra-red (IR) camera strapped to a tree or post at ~1m high and focused on a bait chamber ~2m away (Plate 13). Bait chambers were 150mm long PVC pipe (50mm diameter) capped at both ends and perforated with numerous holes. One bait chamber was baited with chicken wings and the other with peanut butter, honey and oats. Fish sauce was drizzled over the chicken bait chambers to serve as an additional attractant. Bait chambers were anchored to the ground with a tent peg.

Adjacent habitat sampling occurred for four weeks and was conducted during the period of underpass monitoring. Cameras were set on medium sensitivity and programmed to take 3 pictures/activation. Images were saved onto 4GB memory cards and retrieved at the end of the four-week period. Due to false triggering caused largely by moving vegetation, cameras were active for varying number of days during the sampling period (Table 4). False triggering was most prevalent at the Emerald Beach site. This site is more open and consequently more vulnerable to vegetation movement caused by wind. One camera was stolen during the two sampling periods. It was taken from the east side of the Emerald Beach site during autumn sampling.

Plate 13: Camera bait stations featured a Scoutguard KG680V strapped to a tree at ~1m high and focused on a bait chamber containing either chicken wings (L) or peanut butter, honey and oats (R).

Table 4: Adjacent habitat camera sampling effort. Days active are for 4 cameras/site.

Method	Autumn 2015		Spring 2015	
	Period	Days active	Period	Days active
Moonee	9/4 - 21/5/15	42/41/14/34	4/9 - 29/9/15	26/26/26/26
Emerald Beach	9/4 - 21/5/15	16/42/42/stolen	4/9 - 29/9/15	8/6/9/6
Arrawarra south	10/4 - 21/5/15	16/40/28/41	4/9 - 28/9/15	22/25/25/12
Arrawarra north	10/4 - 21/5/15	36/16/41/41	4/9 - 28/9/15	14/25/23/25

3.2 Vegetated median

3.2.1 Design and monitoring methods

The vegetated median at Arrawarra (ch.29100-30200) was 1100m long and ranged in width between 10-35m (Plate 6). The vegetation was largely dry open forest with tree heights of up to ~35m. The most prominent trees were located in the central 600m of the median. Canopy gaps along the carriageways were ~30-60m.

Determining whether gliders, particularly the threatened yellow-bellied glider and squirrel glider, use the vegetated median to cross the highway involved surveys both within the median and within retained habitat either side of the upgrade corridor. The EMP suggests monitoring through spotlighting, hair funnels and nest boxes. However, such methods, on their own, would unlikely provide a definitive answer to the question of road crossing. Therefore, we complemented the above techniques with call playback targeting yellow-bellied gliders during spotlighting and arboreal trapping targeting squirrel and sugar gliders. The arboreal trapping and nest box program also utilised a mark-release-recapture approach to detect possible crossings by individual animals. Further, monitoring was conducted during two eight week periods in summer/autumn and winter/spring as this better accounts for discrepancies in glider breeding and dispersal activity than a prolonged period of monitoring in winter/spring as proposed in the EMP. A summary of survey effort and timing for each method is detailed in Table 5.

Table 5: Methods used and survey effort to determine use of vegetated median by gliders.

Method	Summer-Autumn 2015		Winter-Spring 2015		Total Effort
	Period	Effort	Period	Effort	
Nest boxes	11/2 & 25/3/15	2 checks x 20 boxes	10/8 & 30/9/15	2 checks x 20 boxes	4 checks
Trapping	23-27/3/15	4 nights x 30 traps	28/9 - 2/10/15	4 nights x 30 traps	240 trap-nights
Spotlighting	24 & 26/3/15	2 nights x 3 t'sects	30/9 & 26/10/15	2 nights x 3 t'sects	4 nights
Hair funnels	11/2 - 24/3/15	41 nights x 30 funnels	13/8 - 1/10/15	49 nights x 30 funnels	2700 funnel-nights

3.2.2 Nest boxes

At the beginning of the summer/autumn monitoring period, two 500m-long transects were established in habitat immediately to the east and west of the vegetated median (Figure 1; Plate 6). Each transect ran parallel to the highway and meandered ~5-40m from the forest edge. Transects were used for nest box installation, trapping, hair funnels and spotlighting. A third 500m-long transect was also established in the median for installation of traps, hair funnels and spotlighting.

Ten nest boxes targeting squirrel/sugar gliders (rear-entry, plywood box manufactured by Hollow Logs Homes) were each installed on the east and west transects. No boxes were installed in the vegetated median because, as stated in the EMP, "the purpose of the vegetated median and glider crossing structures will be to maintain habitat connectivity for glider species known to occur in the locality in order to maintain genetic variation and to provide opportunity for dispersal and recolonization" (BEM 2014). Installing nest boxes within the median could encourage resident animals to establish home territories within the median and thus act as a possible deterrent to use by non-resident or dispersing individuals. Boxes were installed at a height of 8m on mature rough-barked trees using a ladder (Plate 14). Boxes were spaced at 50m intervals along each transect. Boxes were installed at the beginning of the summer/autumn monitoring period and inspected at the end of the 8-week period. Boxes were then inspected at both the beginning and end of the 8-week winter/spring period (Table 5).

The contents of nest boxes were inspected by two personnel utilising a purpose-built GoPro camera mounted on an extendable pole. Images from the GoPro camera were wirelessly streamed to an iPad for viewing. Fauna present, signs of use and box condition were recorded for each box. If a box contained gliders, a ladder was used to access the box and remove the individuals. Captured gliders were weighed, sexed and breeding status determined. Each individual was then issued a numbered ear tag and returned to the box.

Plate 14: Nest box, Elliott trap and hair funnel mounted on a trap-tree (L). Nest boxes were inspected using a purpose built, GoPro camera mounted to an extendable pole (R).

3.2.3 Trapping

Trapping targeting squirrel/sugar gliders was conducted for four nights during each 8-week monitoring period (Table 5). Ten trap were installed at 50m intervals along each of the three survey transects. Traps comprised Elliott (type B) aluminium treadle traps each mounted on a wooden bracket which was screwed on to a tree at ~5m height (Plate 14). Traps were baited with a mixture of peanut butter, honey and oats and a dilute mixture of honey water was sprayed up the tree trunk to act as an attractant. Traps were checked at dawn of each morning and captured animals were processed as per nest box captures. One hundred and twenty trap-nights were completed during each monitoring period.

3.2.4 Hair funnels

Hair funnel sampling occurred for at least two weeks during each monitoring period. Hair funnels were installed on all three survey transects. A single hair funnel was screwed to each trap-tree at a height of ~4m for a total of 30 funnels (Plate 14). Funnels were baited with a mixture of peanut butter, honey and oats and a dilute mixture of honey water was sprayed up the tree trunk to act as an attractant. Hair funnels were retrieved at the end of each sampling period and sent to B.Triggs, a recognised hair identification expert. Hair funnels were deployed for 41 nights (Autumn) and 49 nights (Spring) for a combined effort of 2700 funnel-nights (Table 5).

3.2.5 Spotlighting and call playback

Spotlighting and call playback was conducted on all three survey transects on two non-consecutive nights during each monitoring period (Table 5). Surveys were performed by two personnel using 200+ lumen spotlights. Each transect survey was preceded by yellow-bellied glider call playback followed by 30 minutes of spotlighting. Species observed were identified and their location and behaviour recorded.

3.3 Rope bridge and glide pole

3.3.1 Rope bridge - design features

The rope bridge at Moonee (ch.10720) consisted of a ~400mm wide ladder design made from 10mm diameter silver rope woven into a 100mm wide grid pattern. The rope ladder is slung between 3mm wire rope and supported by 10mm wire rope (Plate 15). The bridge spans 86m from pole to pole and rests ~9m above the centre of the highway and 10m at the pole ends. The bridge ends are adjacent to the mid-canopy of dry open forest. Lengths of 25mm diameter silver rope extend from the bulkhead to adjacent trees (Plate 15).

Plate 15: A Reconyx camera mounted to a wooden 'sandwich board' was positioned ~2m from each end of the rope bridge to capture moving fauna (L). 25mm silver rope was used to link the bulkhead to surrounding trees (R).

3.3.2 Rope bridge - monitoring

According to the EMP, monitoring of rope bridge and glide poles only requires use of wireless cameras on the crossing structures during autumn (110 nights) and spring (110 nights). However, this method alone provides no information on arboreal fauna residing in adjoining habitat. To address this, we conducted spotlight surveys and call playback (targeting yellow-bellied gliders) to determine the presence of threatened gliders and other arboreal mammals near the rope bridge and glide poles. A 500m-long transect running parallel to and within 50m of the highway was established in forest either side of the highway. Each transect was spotlighted and call playback performed on four occasions (19/5/15, 21/7/15, 1/10/15, 26/10/15) during the monitoring period. Spotlight and call playback surveys were conducted as per those described in section 3.2.4.

Camera monitoring of the rope bridge aimed to achieve 220 days of monitoring during the period of March-November. To action this, a Reconyx SC950 motion-activated infra-red cameras was installed at each end of the rope bridge on 9/4/2015 by a tree climber. Each camera was mounted to a purpose-built bracket and positioned in front of the bulkhead and orientated along the rope bridge (Plate 15). Cameras were scheduled to turn on at 1700hrs and turn off at 0500hrs eastern standard time (EST). Cameras were set at high sensitivity and programmed to take five 'rapidfire' pictures/trigger with no delay between triggers. Cameras were checked to refresh batteries and change memory cards every 1-3 months.

Due to the low height of the rope bridge, excessive false-triggering caused by moving traffic resulted in early battery fatigue and/or filled memory cards and loss of monitoring days. The east camera was especially affected resulting in loss of 8 days. To mitigate this, the camera was moved 2m out along the rope bridge and orientated back towards the bulkhead on 14/5/15. Twelve monitoring days were lost from the west camera when it was knocked out of alignment (possibly by a falling branch) during September. To account for lost days and to fulfill the required 220 days, monitoring continued until 15/12/15 (Table 6).

Table 6: Installation dates and number of days active for cameras installed on the rope bridge at Moonee and glide pole at Arrawarra Creek.

Structure	Camera position	Install date	Final check	Days active
Rope Bridge	East	9/4/15	15/12/15	242
	West	9/4/15	15/12/15	238
Glide pole	East	9/4/15	15/12/15	231
	North	9/4/15	15/12/15	250

3.3.3 Glide pole - design features

Two glide poles were located at Arrawarra Creek (ch.31000) - one between the northbound (NB) and southbound (SB) carriageways and the other between the SB carriageway and Solitary Islands Way immediately to the east (Plate 16). In considering the spacing/position of the glide poles together with the glide capacity of target gliders (see Goldingay & Taylor 2009; Goldingay 2014; Jackson 1999), it was determined that gliders would need to use the central/median glide pole to successfully cross the road corridor. Therefore, monitoring of the central/median glide pole only was required to determine highway crossings. This approach was consistent with the intent of the EMP (D.Owner pers. comm.)

The central glide pole stands 21.5m and the east pole ~18m above road level. Both poles are treated hardwood and ~500mm diameter at breast height. Two arms for gliders to launch from project east-west (upper arm) and north-south (lower arm). Each arm is ~3000mm long and 150 x 100mm thick undressed hardwood and are brace-mounted to the pole. The arms are positioned ~200mm and ~900mm from the pole top. The central pole is 36m from the closest roadside tree to the west and 25m to the glide pole to the east side and a further 23.5m to the closest roadside tree. Roadside tree canopy heights are up to ~25m on the west side and up to ~22m on the east side.

Plate 16: View of the glide pole array at Arrawarra creek looking north where cameras were installed on the central glide pole positioned between the carriageways (red circle) (L). Solitary Islands Way adjoins the dual carriageway immediately to the east (right of the photo). A Reconyx camera was mounted near the end of each arm of the pole (R).

3.3.4 Glide pole - monitoring

Infra-red (IR) cameras were installed on the central glide pole by a tree-climber on 9/4/15 (Plate 16). A Reconyx HC500 camera was mounted to a metal L-bracket near the east end of the upper/east-west oriented arm and a Reconyx SC950 was mounted near the north end of the lower/north-south oriented arm. The schedulable SC950 camera was set to turn on at 1700hrs and turn off at 0500hrs EST. Both cameras were set at high sensitivity and programmed to take five 'rapidfire' pictures/trigger with no delay between triggers.

Cameras were checked to refresh batteries and change memory cards every 1-3 months. Early battery fatigue occurred on one occasion in the east camera resulting in loss of ~19 monitoring days during the monitoring period. To account for lost days and to fulfill the required 220 days, monitoring continued until 15/12/15 (Table 6).

Spotlight surveys and call playback was conducted in forest habitat adjacent to the glide poles to determine the presence of threatened gliders and other arboreal mammals. A 500m-long transect running parallel to and within 50m of the highway was established in forest either side of the highway. Each transect was spotlighted and call playback performed on four occasions (19/5/15, 21/7/15, 1/10/15, 26/10/15) during the monitoring period. Spotlight and call playback surveys were conducted as per those described in section 3.2.3.

3.4 Data Summary and Analysis

All images were uploaded to a computer and viewed using Windows Photo Viewer. Senior staff reviewed all images, with reference to standard field guides (i.e. Menkhorst & Knight 2003; Pizzey & Knight 2007). Data recorded included: site, date, time, species, accuracy (definite (90%+ certainty), probable (75-90% certainty), possible (60-75% certainty)), movement direction (east or west), number of images and image numbers. For rope bridge pictures the portion of rope bridge used (i.e. edge, center) and for the glide pole which part of the pole/arm used was also recorded. A hierarchical approach was adopted to species identification that included: species, genus or group.

Passes (underpasses, rope bridge) or events (glide pole) were defined as a photo sequence separated by at least 10 minutes or when individuals in consecutive sequences were clearly distinguishable. Pass totals for each structure was summed for the two cameras for each season. Full crossing of an underpass or rope bridge was scored when an individual was recorded moving away from one camera and then photographed less than 10 minutes later by the opposite camera exiting the structure, or when an animal was recorded making directional movement by one camera and was not recorded again by the same camera within a period of 10 minutes (see Cramer 2013; Goldingay et al. 2013; Soanes et al. 2015). In the latter scenario, a crossing is inferred based on direction of movement. The absence of photographs at the other end of the structure is presumed to be an instance of detection evasion. This approach distinguishes crossings from 'visits' whereby an individual is observed turning around or returning in <10 minutes or does not demonstrate clear directional movement (e.g. exploratory movements). A full crossing of the Emerald Beach pipe series, which feature cameras on one side of the underpass only, was scored when an individual demonstrated directional movement either into or out of the pipes.

Road crossings via the glide pole could not be confirmed because direction of travel to and from the glide pole cannot be determined. While we acknowledge that an individual may glide to the central pole and return to the same side, we expect this to represent a very small proportion of detections. There is no habitat in the center of the carriageways and, therefore, no apparent reason for gliders to repeatedly access the glide pole without completing a crossing. This is consistent with analyses of glide pole monitoring records from the Hume Highway which was supported by radio-tracking data (see Soanes et al. 2015). Therefore, a photo sequence of an individual glider on the glide pole was scored as a road crossing though we acknowledge that the total figure may be an overestimate.

4. Results

4.1 Underpasses and adjacent habitat

4.1.1 Species in adjacent habitat

Thirty-nine species/groups of vertebrate fauna were detected by cameras in habitat adjacent to underpasses (Table 7; Plate 17). Moonee was the most diverse site (18 species) and Emerald Beach and vegetated median north the least (14 species). All sites recorded a similar number of species on each side of the underpass except the east side of vegetated median north site was half as diverse as the west side (6 versus 12). An equivalent number of species were recorded in each season except markedly fewer species were recorded in autumn at the vegetated median north site. Northern brown bandicoot (*Isoodon macrourus*), long-nosed bandicoot (*Perameles nasuta*), swamp wallaby (*Wallabia bicolor*) and red fox (*Vulpes vulpes*) were the most commonly detected species and were recorded at all sites.

One threatened species - a spotted-tail quoll (*Dasyurus maculatus maculatus*) - was recorded on one occasion during autumn on the east side of Moonee underpass (Plate 18). Spotted-tail quoll is listed as vulnerable by the NSW *Threatened Species Conservation (TSC) Act* 1995 and endangered under the Commonwealth *Environment Protection and Biodiversity Conservation (EPBC) Act 1999*.

Full details of adjacent habitat camera monitoring effort are provided in Table A1 and A2 (Appendix A).

Table 7: Fauna recorded at camera bait stations in habitat adjacent to underpasses during Autumn (A) and Spring (S) survey periods. E = East; W = West; * = listed as vulnerable on NSW TSC Act & endangered on EPBC Act; Pr = Probable; # = humans were excluded from the species counts.

Species name	Common Name	Moonee (dedicated)		Emerald Bch (pipes)		Veg Med Sth (dedicated)		Veg Med Nth (dedicated)	
		E	W	E	W	E	W	E	W
Varanus varius	Lace monitor				S	A, S	S		
Physignathus lesuerii	Eastern water dragon					A	S		S
Egernia major	Land Mullet		A, S				A		
Tachyglossus aculeatus	Echidna	S	S			A	S		A, S
Dasyurus maculatus	Spotted-tail quoll *	A							
Antechinus sp.	Antechinus sp.		A			A		A	S
Parameles nasuta	Long-nosed bandicoot	A, S	S		S	A, S	A, S	S	
Isoodon macrourus	Nthn brown bandicoot	A	S	A, S	A, S	S	A, S	A, S	A, S
Trichosurus caninus	Short-eared brushtail possum	A	A			S	S		S
Trichosurus vulpecula	Common brushtail possum	A	A, S			S			A, S
Trichosurus sp.	Brushtail possum sp.	S							
Macropus giganteus	Eastern grey kangaroo	A		A, S	A, S	A, S			
Macropus rufogriseus	Red-necked wallaby			S					
Wallabia bicolor	Swamp wallaby	A, S	A, S	A	A, S	A, S	A, S	A, S	A, S
Wallaby sp.	Wallaby sp.				S				
Hydromys chrysogaster	Water rat								S
Rattus lutreolus	Swamp rat								A
Rattus fuscipes	Bush rat					A(Pr)			
Rattus rattus	Black rat		S	A					
Rattus spp	Rodent sp.	A, S	A, S			A, S	A, S	A	A, S
Canis familiaris	Dog				A				
Vulpes vulpes	Red fox	A, S	S	S	A		A	A	
Felis catus	Cat	A		A		S			
Bos Taurus	Cow				S				
Homo sapien	Human #	S							
Alectura lathami	Brush turkey	S				S	S		S
Dacelo novaeguineae	Kookaburra				A, S	A			
Gallirallus philippensis	Buff-banded rail				A				
Pitta versicolor	Noisy pitta	A							
Malurus sp.	Fairy wren sp.			A, S					
Psophodes olivaceus	Eastern whipbird		S						
Colluricincla harmonica	Grey shrike-thrush	A, S							
Strepera graculina	Pied currawong								S
Number of species/side		**14**	**12**	**8**	**11**	**15**	**11**	**6**	**12**
Number of species/site		**18**		**14**		**17**		**14**	
Number of species/season/site (A/S)		**14/13**		**10/11**		**13/12**		**8/12**	

Plate 17: Twenty-nine vertebrate species were recorded in habitat adjoining fauna underpasses, including common brushtail possum (top L), echidna (top M), lace monitor (top R), long-nosed bandicoot (bottom L), swamp wallaby (bottom M) and eastern grey kangaroo (bottom R).

Plate 18: The threatened spotted-tail quoll (L & R) was detected on one occasion in habitat to the east of the Moonee underpass.

4.1.2 Species using underpasses

Seven fauna species were confirmed using at least one of the four fauna underpasses during autumn and spring monitoring (Table 8; Plate 19). Echidna is not included as it was only recorded on one occasion exploring the outside of the Emerald Beach pipe series and did not demonstrate directional movement in or out of a pipe (i.e. visit). One hundred and twenty-seven passes and 89 full crossings were recorded by the eight cameras. More passes and crossings were recorded in spring than autumn (95 and 69 versus 32 and 20) although this was largely attributed to high use of Moonee underpass by red fox during spring. Moonee was the most frequented underpass with 84 passes and 63 full crossings although this is similarly attributed to high use by red fox. Vegetated median north and south were underpasses most frequented by native fauna (14 passes each) and Moonee and Emerald the least frequented (6 and 7 passes respectively). Vegetated median north featured the greatest diversity of native species users, including lace monitor (*Varanus varius*), eastern grey kangaroo (*Macropus giganteus*), red-necked wallaby (*Macropus rufogriseus*) and swamp wallaby. Emerald Beach also recorded four native species around the entrance area but only northern brown bandicoot was recorded crossing based on directional movement toward the pipe opening (Plate 19).

Six mammal species were recorded using the four underpasses (Table 8). Eastern grey kangaroo made passes of cameras at all underpasses yet was only recorded making full crossings at vegetated median north. Swamp wallaby was the most prolific native species user, registering the most passes and crossings (26/20) and was recorded at all underpasses except Emerald Beach (Plate 19). Northern brown bandicoot was recorded making a crossing through a pipe at Emerald Beach based on strong directional movement (Plate 19). Two introduced mammal species, red fox and dog (*Canis familiaris*), were recorded at Moonee and Emerald Beach (fox only) underpasses. Red fox frequently made full crossings of the Moonee underpass and was photographed with prey in its mouth on four occasions (Plate 19). Lace monitor was the only reptile species recorded. It made passes at three of the four underpasses, including full crossings at Moonee and vegetated median north (Plate 19).

Full details of underpass camera monitoring effort and detections are provided in Table A1 and A3 (Appendix A).

Table 8: Species detected and number of passes and full crossings (passes/crossings) recorded by cameras at each end of fauna underpasses. A = Autumn; S = Spring. # = humans and motorbikes are not included in Passes/Crossings Totals.

Species name	Common Name	Moonee		Emerald Bch		Veg Med sth		Veg Med nth		Total pass/cross
		A	S	A	S	A	S	A	S	
Varanus varius	Lace monitor		1/1		1/0				3/3	5/4
Tachyglossus aculeatus	Echidna			1/0						1/0
Isoodon macrourus	Ntnn br bandicoot			1/1						1/1
Macropus giganteus	Estn grey kangaroo		1/0	1/0	3/0		1/0		1/1	7/1
Macropus rufogriseus	Red-necked wallaby								1/1	1/1
Wallabia bicolor	Swamp wallaby	1/0	3/2			4/3	9/7	7/6	2/2	26/20
Canis familiaris	Dog		2/1							2/1
Vulpes vulpes	Red fox	12/9	64/50	5/1	3/1					84/61
Homo sapien	Human		*5/2*		*2/0*			*2/1*		*9/3*
	Motorbike						*4/2*	*4/2*	*2/1*	*10/5*
Total Fauna Passes/Crossings #		**13/9**	**71/54**	**8/2**	**7/1**	**4/3**	**10/7**	**7/6**	**7/7**	**127/89**

Plate 19: Seven species were recorded making crossings of the underpasses, including northern brown bandicoot at Emerald Beach (top L), swamp wallaby at vegetated median south (top M), red fox (top R; with prey in its mouth), lace monitor at Moonee (bottom L) and eastern grey kangaroos at vegetated median south (bottom R).

4.1.3 Species in adjacent habitat using underpasses

The proportion of fauna detected in adjacent habitat (excluding birds) and recorded using the respective underpass ranged between 14% and 38% (Table 9). Forest birds detected in adjacent habitat have been excluded from analyses because they are not targeted or recorded using underpasses and potentially confound comparisons. The highest proportion of adjacent habitat fauna using the respective underpass was recorded at Moonee (38%) and the least at vegetated median south (14%). The proportion of native species detected in adjoining habitat and recorded using the respective underpass ranged from 14% at Emerald Beach to 40% at vegetated median north (Table 9). Some species were recorded in underpasses and not detected in surrounding habitat surveys, including lace monitor at Moonee and vegetated median north, dog at Moonee, and eastern grey kangaroo and red-necked wallaby (*Macropus rufogriseus*) at vegetated median north.

Macropods were the most well represented underpass user whereas reptiles, rodents and arboreal mammals were poorly represented in underpass records (Table 9). Introduced predators were present at all sites but only recorded in underpasses at Moonee (dog, red fox) and Emerald Beach (red fox). No introduced predators were recorded using the vegetated median underpasses.

Table 9: Species recorded in adjacent habitat and species recorded using underpasses. Data for autumn and spring are pooled. Birds detected in adjoining habitat have not been included as they are not the target of underpass deployment and have not been recorded using underpasses.

Species name	Common Name	Moonee (dedicated)		Emerald Bch (pipes)		Veg Med Sth (dedicated)		Veg Med Nth (dedicated)	
		UP	Adj	UP	Adj	UP	Adj	UP	Adj
Varanus varius	Lace monitor	X			X		X	X	
Physignathus lesuerii	Eastern water dragon						X		X
Egernia major	Land Mullet		X				X		
Tachyglossus aculeatus	Echidna		X		X		X		X
Dasyurus maculatus	Spotted-tail quoll		X						
Antechinus sp.	Antechinus sp.		X				X		X
Parameles nasuta	Long-nosed bandicoot		X		X		X		X
Isoodon macrourus	Northern brown bandicoot		X	X	X		X		X
Trichosurus caninus	Short-eared brushtail possum		X				X		X
Trichosurus vulpecula	Common brushtail possum		X				X		X
Trichosurus sp.	Brushtail possum sp.		X						
Macropus giganteus	Eastern grey kangaroo	X	X		X	X	X	X	
Macropus rufogriseus	Red-necked wallaby				X			X	
Wallabia bicolor	Swamp wallaby	X	X		X	X	X	X	X
Hydromys chrysogaster	Water rat								X
Rattus lutreolus	Swamp rat								X
Rattus fuscipes	Bush rat						X		
Rattus rattus	Black rat		X		X				
Canis familiaris	Dog	X			X				
Vulpes vulpes	Red fox	X	X	X	X		X		X
Felis catus	Cat		X		X		X		
Bos Taurus	Cow				X				
Number of species		**5**	**13**	**2**	**12**	**2**	**14**	**4**	**11**
Proportion of species in adj hab using u'pass		**38%**		**17%**		**14%**		**36%**	
Number of native species		**3**	**10**	**1**	**7**	**2**	**11**	**4**	**10**
Proportion of native species in adj hab using u'pass		**30%**		**14%**		**18%**		**40%**	

4.2 Vegetated median

4.2.1 Species Occurrence

Three glider species and two scansorial species were detected by the various methods at the vegetated median site (Table 10; Plate 20). Most records were obtained during the winter/spring session. A male squirrel glider (Petaurus norfolcensis), listed as Vulnerable on the NSW *TSC Act*, was trapped on the west side of the median during summer/autumn and recaptured within the median during spring, confirming a crossing of the northbound carriageway. An unmarked female was also captured in the median during the winter/spring session. A female sugar glider (Petaurus breviceps) with pouch young was retrieved from a nest box on the east side of the median during winter/spring. Squirrel or sugar glider nests were evident in nest boxes on both the east (3) and west (2) sides of the median during winter/spring (Plate 20). Sugar or squirrel glider hair was

also detected in hair funnels in the median. Hair of the two species cannot be reliably differentiated (see Lobert et al. 2002). The other glider species detected was feathertail glider (Acrobates pygmaeus). An individual was observed within the median during spotlighting in summer and a leaf nest typical of a feathertail glider was recorded in a nest box west of the median during winter/spring (Plate 20).

Two non-volant mammal species detected at the vegetated median site were brown antechinus (Antechinus stuartii) and fawn-footed melomys (Melomys cervinipes). Both scansorial species were captured either side of the median and brown antechinus were also captured in the median (Plate 20). Both species were also detected in hair funnels (Table 10).

Full details of vegetated median monitoring are provided in Table B1-B6 (Appendix B).

Table 10: Arboreal mammals recorded within the vegetated median and/or adjoining habitat. Data for autumn and spring are pooled. xT = number of Trap captures (number of individuals); xS = number of individuals Spotlighted; xNB = number of Nest Boxes detected in (number of individuals); xHF = number of Hair Funnels detected in (Pr = probable). ^ = listed as vulnerable on NSW TSC Act.

Species name	Common Name	Summer-Autumn			Winter-Spring		
		East	Median	West	East	Median	West
Antechinus stuartii	Brown antechinus				7T; 1HF	3T; 1HF	3T; 1HF
Antechinus sp.	Antechinus sp.			3HF	2HF; 1NB (nest)	3HF	7HF
Petaurus breviceps	Sugar glider				1NB(1)		
Petaurus norfolcensis	Squirrel glider^			1T(1)		5T(2)	
P.norfocensis/breviceps	Sugar or squirrel glider				3NB (nests)	5HF	1NB (nests)
Acrobates pygmaeus	Feathertail glider		1S				1NB (nest)
Melomys cervinipes	Fawn-footed melomys				2T; 2HF(Pr)		5T

Plate 20: Five arboreal mammal species were recorded at the vegetated median site, including squirrel glider (top L), sugar glider (top M) and the scansorial brown antechinus (top R, seen here with pouch young). Indirect evidence of arboreal mammals was evident from nests constructed in nest boxes, including those of feathertail glider (bottom L), sugar/squirrel glider (bottom M) and brown antechinus (bottom R, latrine evident in right corner).

4.3 Rope bridge and glide pole

4.3.1 Rope bridge and adjacent forest - species detections

Sugar glider and feathertail glider were both detected using the rope bridge (Table 11; Plate 21). A sugar glider was detected at the east end of the bridge and appeared to investigate and return east. It was unlikely that a crossing occurred. A Feathertail glider was recorded at both ends of the bridge on three separate occasions. On two occasions the individual appeared to explore the end of the bridge with no suggestion of directional movement across the bridge. The third occasion involved a single photograph of strong and rapid directional movement towards the west camera, probably indicating a complete crossing (Plate 21). Feathertail gliders were also detected in the east forest on two occasions, 200m and 350m from the rope bridge. In the west forest, a sugar or squirrel glider was observed on one occasion high in a tall blackbutt ~400m to the north of the rope bridge.

Full details of rope bridge monitoring and adjacent forest spotlight surveys are provided in Table C1-C3 (Appendix C).

Table 11: Photo event records of arboreal mammals on the rope bridge during camera monitoring and arboreal mammals detected during spotlighting in adjoining forest habitat within 400m of the rope bridge (X).

Common Name	Spc	East cam	West cam	Behaviour	Crossing likelihood	East forest	West forest
Petaurus breviceps	Sugar glider	30/5/15		Slowly move 1m west along edge & return east	Unlikely		
P. breviceps or P.norfolcensis	Sugar or squirrel glider						X
Acrobates pygmaeus	Feathertail glider		2/11/15	Single photo; individual rapidly moving west along edge towards camera	Probable	X	
		11/11/15		Exploring center of ladder near camera	Unlikely		
			14/12/15	Exploring center of ladder near camera	Unlikely		

Plate 21: A sugar glider was detected exploring the east end of the rope bridge on one occasion (L). Feathertail glider was detected at each end of the rope bridge on three separate occasions including one occasion featuring strong directional towards the west camera (R), probably indicating a crossing.

4.3.2 Glide poles and adjacent forest - species detections

Sugar glider and feathertail glider were both detected using the glide pole (Table 12; Plate 22). A sugar glider was detected on the lower, east-west oriented arm on three occasions. The individual appeared to leap up the pole on two of these occasions and explore the arm on the other occasion (Plate 22). A single photograph of ears of either a sugar or squirrel glider was also recorded on one occasion. Feathertail glider was recorded on both arms of the glide pole on 11 occasions. The behaviour in photo events was largely exploratory, typified by rapid movements over different surfaces of the pole and pole arms (Plate 22). Launching off the end of an arm was not evident from the photographs.

Spotlight surveys in adjoining forest revealed sugar gliders (2 individuals) ~40m and ~80m south of the pole array. Individual feathertail gliders were observed on three occasions ~40m/50m/80m south of the pole array. A feathertail glider was also detected in the west forest ~200m south of the pole array.

Full details of glide pole monitoring and adjacent forest spotlight surveys are provided in Table D1-D3 (Appendix D).

Table 12: Photo event records of gliding mammals on the central glide pole during camera monitoring and arboreal mammals detected during spotlighting in adjoining forest habitat within 400m of the rope bridge (X).

Common Name		Upper -arm cam	Lower - arm cam	Behaviour	East forest	West forest
Petaurus breviceps	Sugar glider		16/4/15	Explore arm	X	
			11/11/15	Leap up pole from arm		
			5/12/15	Leap up pole from arm		
P. breviceps or P.norfolcensis	Sugar or squirrel glider		12/7/15	Single pic of ears only		
Acrobates pygmaeus	Feathertail glider		12/9/15	Explore arm	X	X
			5/10/15	Explore arm		
			15/10/15	Explore arm		
			21/10/15	Explore arm		
		9/11/15		Climb pole top		
		13/11/15		Explore pole top & arm		
		17/11/15		Explore arm		
		18/11/15		Explore arm		
		5/12/15	5/12/15	Explore both arms		
		6/12/15		Explore arm		

Plate 22: A sugar glider was detected on three occasions on the lower arm of the glide pole (L) which orientates E-W. Feathertail gliders were detected on 11 occasions on both the upper (R) and lower arms.

5. Discussion

5.1 Project compliance

5.1.1 Monitoring requirements

Year one fauna mitigation monitoring at S2W satisfied the intent of the EMP and in some cases exceeded its requirements. A small number of survey days were lost during camera-trap surveys of habitat adjacent to underpasses due to theft of a camera and false triggering caused by moving vegetation. Such constraints are commonly encountered during ground-based camera-trap surveys. The small loss of survey time is not considered to have compromised data quality, particularly as two cameras were positioned in adjacent habitat each side of the highway to aid in compensating for potential malfunction/loss of one of the cameras. Loss of monitoring days was also experienced at the rope bridge site caused by a knock to one of the cameras and instances of excessive false-triggering. Camera position was shifted to mitigate this and the period of camera monitoring was extended to comply with the minimum 220 active monitoring days.

5.1.2 Monitoring aim and indicators of success

The broad aim of the EMP is "to allow the effectiveness of mitigation and offset measures to be assessed and allow for their modification if necessary" (BEM 2014). Moreover, the EMP describes several indicators of success with which to assess the performance of fauna mitigation measures.

Indicators of success include:

- **Fauna underpasses:**
    i. Low rates of use of fauna underpasses and adjacent habitats by feral predators;
    ii. High levels of fauna underpass use by a wide variety of native fauna species;
    iii. Evidence of use by dispersing individuals and different age cohorts;
    iv. Use by cover-dependent species and species with low mobility;
    v. Low incidence of fauna road strike mortality.
- **Vegetated median and aerial crossing structures:**
    i. Evidence of regular use of the median vegetation by the target glider species;
    ii. Evidence of use by dispersing individuals and different age cohorts;
    iii. Use by glider species other than threatened species e.g. sugar glider, greater glider.

The following sections discuss the success of the monitoring program with reference to the indicators of success. This is followed by a series of recommendations relevant to subsequent years of the monitoring program.

5.2 Species use of underpasses

5.2.1 Underpass use and comparison with other studies

Our investigations at the S2W upgrade has revealed seven fauna species using at least one of four underpasses to cross the highway corridor (Table 8). A comparative table of similar monitoring studies conducted at other

highway upgrade locations in south-east Australia shows that use of underpasses investigated at S2W is relatively low for all species groups except large mammals (Table 13). The low rates at S2W includes no recorded use by small mammals, birds or amphibians. Use by small reptiles and frogs is difficult to detect, particularly for infra-red cameras. This was also evident at Glenugie (Sandpiper 2015a) which used cameras only. Use by introduced mammals (i.e. red fox, dog) was comparable to other sites.

The relatively high number of large mammals is likely due to the grassy understorey (vegetated median underpasses) and open grassland (Moonee and Emerald Beach) areas adjoining most underpass entrances which are favourable for large macropods. Conversely, the prevalence of grassland, relatively broad gaps between underpass entrances and forest habitat and the lack of vegetative cover near underpass entrances likely contributed to the lack of small mammal use (see Connolly-Newman et al. 2013). This may also explain the lack of use by medium-sized mammals such as possums which were recorded in adjoining habitat at all sites except Emerald Beach. Further, the type of underpass sites chosen for the monitoring program may also explain why aggregate fauna usage was comparatively low. The selection of underpass monitoring sites, as described in the EMP (BEM 2014), was largely based on a desire to determine whether fauna would use: an underpass positioned on a mid-slope (vegetated median south); a relatively long single-cell, dedicated underpass (Moonee); and combined structures (drainage pipe series and dual-cell culvert at Emerald Beach). The later dual-cell culvert was abandoned due to permanent inundation and substituted for another vegetated median underpass (vegetated median north) close to a drainage line. As such, these different structures/locations may be expected to feature less fauna use, particularly compared to most other underpass studies. This is further discussed below.

The EMP identifies several threatened species targeted by the fauna underpasses, including common planigale, spotted-tail quoll, rufous bettong, long-nosed potoroo, brush-tailed phascogale and eastern pygmy possum. Spotted-tail quoll was the only species of this list detected in surrounding habitat (Moonee east) during this study and eastern pygmy possum was detected in the north of the alignment during the EA. No threatened species were detected using underpasses investigated during year one. While eastern pygmy possum and common planigale have not been recorded using underpasses, other operation phase highway studies have reported use by spotted-tail quoll, rufous bettong, long-nosed potoroo and brush-tailed phascogale (e.g. AMBS 2002; Sandpiper 2014, 2015a). Absent or low population densities of threatened species in the vicinity of the investigated structures would contribute to this as would the lack of cover near entrances and vegetative links to adjoining forest.

Table 13: Number of fauna and fauna groups recorded in a selection of underpass studies conducted in eastern Australia. SP = sand pads; C = camera; SM = small mammal; MM = medium mammal; LM = large mammal; iM = introduced mammal; B = bird; R = reptile; A = amphibian; 1 = Bond & Jones (2008); 2 = Fitzgerald (2005); 3 = Taylor & Goldingay (2003); 4 = Sandpiper (2015a); 5 = Sandpiper Ecological (2010); 6 = Sandpiper Ecological (2014); 7 = AMBS (2002); 8 = Sandpiper Ecological (2009); 9 = Sandpiper Ecological (2015b); 10 = current study. ^ = construction phase monitoring.

Study	Structure Type	No Structures (Method)	Fauna Groups						
			SM	MM	LM	iM	B	R	A
Compton Rd[1]	Culvert	2 (SP)	2	3	1	4	1	1	1
Chinderah[2]	Culvert, bridge, overpass	16 (SP)	3	6	1	4	3	8	2
Brunswick Heads[3]	Culvert	9 (SP)	2	5	1	2	1	3	1
Glenugie[4]	Culvert & bebo arch	7 (C)	4	5	5	7	7	2	1
Bonville[5]	Large bridges	3 (SP)	2	2	2	4	8	5	2
Coopernook[6]	Culvert	3 (SP, C)	1	5	1	4	2	3	0
Coolongalook[7]	Culvert	11 (SP, C)	7	8	5	6	0	4	0
Karuah[8]	Small bridge	1 (SP)	2	2	2	4	1	3	2
^Urunga[9]	Culvert, bridge	8 (SP, C)	4	5	2	4	1	4	3
S2W[10]	Culvert; pipe series	4 (C)	0	1	3	2	0	1	0

5.2.2 Difference in use between underpasses

There were differences in the diversity of fauna using each underpass and the number of passes. These differences are attributed to site characteristics and variations in habitat quality and fauna distribution. Some studies have identified relationships between site and underpass characteristics and fauna use (e.g. Clevenger and Waltho 2005). Sample sizes in the current study are insufficient to fully investigate such relationships though some observations on use are worth noting. Firstly, the vegetated median north underpass recorded the highest diversity of native fauna users (4 spp.), the most passes/crossings by native fauna (14/13) and the highest proportion of native species detected in adjoining forest recorded using the underpass (40%). These results are probably best explained by three context features:

(i) it is surrounded by continuous moderate-high quality forest;
(ii) is situated on a drainage line; and
(iii) the average distance between forest edge and underpass entrance is lower than the other underpasses.

Indeed, several studies have reported negative correlations between distance to forest edge and underpass use (e.g. Connolly-Newman et al. 2013). Secondly, Emerald Beach pipe series and Moonee culvert were the two longest underpasses (i.e. 74.5m & 102.4m) and featured the smallest opening sizes (i.e. 1200mm diam. & 2400 x 3000). The combination of relatively small entrance diameter and long length of the Emerald beach pipes may act as a behavioural deterrent. Eastern grey kangaroo, echidna and lace monitor were recorded around the pipe entrance area but were not photographed making directional movement into or out of the pipes. Northern brown bandicoot was the only native species recorded making directional movement into the pipe and has been reported using similarly long, small box culverts (see Taylor and Goldingay 2014). Thirdly, the vegetated median south underpass is positioned on a mid-slope and 15.8m and 28.4m from the edge of surrounding forest. The combination of these factors likely contributed to the low rate of use by native fauna, particularly cover-dependent species. Moreover, unlike the other three sites, this site is well away from a drainage line. Creek and drainage lines are recognised as important fauna movement corridors (Bennett 1998).

5.2.3 Use by introduced predators

Introduced predators are commonly encountered during underpass monitoring though their impact on use by native species remains equivocal (e.g. Fitzgerald 2005; Taylor & Goldingay 2014). Introduced predators were present in adjacent habitat at all sites yet only Moonee (dog, red fox) and Emerald Beach (red fox) recorded their use in an underpass. Emerald Beach and Moonee feature disturbed, fragmented and peri-urbanised landscapes compared to the continuous forest context of the vegetated median sites. As such, there may be a higher abundance of introduced predators surrounding the Emerald Beach and Moonee sites.

Despite the proposition that underpasses may function as prey traps remaining somewhat equivocal (see Chambers & Bencini 2014), the prevalence of red fox at Emerald Beach and Moonee is concerning. Red fox was photographed with prey in its mouth at the Moonee underpass on four occasions. Predation by red fox near underpasses has also been recently reported at Glenugie (Sandpiper 2015a). Construction phase monitoring at Nambucca Heads to Urunga also featured widespread use of recently-constructed underpasses by red fox, cat and dog (Sandpiper Ecological 2015c). This suggests that introduced predators habituate rapidly to underpasses and may require control, particularly around underpasses that target high risk (i.e. critical weight range <5000g) species.

5.2.4 Logistical considerations

The results of underpass monitoring show considerable variation in detection between cameras within the same underpass (excluding Emerald Beach where cameras were positioned on the outside of one end of the underpass). Similar camera performance has been reported at other highway monitoring locations (e.g. Goldingay & Taylor 2014; Sandpiper 2015a, 2015b). Indeed, Hughson *et al.* (2010) compared detection rates between identical camera models at the same sites and found substantial differences in detection of the same species and the total number of detections. They suggest that small variations in orientation can affect results. We endeavoured to standardise camera installation but acknowledge that differences exist due to variation in underpass type and dimensions. It is likely that these contribute to variation in detection between cameras. Ground slope (particularly vegetated median south) and light penetration (particularly vegetated median sites) varied for each camera position and may have affected performance. The results of this and other studies suggest that cameras will not detect all fauna movement and sampling over a long period of time using multiple cameras at each underpass is required to obtain an accurate inventory of species. Consideration will be given to extending the length of subsequent monitoring seasons.

5.2.5 Indicators of success

1. Low rates of use of fauna underpasses and adjacent habitats by feral predators.
    a. Introduced predators were recorded in adjacent habitat at all sites but were not recorded using vegetated median underpasses. Fox was recorded using Moonee underpass (high rate of use) and Emerald Beach pipe series (low rate of use).
2. High levels of fauna underpass use by a wide variety of native fauna species.
    a. The proportion of native fauna detected in surrounding habitat and recorded using an underpass was ranged between 14% (Emerald Beach pipes) and 40% (vegetated median north), which would be regarded as low to moderate use.
3. Evidence of use by dispersing individuals and different age cohorts.
    a. Difficult to determine but likely sub-adult and adult cohorts.
4. Use by cover-dependent species and species with low mobility.
    a. Species recorded using underpasses are known to readily access open habitat to either forage in or move through. They are also relatively mobile species.

5.3 Aerial crossing structures and vegetated median

5.3.1 Rope bridge and glide pole detections and crossings

Rope bridges have proven effective in enabling arboreal mammals to cross two and four lane roads (Goldingay *et al.* 2013; Soanes *et al.* 2015) and are important in connecting isolated populations (Taylor & Goldingay 2009; van der Ree *et al.* 2010; Taylor & Goldingay 2012). Several species have been recorded using rope bridges across the Pacific and Hume Highways, including; squirrel, sugar and feathertail gliders, common brushtail and common ringtail possums, brush-tailed phascogale and *Antechinus* sp. (Sandpiper 2015a; Soanes *et al.* 2015; Goldingay *et al.* 2013). Lemuroid, Herbert River, and green ringtail possums, *Melomys* sp. and long-tailed pygmy possum have also been recorded using shorter bridges over two lane roads in north Queensland (Weston et al. 2011).

Glide poles are another type of aerial crossing that have also proven effective in enabling sugar and squirrel gliders to cross roads (Soanes *et al.* 2015; Taylor & Goldingay 2013) and represent a cost-effective means of connecting fragmented forest habitat (Ball & Goldingay 2008; Goldingay *et al.* 2011). Poles may be the most appropriate crossing structure for yellow-bellied glider, which is yet to be recorded using a rope bridge. There is a single record of a yellow-bellied glider on a glide pole on the Oxley Highway, Port Macquarie (Goldingay & Taylor 2014).

At S2W, a feathertail glider was recorded at either end of the rope bridge on three occasions and a sugar glider was recorded on one occasion at the east end. Whereas the sugar glider appeared to explore the end and return, one of the feathertail photo sequences included a single photo of an individual moving rapidly in a westerly direction past the west camera. This strong directional movement was scored as a probable crossing. Whilst this may be the case, it should be noted that the behaviour of feathertail gliders on a rope bridge is typically erratic and exploratory and determining clear, directional movement difficult (see Sandpiper 2015a). The absence of photographs at the other end of the bridge may be indicative of an instance of non-detection by that camera or perhaps an individual glided onto the rope bridge (or off, in the case of evading detection at the exit end) and evaded camera detection (see Goldingay et al. 2013).

Sugar and feathertail glider were also recorded on a number of occasions on the Arrawarra creek glide pole which we have scored as road crossings. The direction of movement could not be determined in the photographs but the pole is positioned in the center of the dual carriageway and gliding distances in either direction is within the capacity of both species. Video footage may provide insight on direction of movement. Installation of video-capable cameras will be considered for year 2 monitoring. Both sugar and feathertail gliders were observed in east side habitat within 50m of the pole array and feathertail glider was observed on the west side of the highway within 200m of the pole array. As such, a glide crossing in either direction is feasible. The feathertail record is one of few records of this species using glide poles to cross a highway (see Goldingay and Taylor 2014).

Despite the low number of records, both the rope bridge and glide pole have recorded use by gliding mammals. Neither of the threatened gliders, squirrel or yellow-bellied glider, were detected in the adjoining forest or on the aerial crossing structures during monitoring. During the clearing phase, yellow-bellied glider was recorded on a number of occasions in forest to the west of Arrawarra creek (glide pole array) and squirrel gliders were recorded in close proximity to both aerial crossing sites (BEM 2013). Squirrel gliders have also been recorded during this study at the north-west edge of the vegetated median, 1.1km to the south of the pole array. Further, squirrel gliders have reportedly used rope bridges and glide poles at several road sites (e.g. Sandpiper 2015a; Soanes *et al.* 2015; Goldingay *et al.* 2013), so the absence of records at S2W is probably indicative of low abundance near the aerial structures. This is probably more pronounced for the yellow-

bellied glider, particularly at the rope bridge site where the closest record is ~2.5km to the north-west (Bionet 2016).

5.3.2 Camera performance

Camera performance on both the rope bridge (Reconyx SC950) and glide pole (SC950 & HC500) has generally been very good. Loss of monitoring days due to battery fatigue or full memory card has been minimal (8 and 19 days respectively) and at least one of the cameras at each structure has been operational during the whole monitoring period. Traffic movements causing excessive false-triggering at the rope bridge east camera were resolved by moving the camera 2m along the rope bridge and directing it back to the bulkhead. The west camera still incurs moderate levels of false triggering and this camera may be similarly repositioned if the issue persists. Use of the schedulable Reconyx SC950 programmed to operate only at night has greatly reduced the quantity of traffic-activated false-triggers.

Cameras positioned on arms of the glide pole have largely been false-trigger free and are well positioned to record use. The lack of false-triggering at this site removes the need for a camera with a scheduling function. In this case, the Reconyx HC500 is appropriate for the task.

5.3.3 Vegetated median detections and crossings

Vegetated medians are another means of providing opportunity for gliding mammals to cross highway corridors. Their use has been reported for squirrel gliders on the Hume Highway (van der Ree et al. 2010) and sugar gliders on the Pacific Highway (Taylor & Rohweder 2013). At S2W, mark-recapture methods revealed crossing of the northbound carriageway by a male squirrel glider. A female squirrel glider was also captured in the median, presumably having crossed from either the east or the west. Nests of either sugar or squirrel gliders were evident on the east side and squirrel gliders were detected in nest boxes ~200m to the south-east. Evidently, squirrel gliders are residing either side of the vegetated median and moving to and from the median.

Sugar gliders were confirmed on the east side of the vegetated median and hair funnel records in the median and nests in boxes on the west of the median may have been those of sugar glider. If so, it would indicate a crossing of at least the southbound carriageway. Feathertail gliders may also have crossed one or both of the carriageways. The individual observed within the median during spotlighting may be residing in the median though it is more likely accessing the median to forage and residing in the east and/or west forest. Denning potential in the median is limited due to few hollow bearing trees.

5.3.4 Performance indicators

Vegetated median and aerial crossing structures:

1. Evidence of regular use of the median vegetation by the target glider species;
    a. Confirmed use of median by squirrel gliders (at least two individuals) and feathertail gliders and possible use by sugar gliders.
    b. Sugar glider and feathertail glider were recorded using both the glide pole and rope bridge.
2. Evidence of use by dispersing individuals and different age cohorts;
    a. Captured squirrel gliders were both young adults and the female carried a single pouch young.
3. Use by glider species other than threatened species e.g. sugar glider, greater glider.
    a. In addition to the threatened squirrel glider, feathertail glider was observed within the vegetated median and hair records suggest that sugar glider may have utilized the vegetated median. Yellow-bellied glider and greater glider were not detected at the site during the monitoring period.

b. Sugar glider and feathertail glider were recorded using the glide pole to make road crossings on three and 10 occasions respectively. Feathertail glider likely completed a single full crossing of the rope bridge

6. Recommendations

6.1 Underpasses

- Extend each monitoring period by one month to increase fauna detections and gain a better understanding of the full suite of species using the underpasses.
- Continue to observe vegetation regrowth near culvert entrances and between entrance and adjoining forest;
- Discuss with Country Energy the feasibility of allowing revegetation using understory plants to create a vegetated corridor linking the Moonee underpass across the powerline easement with adjoining forest to the east. Importantly, this was the location of the spotted-tail quoll record.
- Consider options for predator control around the Moonee underpass. Liaise with landholder to undertake predator control actions in compensatory habitat block on east side of highway.

6.2 Aerial crossing structures and vegetated median

- Trial use of camera with video function (e.g. ScoutGuard) on the glide pole to possibly capture launch sequences and direction of travel.

6.3 Future highway upgrade projects

- Rope bridges should be installed at mid-upper canopy level to improve accessibility to arboreal fauna;
- Rope bridge ends should be positioned as close to the adjacent canopy as practical and no more than 5m from the canopy.
- Rope bridges should be a minimum of 12m above road level at their lowest point;
- Disturbance should be minimised around the entrance to dedicated fauna culverts during the construction phase and effective revegetation and furniture installation (i.e. logs and rocks) implemented before completion to provide cover.
- A strategy for introduced predator control should be developed for dedicated culverts that target high risk (i.e. critical weight range <5000g) species.

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Appendix A – Underpass and adjacent habitat data

Table A1: Camera-trap effort for surveys of underpasses and adjacent habitat during autumn and spring 2015.

Site (chainage)	Structure	Camera	Esting	Nthing	Autumn 2015					Spring 2015						
					Install date	Collect date	Bait	Days Active	Pics	Install date	Check date	Days active	Collect date	Days Active	Pics	Battery
Moonee (ch.11500)	Dedicated RCBC (2400H x 3000W x 102.4L)	UP-E			26/3/15	21/5/15		56	420	4/9/15	29/9/15	26	30/10/15	32	470	Active
		AdjHab-E-N	514243	6657966	9/4/15	21/5/15	C	42	650	4/9/15			29/9/15	26	153	Active
		AdjHab-E-S	514216	6657894	9/4/15	21/5/15	O	41	569	4/9/15			29/9/15	26	180	Active
		UP-W			26/3/15	21/5/15		56	100	4/9/15	29/9/15	26	30/10/15	32	393	Active
		AdjHab-W-N	514098	6657943	9/4/15	13/5/15	O	14	325	4/9/15			29/9/15	26	928	Active
		AdjHab-W-S	514064	6657918	9/4/15	13/5/15	C	34	161	4/9/15			29/9/15	26	181	Active
Emerald Bch (ch.17500)	Incidental RCP (11 x 1200diam x 74.5L)	UP-E-N			26/3/15	21/5/15		56	1788	4/9/15	29/9/15	26	30/10/15	32	178	Active
		UP-E-S			26/3/15	21/5/15		56	255	4/9/15	29/9/15	26	30/10/15	32	264	Active
		AdjHab-E-N	516951	6662277	9/4/15	13/5/15	C	Stolen		4/9/15			29/9/15	8	1386	Flat
		AdjHab-E-S	516902	6662273	9/4/15	13/5/15	O	16	2981	4/9/15			29/9/15	6	1611	Flat
		AdjHab-W-N	516879	6662434	9/4/15	21/5/15	O	42	1689	4/9/15			29/9/15	9	1558	Flat
		AdjHab-W-S	516830	6662374	9/4/15	21/5/15	C	42	574	4/9/15			29/9/15	6	2611	Flat
Veg Median South (ch.29380)	Dedicated RCBC (3000H x 3000W x 21.4 & 21.4L);	UP-E			26/3/15	21/5/15		56	321	4/9/15	30/9/15	27	30/10/15	31	184	Active
		AdjHab-E-N	516804	6672289	10/4/15	21/5/15	O	16	69	4/9/15			28/9/15	22	249	Flat
		AdjHab-E-S	516799	6672259	10/4/15	21/5/15	C	40	234	4/9/15			28/9/15	25	633	Active

	connects to 31.8 m wide veg median	UP-W			26/3/15	21/5/15		56	558	4/9/15	30/9/15	27	30/10/15	31	224	Active
		AdjHab-W-N	516676	6672349	10/4/15	21/5/15	O	28	71	4/9/15			28/9/15	25	330	Active
		AdjHab-W-S	516648	6672330	10/4/15	21/5/15	C	41	75	4/9/15			28/9/15	12	417	Flat
Veg Median North (ch.29930)	Dedicated RCBC (3000H x 3000W x 19 & 21.8 L); connects to 38.4 wide veg median	UP-E			24/3/15	21/5/15		58	335	4/9/15	30/9/15	27	30/10/15	31	134	Active
		AdjHab-E-N	517258	6672786	10/4/15	21/5/15	C	36	257	4/9/15			29/9/15	14	39	Flat
		AdjHab-E-S	517243	6672762	10/4/15	21/5/15	O	16	154	4/9/15			29/9/15	25	639	Active
		UP-W			24/3/15	21/5/15		58	315	4/9/15	30/9/15	27	30/10/15	31	110	Active
		AdjHab-W-N	517144	6672906	10/4/15	21/5/15	O	41	290	4/9/15			29/9/15	23	753	Flat
		AdjHab-W-S	517123	6672852	10/4/15	21/5/15	C	41	157	4/9/15			29/9/15	25	150	Active

Appendix A – Underpass and adjacent habitat data

Table A2: Fauna detected in adjacent habitat during camera-trap surveys in autumn (A) and spring (S) 2015. E = East side of highway; W = West side of highway.

Species	Moonee Bch (ded culv)		Emerald Bch (pipes)		Veg Med Sth (ded culv)		Veg Med Nth (ded culv)	
	E	W	E	W	E	W	E	W
Echidna	S	S			A	S		A, S
Sp-tail quoll	A							
Antechinus sp.		A			A		A	S
Long-nosed bandicoot	A, S	S		S	A, S	A, S	S	
Northern brown b'icoot	A	S	A, S	A, S	S	A, S	A, S	A, S
Short-eared b'tail possum	A	A			S	S		S
Common b'tail possun	A	A, S			S			A, S
B'tail possum sp.	S							
Estn grey kangaroo	A		A, S	A, S	A, S			
Red-necked wallaby			S					
Swamp wallaby	A, S	A, S	A	A, S	A, S	A, S	A, S	A, S
Wallaby sp.				S				
Water rat								S
Swamp rat								A
Bush rat					A(Pr)			
Black rat		S	A					
Rodent sp.	A, S	A, S			A, S	A, S	A	A, S
Dog				A				
Red fox	A, S	S	S	A		A	A	

Cat	A		A		S			
Cow				S				
Human	S							
Brush turkey	S				S	S		S
Kookaburra				A, S	A			
Buff-banded rail				A				
Noisy pitta	A							
Fairy wren sp.			A, S					
Estn whipbird		S						
Grey shrike-thrush	A, S							
Pied currawong								S
Lace monitor				S	A, S	S		
Eastern water dragon					A	S		S
Land Mullet		A, S				A		

Appendix A – Underpass and adjacent habitat data

Table A3: Fauna recorded by cameras in underpasses during autumn and spring 2015. Accuracy/Likelihood: D = Definite; Pr = Probable; Po = Possible.

Date	Time	Species	Accu-racy	Move-ment	Pic No.	Crossing Likelihood	Date	Time	Species	Accu-racy	Move-ment	Pic No.	Crossing Likelihood	Comments
Moonee Bch East							**Moonee Bch West**							
29/3/15	0710	Fox	D	E,turn,W	116-21	Unlikely								
5/4/15	0138	Fox	D	E	121-25	Pr								
11/4/15	0123	Fox	D	W	136-40	D	11/4/15	0209	Fox	D	W	71-75	D	
11/4/15	0358	Fox	D	E	141-45	Pr								
12/4/15	2102	Fox	D	E	146-50	Pr								
16/4/15	2225	Fox	D	E	151-55	Pr								
26/4/15	1959	Fox	D	W,turn,E	156-60	No								
27/4/15	2249	Fox	D	W	161-65	Pr								
28/4/15	0204	Fox	D	E	166-70	Pr								b'coot? In mouth
4/5/15	600	Fox	D	E	171-75	Pr								
10/5/15	0406	Fox	D	E	176-80	Pr								
11/5/15	1211	Swamp wallaby	D	NDM	136-40	Po								
							5/9/15	0331	Fox	D	W	46-50	Pr	
6/9/15	0855	Humanx3 & dogx2	D	W, return E	61-115	D		0858	Humanx3 & dogx2	D	W return E	51-85	D	
8/9/15	0316	Fox	D	E,pause,E	116-30	Pr								

							10/9/15	0103	Fox	D	W	86-90	Pr	
10/9/15	0252	Fox	D	E	131-35	Pr								
14/9/15	2144	Fox	D	E	136-40	Pr								
							15/9/15	0135	Swamp wallaby	D	W	91-95	Pr	
16/9/15	0304	Fox	D	W,turn,E	141-50	Unlikely								
17/9/15	2144	Fox	D	E	151-55	Pr								
18/9/15	2335	Fox	D	E	156-60	Pr								
21/9/15	2324	Fox	D	E	161-65	Pr								
22/9/15	0235	Fox	D	E	166-70	Pr								
22/9/15	2006	Fox	D	E	171-75	Pr								
22/9/15	2008	Fox(b)	D	E & W	176-230	D	22/9/15	2021	Fox	D	E & W	96-105	D	
23/9/15	2432	Fox	D	E	231-35	Pr								
							23/9/15	2445	Fox	D	W	106-110	Pr	
23/9/15	2100	Fox	D	E	236-40	Pr								
23/9/15	2233	Fox	D	E & W	241-255	D	23/9/15	2233	Fox	D	E & W	111-15	D	
							24/9/15	2434	Fox	D	E turn W	116-25	Unlikely	
24/9/15	2129	Fox	D	E	256-60	Pr								
26/9/15	0423	Fox	D	E	261-65	Pr								
							26/9/15	1950	Fox	D	W	126-30	Pr	
26/9/15	1951	Fox	D	E	266-70	Pr								
29/9/15	0211	Fox	D	E	271-75	Pr								
							29/9/15	0419	Fox	D	E	131-35	Pr	

							29/9/15	2008	Fox	D	E	56-60	Pr	
30/9/15	0157	Fox	D	E	61-64	Pr								
30/9/15	0256	Fox	D	E	61-64	Pr								
30/9/15	0939	Human x2	D	W & E	81-125	D	30/9/15	0943	Human x2	D	W & E	61-90	D	
							4/10/15	0257	Fox	D	W	56-60	Pr	
4/10/15	1004	Cyclist x2	D	W,turn,E	125-95	Unlikely								
							5/10/15	1909	Fox	D	E	96-100	Pr	
6/10/15	0313	Fox	D	E	196-200	Pr								
6/10/15	2302	Fox	D	W	201-05	Pr								
							7/10/15	0256	Fox	D	E	101-05	Pr	
7/10/15	2032	Fox	D	E	206-10	Pr								
7/10/15	2254	Fox	D	E	211-15	Pr								
8/10/15	0418	Fox	D	E	216-20	Pr								
8/10/15	2300	Fox	D	E	221-25	D	8/10/15	2259	Fox	D	E	106-10	D	
9/10/15	0428	Fox	D	E	226-30	Pr								
							10/10/15	2231	Fox	D	E	111-15	Pr	
							11/10/15	2219	Fox	D	W	116-20	Pr	
							12/10/15	2014	Swamp wallaby	D	W	121-25	Pr	
14/10/15	1938	Fox	D	W & E	231-40	D	14/10/15	1941	Fox	D	W	126-30	D	
17/10/15	0936	Fox	D	W	241-50	D	17/10/15	0937	Fox	D	W	131-35	D	
17/10/15	1137	Fox	D	E	251-55	D	17/10/15	1136	Fox	D	E	136-40	D	Bird? in mouth
17/10/15	1446	Fox	D	W	256-60	D	17/10/15	1447	Fox	D	W	141-45	D	
17/10/15	1617	Fox	D	E	261-65	D	17/10/15	1617	Fox	D	E	146-50	D	Lizard? in mouth

							17/10/15	1818	Swamp wallaby	D	E turn W	151-65	Unlikely	
19/10/15	1148	Lace monitor	D	E	266-70	Pr								
20/10/15	0845	Fox	D	W	271-75	D	20/10/15	0846	Fox	D	W	166-70	D	
20/10/15	1046	Fox	D	E	276-80	D	20/10/15	1046	Fox	D	E	171-75	D	Rodent? in mouth
24/10/15	1930	Fox	D	E	281-85	Pr								
25/10/15	0300	Fox	D	E	286-90	Pr								
25/10/15	1331	Fox	D	W	291-95	D	25/10/15	1332	Fox	D	W	176-80	D	
25/10/15	1415	Fox	D	E	296-300	D	25/10/15	1415	Fox	D	E	181-85	D	
25/10/15	2253	Fox	D	E	301-05	Pr								
							26/10/15	0008	Fox	D	W	186-90	Pr	
29/10/15	0219	Fox	D	E	306-10	Pr								
30/10/15	0045	Estn grey k'roo x2	D	Explore	311-455	Po								
Emerald Bch East-North							**Emerald Bch East-South**							
28/3/15	0218	Fox	D	W,turn,E	413-16	Unlikely								
28/3/15	1941	Fox	D	E?,stop	1354-58	Po								
							12/4/15	1857	Nthn br b'coot	D	W	146-48	Pr	
23/4/15	0408	Fox	D	W,turn,E	1557-61	Unlikely								
7/5/15	1928	Fox	Pr	E	1561	Pr								
9/5/15	1625	Echidna	D	Across entrance	1566-69	Po								
17/5/15	0336	Fox	D	W,turn,E	1582	Unlikely								

18/5/15	0705	Estn grey kangaroo	D	Graze E entr	1586-1700	Unlikely								
4/9/15	2022	Fox	D	W? stop	21-25	Po								
5/9/15	0149	Fox	D	W,turn,E	26-30	Unlikely								
9/9/15	2257	Fox	D	W	31-35	Pr								
							20/9/15	0332	Estn grey kangaroo	D	Graze E entr	46-55	Unlikely	
28/9/15	2027	Estn grey kangaroo	D	Graze E entr	36-145	Unlikely								
							5/10/15	1229	Lace monitor	D	Move past	211-15	Po	
14/10/15	1341	Human x2	D	Explore	56-80	Unlikely	14/10/15	1343	Human x2	D	Explore	216-25	Unlikely	
19/10/15	1819	Estn grey kangaroo	D	Graze E entr	81-150	Unlikely								
Veg Med South-East							**Veg Med South-West**							
							6/4/15	0918	Swamp wallaby	D	E	111-15	Pr	
							9/4/15	0652	Swamp wallaby	D	E	116-20	Pr	
9/4/15	0904	Swamp wallaby	D	W,stop	101-05	D	9/4/15	0904	Swamp wallaby	D	W	121-25	D	
							8/9/15	0809	Swamp wallaby	Pr	E	131-35	Pr	
9/9/15	0822	Swamp wallaby	D	E	56-60	D	9/9/15	0821	Swamp wallaby	D	E	136-40	D	
9/9/15	1001	Swamp wallaby	D	W	61-65	D	9/9/15	1001	Swamp wallaby	D	W	141	D	
							10/9/15	0451	Swamp wallaby	Pr	E,pause,E	146-50	Pr	

12/9/15	1508	Trail bike	D	W	66-70	D	12/9/15	1505	Trail bike	D	W	151-55	D	
							22/9/15	0821	Swamp wallaby	Pr	E	161-65	Pr	
27/9/15	0820	Swamp wallaby	Pr	W	71-75	Pr								
17/10/15	0809	Swamp wallaby	Pr	E	61-65	Pr								
25/10/15	0537	Estn grey k'roo	D	NDM	66-70	Po								
25/10/15	0919	Trail bikes x4	D	W	71-160	D	25/10/15	0922	Trail bikes x4	D	W	171-85	D	
Veg Med North-East							**Veg Med North-West**							
26/3/15	1817	Swamp wallaby	Pr	W	56-60	Pr								
							1/4/15	1107	Swamp wallaby	D	W	81-85	Pr	
3/4/15	1045	Trail bikes x2	D	E	71-75	D	3/4/15	1044	Trail bikes x2	D	E	86-90	D	
4/4/15	1314	Trail bikes x3	D	W,E,W	76-90	D	4/4/15	1316	Trail bikes x3	D	W	95-105	D	
							5/4/15	1141	Swamp wallaby	D	W	106-10	Pr	
11/4/15	201	Swamp wallaby	Pr	W	151-55	Pr								
14/4/15	945	Swamp wallaby	D	W,turn,E	156-65	No								
26/4/15	1451	Human	D	W,E	171-90	D	26/4/15	1447	Human	D	W,E	166-80	D	
12/5/15	1740	Swamp wallaby	Pr	W	196-200	Pr								

12/5/15	2056	Swamp wallaby	Pr	E	201-205	Pr								
12/9/15	0850	Estn grey k'roo x3	D	W	51-60	Pr								
12/9/15	1511	Trail bike	D	E	61-65	D	12/9/15	1512	Trail bike	D	E	76-80	D	
							17/9/15	1405	R-n wallaby	Pr	E	81-85	Pr	
							26/9/15	0915	Swamp wallaby	Pr	E	86-90	Pr	
9/10/15	1259	Lace monitor	D	W	101-5	Pr								
17/10/15	1143	Lace monitor	D	W	106-10	Pr								
20/10/15	0942	Lace monitor	D	W	111-15	Pr								
27/10/15	0739	Swamp wallaby	D	E	116-20	Pr								

Appendix B – Vegetated median data

Table B1: Squirrel/sugar glider trap location and effort.

Trap id	Easting	Northing	Tree species	Summer 2015 (23-27/3/15)	Spring 2015 (28/9-2/10)
East 1	516871	6672372	White mahogany	4 nights	4 nights
East 2	516924	6672402	White mahogany	4 nights	4 nights
East 3	516945	6672476	Grey ironbark	4 nights	4 nights
East 4	516997	6672503	White mahogany	4 nights	4 nights
East 5	517011	6672536	Tallow wood	4 nights	4 nights
East 6	517040	6672580	Tallow wood	4 nights	4 nights
East 7	517097	6672628	Blackbutt	4 nights	4 nights
East 8	517129	6672650	Tallow wood	4 nights	4 nights
East 9	517155	6672704	Blackbutt	4 nights	4 nights
East 10	517222	6672763	Red mahogany	4 nights	4 nights
Median 1	516835	6672411	Tallow wood	4 nights	4 nights
Median 2	516890	6672477	Small-fruited grey gum	4 nights	4 nights
Median 3	516923	6672523	Pink bloodwood	4 nights	4 nights
Median 4	516952	6672561	Small-fruited grey gum	4 nights	4 nights
Median 5	516975	6672594	Blackbutt	4 nights	4 nights

Median 6	517018	6672607	Tallow wood	4 nights	4 nights
Median 7	517061	6672700	P bloodwood	4 nights	4 nights
Median 8	517084	6672718	Blackbutt	4 nights	4 nights
Median 9	517127	6672768	Tallow wood	4 nights	4 nights
Median 10	517185	6672807	Blackbutt	4 nights	4 nights
West 1	516722	6672454	Small-fruited grey gum	4 nights	4 nights
West 2	516772	6672480	White mahogany	4 nights	4 nights
West 3	516801	6672530	Grey ironbark	4 nights	4 nights
West 4	516835	6672540	White mahogany	4 nights	4 nights
West 5	516866	6672594	Tallow wood	4 nights	4 nights
West 6	516911	6672615	White stringybark	4 nights	4 nights
West 7	516973	6672649	Blackbutt	4 nights	4 nights
West 8	516995	6672709	Tallow wood	4 nights	4 nights
West 9	517058	6672758	Tallow wood	4 nights	4 nights
West 10	517075	6672806	Blackbutt	4 nights	4 nights

Appendix B – Vegetated median data

Table B2: Trap and nest box (NB) captures. SqG = squirrel glider; SuG = sugar glider; Br = brown; F-f = fawn-footed; recap = recapture

Trap/ NB Location	Date	Species (recapture)	Tag no./L or R/colour	In bag wt	Bag wt	Net wt	Sex	Upr teeth	Lwr teeth	Vent colour	Breeding status	Comments
W8-trap	26/3/15	SqG	513/L/Red	296	99	197	M	A/B	slight	Cream	Nil secretions	Young adult
E3-NB	13/8/15	SuG	509/R/green	225	101	*124#*	F	A/B	slight	Grey	2xPY(~50mm)	*#Body wt inc pch yng*
E10-trap	29/9/15	Br A'chinus		48	13	35	F				8xPY	
E5-trap	29/9/15	Br A'chinus		46	14	32	F				7xPY	
M2-trap	29/9/15	SqG-recap	513/L	314	110	204	M	B	slight	Cream	Slight secretions	Tape off
W1-trap	30/9/15	F-f melomys		73	12	61	M					
M8-trap	30/9/15	Br A'chinus		46	13	33	F				6xPY	
M6-trap	30/9/15	SqG-recap	513/L				M	B	slight	Cream	Slight secretions	Tape off
M2-trap	30/9/15	SqG	510/L/red	228	84	144	F	A/B	slight	Cream	1xPY(10mm)	
E3-trap	30/9/15	Br A'chinus		49	13	36	F				8xPY	
E10-trap	30/9/15	Br A'chinus		48	12	36	F				8xPY	
E3-trap	1/10/15	F-f melomys		70	11	59	M					
E8-trap	1/10/15	Br A'chinus		45	11	34	F				7xPY	
E9-trap	1/10/15	F-f melomys		94	15	79	F					
E10-trap	1/10/15	Br A'chinus		50	15	35	F				6xPY	
W4-trap	1/10/15	Br A'chinus					F				7xPY	

W5-trap	1/10/15	F-f melomys					M					
E10-trap	2/10/15	Br A'chinus		48	13	35	F				8xPY	
M7-trap	2/10/15	Br A'chinus		44	13	31	F				8xPY	
M6-trap	2/10/15	Br A'chinus		48	13	31	F				8xPY	
M4-trap	2/10/15	SqG-recap	510/L/red				F				1xPY(10mm)	
M3-trap	2/10/15	SqG-recap	513/L				M				Slight secretions	Tape off
W10-trap	2/10/15	F-f melomys		57	12	45	F				Nulliporous	Dead in trap; no signs of physical damage
W6-trap	2/10/15	Br A'chinus					F				Escaped	
W5-trap	2/10/15	F-f melomys		70	13	57	F					
W3-trap	2/10/15	Br A'chinus		44	13	31	F				8xPY	
W1-trap	2/10/15	F-f melomys		85	12	73	F					

Appendix B – Vegetated median data

Table B3: Nest box installation data.

Nest Box ID	Install Date	Easting	Northing	Tree species	DBH	Ht	Aspect
East 1	11.2.15	516871	6672372	White mahogany		6	NE
East 2	11.2.15	516924	6672402	White mahogany		6	E
East 3	11.2.15	516945	6672476	Grey ironbark		6	NNE
East 4	11.2.15	516997	6672503	White mahogany		6	NE
East 5	11.2.15	517011	6672536	Tallow wood		6	NE
East 6	11.2.15	517040	6672580	Tallow wood		6	E
East 7	11.2.15	517097	6672628	Blackbutt	650	6	ENE
East 8	11.2.15	517129	6672650	Tallow wood	550	6	NE
East 9	11.2.15	517155	6672704	Blackbutt	620	6	ENE
East 10	11.2.15	517222	6672763	Red mahogany	400	6	NE
West 1	11.2.15	516722	6672454	Small-fruited grey gum		6	NE
West 2	11.2.15	516772	6672480	White mahogany		6	NE
West 3	11.2.15	516801	6672530	Grey ironbark		6	NNE
West 4	11.2.15	516835	6672540	White mahogany		6	NE
West 5	11.2.15	516866	6672594	Tallow wood		6	ENE
West 6	11.2.15	516911	6672615	White stringybark		6	E
West 7	11.2.15	516973	6672649	Blackbutt		6	NE
West 8	11.2.15	516995	6672709	Tallow wood		6	ENE
West 9	11.2.15	517058	6672758	Tallow wood		6	SE
West 10	11.2.15	517075	6672806	Blackbutt		6	NE

Appendix B – Vegetated median data

Table B4: Nest box inspection data for summer-autumn and winter-spring 2015. SuG = sugar glider; SqG = squirrel glider; FtG = feathertail glider. Pr = probable.

Nest Box ID	Summer 2015				Spring 2015									
	Inspect date	Fauna	Signs	Condition	Inspect date	Fauna	Signs	Condition	Pic no.	Inspect date	Fauna	Signs	Condition	Pic no.
East 1	24/3/15	Nil	Nil	Good	10/8/15	Nil		Good	20	30/9/15	Nil	Nil	Good	20
East 2	24/3/15	Nil	Nil	Good	10/8/15	Nil		Good	19	30/9/15	Nil	Nil	Good	19
East 3	24/3/15	Nil	Nil	Good	10/8/15	SuG	Fresh euc leaf nest (exited box)#	Good	18	30/9/15	Nil	Old euc leaf nest (SuG or SqG (pr))	Good	18
East 4	24/3/15	Nil	Nil	Good	10/8/15	Nil		Good	17	30/9/15	Nil	Nil	Good	17
East 5	24/3/15	Nil	Nil	Good	10/8/15	Nil	Old euc leaf nest (SuG/SqG (pr))	Good	16	30/9/15	Nil	Old euc leaf nest (SuG or SqG (pr))	Good	16
East 6	24/3/15	Nil	Black ants	Good	10/8/15	Nil		Good	15	30/9/15	Nil	Nil	Good	15
East 7	24/3/15	Nil	Nil	Good	10/8/15	Nil		Good	14	30/9/15	Nil	Nil	Good	14
East 8	24/3/15	Nil	Nil	Good	10/8/15	Nil	Old euc leaf nest (SuG/SqG (pr))	Good	13	30/9/15	Nil	Old euc leaf nest (SuG or SqG (pr))	Good	13
East 9	24/3/15	Nil	Nil	Good	10/8/15	Nil		Good	12	30/9/15	Nil	Nil	Good	12
East 10	24/3/15	Nil	Nil	Good	10/8/15	Nil	Old lvs/bark (rodent/Achinus-po)	Good	11	30/9/15	Nil	Old lvs/bark (rodent/Achinus-po)	Good	11
West 1	25/3/15	Nil	Nil	Good	10/8/15	Nil		Good	1	30/9/15	Nil	Black ants	Good	1
West 2	25/3/15	Nil	Nil	Good	10/8/15	Nil		Good	2	30/9/15	Nil	Nil	Good	2
West 3	25/3/15	Nil	Nil	Good	10/8/15	Nil	mud wasp nests	Good	3	30/9/15	Nil	Mud Wasp nests	Good	3
West 4	25/3/15	Nil	Nil	Good	10/8/15	Nil		Good	4	30/9/15	Nil	Nil	Good	4
West 5	25/3/15	Nil	Nil	Good	10/8/15	Nil		Good	5	30/9/15	Nil	Black ants	Good	5
West 6	25/3/15	Nil	Mud wasp nests	Good	10/8/15	Nil	Black ants	Good	6	30/9/15	Nil	Fresh, flouncy euc leaf nest (FtG (pr))	Good	6

West 7	25/3/15	Nil	Nil	Good	10/8/15	Nil		Good	7	30/9/15	Nil	Fresh euc leaf nest (SuG or SqG (pr))	Good	7
West 8	25/3/15	Nil	Black ants	Good	10/8/15	Nil		Good	8	30/9/15	Nil	Nil	Good	8
West 9	25/3/15	Nil	Nil	Good	10/8/15	Nil	Black ants	Good	9	30/9/15	Nil	Black ants	Good	9
West 10	25/3/15	Nil	Black ants	Good	10/8/15	Nil	Black ants	Good	10	30/9/15	Nil	Black ants & mud wasp nests	Good	10

Appendix B – Vegetated median data

Table B5: Hair funnel sampling data for summer-autumn and winter-spring 2015.

Funnel id	Easting	Northing	Tree species	DBH	Height	Summer 2015			Spring 2015		
						Install Date	Collect date	Fauna	Install Date	Collect date	Fauna
East 1	516871	6672372	White mahogany		6	11.2.15	24/3/15		13/8/15	1/10/15	
East 2	516924	6672402	White mahogany		6	11.2.15	24/3/15		13/8/15	1/10/15	
East 3	516945	6672476	Grey ironbark		6	12.2.15	24/3/15		13/8/15	1/10/15	M.cervinipes (pr)
East 4	516997	6672503	White mahogany		6	12.2.15	24/3/15		13/8/15	1/10/15	
East 5	517011	6672536	Tallow wood		6	12.2.15	24/3/15		13/8/15	1/10/15	
East 6	517040	6672580	Tallow wood		6	12.2.15	24/3/15		13/8/15	1/10/15	
East 7	517097	6672628	Blackbutt	650	6	12.2.15	24/3/15		13/8/15	1/10/15	Antechinus sp.
East 8	517129	6672650	Tallow wood	550	6	12.2.15	24/3/15		13/8/15	1/10/15	Antechinus sp.
East 9	517155	6672704	Blackbutt	620	6	12.2.15	24/3/15		13/8/15	1/10/15	M.cervinipes (pr)
East 10	517222	6672763	Red mahogany	400	6	12.2.15	24/3/15		13/8/15	1/10/15	A.stuartii
Median 1	516835	6672411	Tallow wood	310	4	12.2.15	23/3/15		13/8/15	1/10/15	P.breviceps (pr)
Median 2	516890	6672477	Small-fruited grey gum	550	4	12.2.15	23/3/15		13/8/15	1/10/15	
Median 3	516923	6672523	Pink bloodwood	320	4	12.2.15	23/3/15		13/8/15	1/10/15	P.breviceps (pr)
Median 4	516952	6672561	Small-fruited grey gum	380	4	12.2.15	23/3/15		13/8/15	1/10/15	P.breviceps (pr)
Median 5	516975	6672594	Blackbutt	480	4	12.2.15	23/3/15		13/8/15	1/10/15	P.breviceps (pr)

Median 6	517018	6672607	Tallow wood	430	4	12.2.15	23/3/15		13/8/15	1/10/15	P.breviceps (pr)
Median 7	517061	6672700	Pink bloodwood	400	4	12.2.15	23/3/15		13/8/15	1/10/15	Antechinus sp.
Median 8	517084	6672718	Blackbutt	480	4	12.2.15	23/3/15		13/8/15	1/10/15	Antechinus sp.
Median 9	517127	6672768	Tallow wood	270	4	12.2.15	23/3/15		13/8/15	1/10/15	A.stuartii
Median 10	517185	6672807	Blackbutt	470	4	12.2.15	23/3/15		13/8/15	1/10/15	Antechinus sp.
West 1	516722	6672454	Small-fruited grey gum		6	11.2.15	25/3/15	Antechinus sp.	13/8/15	1/10/15	
West 2	516772	6672480	White mahogany		6	11.2.15	25/3/15	Antechinus sp.	13/8/15	1/10/15	Antechinus sp.
West 3	516801	6672530	Grey ironbark		6	11.2.15	25/3/15		13/8/15	1/10/15	Antechinus sp.
West 4	516835	6672540	White mahogany		6	11.2.15	25/3/15		13/8/15	1/10/15	Antechinus sp.
West 5	516866	6672594	Tallow wood		6	11.2.15	25/3/15		13/8/15	1/10/15	A.stuartii
West 6	516911	6672615	White stringybark		6	11.2.15	25/3/15		13/8/15	1/10/15	Antechinus sp.
West 7	516973	6672649	Blackbutt		6	11.2.15	25/3/15		13/8/15	1/10/15	
West 8	516995	6672709	Tallow wood		6	11.2.15	25/3/15	Antechinus sp.	13/8/15	1/10/15	Antechinus sp.
West 9	517058	6672758	Tallow wood		6	11.2.15	25/3/15		13/8/15	1/10/15	Antechinus sp.
West 10	517075	6672806	Blackbutt		6	11.2.15	25/3/15		13/8/15	1/10/15	Antechinus sp.

Appendix B – Vegetated median data

Table B6: Spotlight effort and detections for summer-autumn and winter-spring 2015.

Site	Date	Observers	Start Time	Finish Time	Species	Comments	Flowering	Moon	Wind	Rain	Visibility	Air Temp	Humidity
East	24/3/15	BT/GM	2115	2148	P coriacea(10+,C); Lim peroni(2,C)			1st 1/4	MSb	Nil	Dark	24	98
	26/3/15	BT/GM	2035	2110	P coriacea(10+,C)			1st 1/4	Still	Nil	Detail seen	28	86.6
	30/9/15	BT/GM	1842	1916	Nil		Twood	full	Nil	Nil	Dark	16.5	80
	26/10/15	NP/GM	0025	0055	GHFF (c)		Iron bark	7/8	Nil	Nil	Bright	18.9	100
Median	24/3/15	BT/GM	2030	2110	**FtG**	Mid-tran		1st 1/4	MSb	Nil	Dark	24	98
	26/3/15	BT/GM	2116	2151	Nil			1st 1/4	Still	Nil	Detail seen	28	86.6
	30/9/15	BT/GM	2014	2050	Nil		Twood	full	Msb	Nil	Dark	13.7	94
	26/10/15	NP/GM	2345	0015	Nil		Tallow, Bbutt	7/8	Nil	Nil	Bright	18.5	99
West	24/3/15	BT/GM	1950	2026	Nil		Br-l p'bk	1st 1/4	MSb	Nil	Dark	24	98
	26/3/15	BT/GM	2000	2032	M fasciolatus (1c); L fallax(1c)			1st 1/4	Still	Nil	Detail seen	28	86.6
	30/9/15	BT/GM	1931	2005	L.latopalmata(2c)			full	Msb	Nil	Dark	16.2	84
	26/10/15	NP/GM	2305	2340	L. Latopalmata (>10c), L. fallax (2c), Lit. peronii (1c)		Tallow	7/8	Msb	Nil	Bright	19	100

Appendix C – Rope bridge data

Table C1: Rope bridge camera monitoring survey effort.

Survey period (days)	East cam				West cam			
	Pics	Days active	Batteries	Comments	Pics	Days active	Battery %	Comments
9/4/15 (Install)				SC950; On:1700,Off:0700; (Lithium); Sense:H; P/trig:5; Rapidfire; Balanced; sandwich board view along rope				SC950; On:1700,Off:0700; (Lithium); Sense:H; P/trig:5; Rapidfire; Balanced; sandwich board view along rope
9/4-14/5/15 (35)	12046	27	0% (L>A)	Turn cam to face bulk head	1932	35	99 (L)	Time: 1min<
14/5-12/8/15 (90)	66	90	1% (A>L)	Sens:High>Med/High; Pics/trig: 5>3	3730	90	99 (L)	No change
12/8-30/10/15 (79)	0	79	99% (L)	Sens:MH>H; Pics/trig: 3>5	8806	67	0% (L>L)	Cam knocked(?) @ right angle; no settings change
30/10-15/12/15 (46)	20	46	99% (L)	No change; time 1min<	9905	46	99% (L)	No change; time 1min<

Appendix C – Rope bridge data

Table C2: Rope bridge camera monitoring detections. NDM = No Directional Movement

Side	Date	Time	Species	Accu-racy	Movement	Bridge sctn	Pic No.	Crossing Likelihood	Comments
E	10/4/15	1710	Kookaburra	D	perch		358-60	Na	
	22/5/15	0633	Torresian crow	D	NDM		1-48	Na	
	30/5/15	0347	Sugar glider(m)	D	W, turn, E	Edge	49-66	Unlikely	
	11/11/15	0043	Feathertail glider	D	Explore	Centre	1-20	Unlikely	
W	2/11/15	2233	Feathertail glider	D	West	Centre	396	Poss	
	14/12/15	0127	Feathertail glider	D	West	Centre	9551-5	Unlikely	

Appendix C – Rope bridge data

Table C3: Rope bridge spotlight survey effort and detections. SuG = sugar glider; SqG = squirrel glider; FtG = feathertail glider. GHFF = grey-headed flying fox; TF = tawny frogmouth; BB = boobook owl; Pr = probable.

Site	Date	Observers	Start Time	Finish Time	Species	Comments	Flowering	Moon	Wind	Rain	Visibility	Air Temp	Humidity
Rope-e	19/5/15	BT&TW	1755	1835	Nil		B-l p'bk	New	Nil	Nil	Dark	19.2	96
	21/7/15	BT/DO	1816	1848	GHFF		Wh strbk	1st 1/4	Mlb	Light	Dark	16.9	87.8
	1/10/15	BT/GM	1845	1917	FtG; GHFF, L.lato, L.fallax,	FtG: SM@200s20e	Bbutt	Full	Nil	Nil	Dark	18.2	71
	26/10/15	NP/GM	1940	2020	FtG, Lim. peroni, Lim. tasmaniensis	FtG: SM@350n5w (in flowering Bbutt)	Bbutt	7/8	Nil	Light	Dark	22.9	87.5
Rope-w	19/5/15	BT&TW	1857	1932	GHFFx2; TF		B-l p'bk, b'butt, i'bk	New	Nil	Nil	Dark	19.2	96
	21/7/15	BT/DO	1914	1948	GHFF, BB		Bl butt	1st 1/4	Mlb	Light	Dark	16.9	87.8
	1/10/15	BT/GM	1933	2010	SuG/SqG; GHFF	SuG/SqG:SE@400n30w	Bbutt; Twood	Full	Msb	Nil	Dark	15.6	86
	2/10/15	NP/GM	22:00	2240	Lit. latopalmata,	Heavy shower prior	Bbutt, Tallow	7/8	Msb	Heavy/Light	Dark	20.2	95.6

Appendix D – Glide pole data

Table D1: Glide pole camera monitoring effort. A camera was placed at the end of the upper and lower arm.

Survey period (days)	Upper/East cam (face west)				Lower/North cam (face south)			
	Pics	Days active	Battery %	Comments	Pics	Days active	Battery %	Comments
9/4/2015 (install)				HC500; (Lithium); Sense:H; P/trig:5; Rapidfire; Balanced				SC950; On:1700,Off:0700; (Lithium); Sense:H; P/trig:5; Rapidfire; Balanced
9/4-14/5/15 (35)	1330	35	88%(L)	Time ok	80	35	99%(L)	Time ok
14/5-12/8/15 (90)	1835	90	1% (L>A)	Time ok	10	90	1% (L>A)	Time ok
12/8-30/10/15 (79)	146	~60	0%(A>L)	Time ok; swap HC500>SC950	60	79	10% (A>L)	Time ok; swap SC950>HC500
30/10-15/12/15 (46)	295	46	99%(L)	No change; 8G>4G	413	46	99%(L)	No change; 8G>4G

Appendix D – Glide pole data

Table D2: Glide pole camera monitoring detections. A camera was positioned at the end of the upper and lower arm. D = definite

Cam	Date	Time	Species	Accu-racy	Movement	Pic No.	Comments
E>W (upper)	11/4-11/5/15	0642	Torresian crow & Australian raven	D	NDM	>1600 pics	
	25/4/15	0957	Welcome swallow	D	perch	851-55	
	5/5/15	1519	Welcome swallow	D	perch	1046-51	
	6/5/15	1258	Welcome swallow	D	perch	1051-55	
	7/5/15	1557	Grey butcherbird	D	NDM	1056-65	
	17/5-12/8/15	0815	Torresian crow & Australian raven	D	NDM	~1700 pics	
	29/7/15	0938	Welcome swallow	D	perch	1546-65	
	6/11-7/12/15		Torresian crow & Australian raven	D	NDM	>30 pics	
	6/11-7/12/15		Welcome swallow	D	perch	>30 pics	
	9/11/15	2357	Feathertail glider	D	Climb pole top	16-20	
	13/11/15	2414	Feathertail glider	D	Explore pole top & arm	66-80	
	17/11/15	2208	Feathertail glider	D	Explore arm	86-90	
	18/11/15	2314	Feathertail glider	D	Explore arm	91-95	
	5/12/15	2148	Feathertail glider	D	Explore arm	251-75	Both cams
	6/12/15	0103	Feathertail glider	D	Explore arm	276-80	

N>S (lower)	16/4/15	0101	Sugar glider	D	Explore arm	001-10	
	23-25/4/15	605	Torresian crow	D	NDM	11-74	
	12/7/15	0154	SuG/SqG	D	NDM	1-5	Ears only
	12/9/15	2012	Feathertail glider	D	Explore arm	1-15	
	5/10/15	2232	Feathertail glider	D	Explore arm	16-25	
	6/10/15	0506	Aust Raven	Pr	Sit	26-30	
	15/10/15	2248	Feathertail glider	D	Explore arm	36-40	
	21/10/15	2434	Feathertail glider	D	Explore arm	41-45	
	23/10/15	0506	Aust Raven	D	Explore	46-60	
	6/11-7/12/15		Torresian crow & Australian raven	D	NDM	>30 pics	
	6/11-7/12/15		Welcome swallow	D	perch	>30 pics	
	11/11/15	2209	Sugar glider (f)	D	Leap up pole from arm	61-65	
	5/12/15	2146	Feathertail glider	D	Explore arm	161-65	Both cams

Appendix D – Glide pole data

Table D3: Glide pole spotlight survey effort and detections. SuG = sugar glider; SqG = squirrel glider; FtG = feathertail glider. GHFF = grey-headed flying fox; TF = tawny frogmouth; ONj = owlet nightjar; Pr = probable.

Site	Date	Observers	Start Time	Finish Time	Species	Comments	Flowering	Moon	Wind	Rain	Visibility	Air Temp	Humidity
Pole-e	19/5/15	BT&TW	1958	2039	**FtG**	@ck	B-l p'bk	New	Nil	Nil	Dark	18	86
	21/7/15	BT/DO	2022	2057	**FtG; SuGx2**	FtG:80s of ck; SuG: 80s & 40s of ck	Bl butt	1st 1/4	Mlb	Light	Dark	15.8	89
	1/10/15	BT/GM	2032	2110	**FtG**	FtG:SG@50s of ck	Bbutt; Twood	Full	Msb	Nil	Dark	15.6	86
	26-27/10/15	NP/GM	0110	0200	Lit. peronii, Lim. peronii			7/8	Msb	Nil	Detail Seen	19	99
Pole-w	19/5/15	BT&TW	2058	2133	**FtG**	200S	B-l p'bk	New	Nil	Nil	Dark	18	86
	21/7/15	BT/DO	2113	2148	Nil			1st 1/4	Mlb	NIL	Dark	15.8	89
	1/10/15	BT/GM	2124	2155	Nil		Bbutt	Full	Msb	Nil	Dark	15	90
	8/10/15	BT/NP	2351	2420	ONj		Twood	3rd 1/4	Msb	Last 24 hrs	Dark	16.7	88